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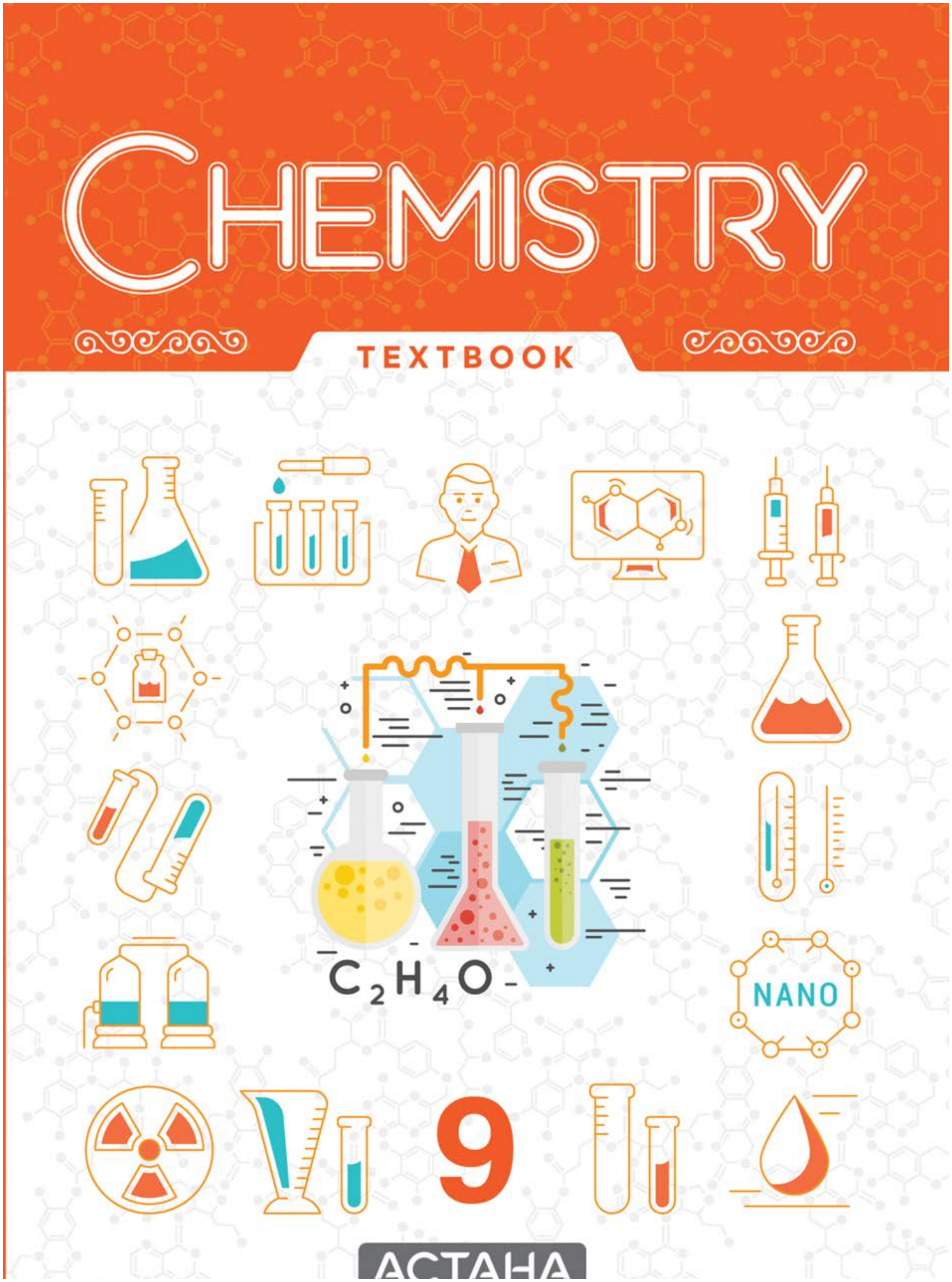

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Kanat Baikenov
Temirlan Khassen
Nurbolat Zhumagulov
Dauren Kaliyev
Olzhas Yussupov
Abylay Samatov
Abdurrahman Sel
Ali Tor

Approved by the Ministry of Education and
Science of the Republic of Kazakhstan

CHEMISTRY

Grade 9

1ST EDITION

АСТАНА

Astana 2018

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UDC 373.167.1
LBC 24 я 72
Ch 51

K. Baikenov
Ch 51 **CHEMISTRY, Grade 9:** Textbook / Kanat Baikenov, Temirlan Khassen, Nurbolat Zhumagulov, Dauren Kaliyev, Olzhas Yussupov, Abylay Samatov, Abdurrahman Sel, Ali Tor
– Almaty: Астана-кітап, 176 p. - 2018
ISBN 978-601-7415-83-9

UDC 373.167.1
LBC 24 я 72

ISBN 978-601-7415-83-9

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PREFACE

Natural science is an exciting and very useful subject. This textbook will show you all the beauty of it and will help you become true explorers. The main aim of this book is to answer the fundamental question: “What is science and what is its importance in our life?”

Starting from the first pages, you will realise that this textbook is completely different from any other usual textbook full of theoretical passages and formulas. Every chapter contains useful information, curious facts, tasks for individual and group work. You will also learn how to conduct research and experiments yourselves, search for information, make your own discoveries.

One more valuable feature of this textbook is the language. Every sentence has been carefully chosen so that it is not difficult for you to understand science in the English language. Each page contains translations of all the important terms, both in Kazakh and Russian. This textbook will not only help you improve your English, but it will also make you a part of a big international science community.

Please pay attention to the structure of this textbook. Remember: a textbook is no longer the only source of information in the modern world. With the help of carefully selected tasks, you are going to learn such important skills as critical thinking, problem solving, information analysis, creativity, imagination, teamwork, digital literacy etc.

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If you have any questions, suggestions or ideas regarding the contents of this book, please feel free to contact us:

via email: admin@astanakitap.kz

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Best regards,

team of authors, “Астана-кітап”

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CHAPTER 1: ELECTROLYTIC DISSOCIATION

1.1 ELECTROLYTES AND NONELECTROLYTES

How does a human body conduct an electric current?

You will:

- know what electrolytes and nonelectrolytes are;
- explain the dependence of electrical conductivity on a type of chemical bond;
- know the electrolytic dissociation theory;
- understand the mechanism of electrolytic dissociation.

The conductivity of a solution depends on the solute. The more ions a solution contains, the greater its conductivity. Substances which dissolve in water by producing ions are called electrolytes. Solutions of electrolytes conduct electricity due to ions. However, nonelectrolytes do not form ions in solution. Therefore, they do not conduct electricity.

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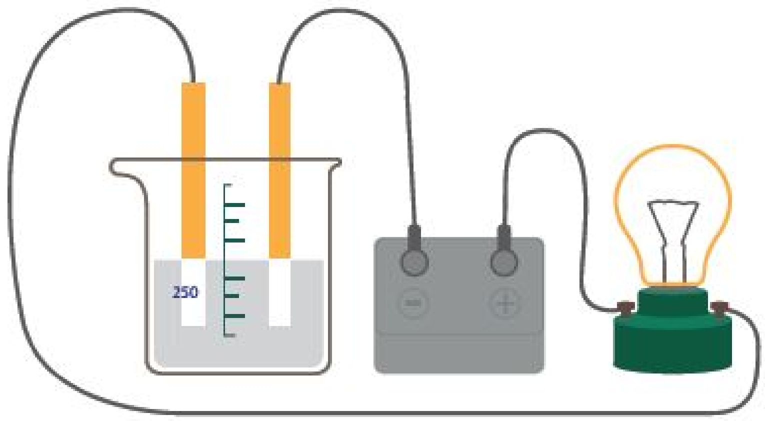
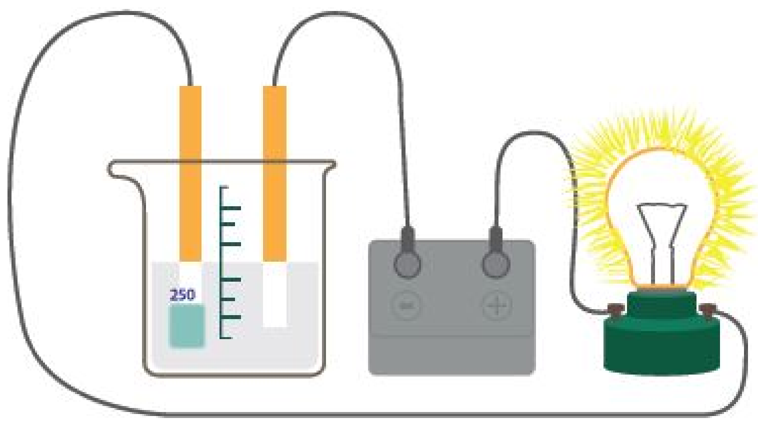


Sucrose solution



Hydrochloric acid solution

How does a car battery work?

A car battery is a device used to power lighting, accessories and other electrical systems. The main components of the car battery are sulfuric acid (H2SO4) and lead (Pb) plate. Sulfuric acid is a strong acid and a good conductor of electricity.

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Car battery

In 1897 Svante Arrhenius introduced his electrolytic dissociation theory that explained the properties of electrolytes. Postulates of Arrhenius theory:

1. Molecules of electrolytes (acids, bases, and salts) dissociate into oppositely charged ions:

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$$NaCl_{(s)} \rightleftarrows Na^{+}_{(aq)} + Cl^{-}_{(aq)}$$

$$HNO_{3(aq)} \rightleftarrows H^{+}_{(aq)} + NO_{3}^{-}{}_{(aq)}$$

$$KOH_{(aq)} \rightleftarrows K^{+}_{(aq)} + OH^{-}_{(aq)}$$

2. Electrolytes (molten compounds) conduct electric current due to produced ions. This is the mechanism of electrolytic dissociation.

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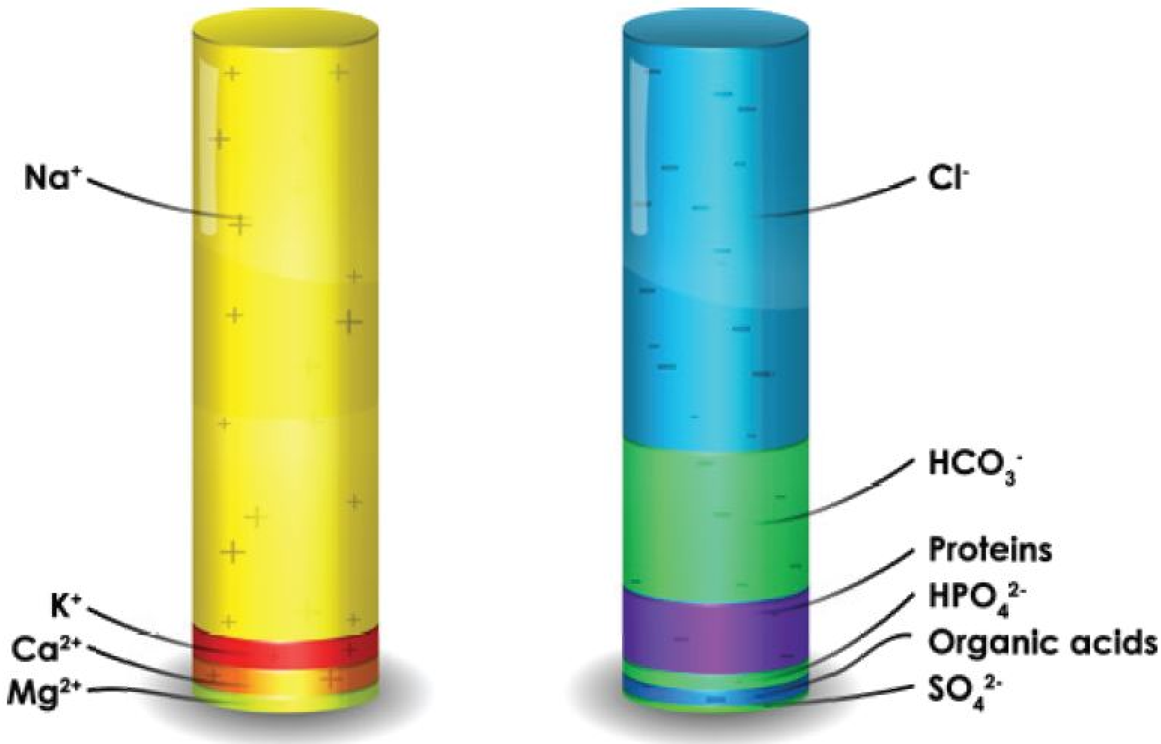

Human blood plasma ion composition

Keep in mind:

Electrolytic dissociation - the separation of a compound into ions in water.

Electrolytes form electrically conducting solutions in water due to produced ions.

Nonelectrolytes do not conduct electric current because of absence of ions.

Literacy

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1. Why do table salt solutions conduct electricity well, while sugar solutions do not?
2. What is the difference between tap water and distilled water? Which of these two solutions conducts electricity? Why?
3. Which of the followings are electrolytes?

Solutions	Electrolyte / Nonelectrolyte
Vinegar	
Hydrogen	
Tap water	
Sodium chloride	
Alcohol	
Sulfuric acid	

Demonstration

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№ 1. Electrolytic dissociation of ionic and covalent compounds.

Materials:

beaker 250 ml (4), 6V bulb, plug-in bulb mouth, steel electrode (2), crocodile leads (2), power supply (12V), acetic acid (vinegar) solution, copper sulfate solution, sugar solution, distilled water.

Procedure:

• Pour distilled water, copper sulfate, vinegar and sugar solutions into four different 250 ml beakers.

• Arrange the circuit as shown in the fi gure for distilled water.

• Switch the power supply to 6V. Observe if the bulb is lightening or not. Record your observation.

• Place the electrodes in copper sulfate, acetic acid, sugar solutions and repeat.

Write your observations on the conductivity table below:

Observation & questions:

	Distilled water	$CuSO_4$ solution	Acetic acid solution	Sugar solution
BULB (on/off)				

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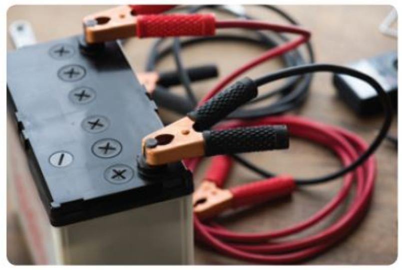
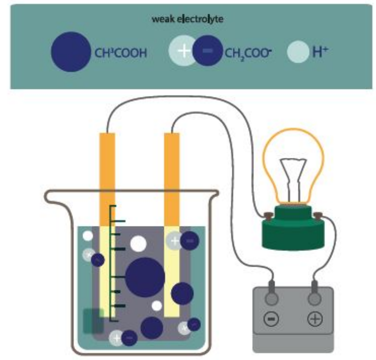
Wear disposable gloves. Avoid skin contact. Wash hands after use.





Terminology

- solute - еріген зат / растворенное вещество;
- solution - ерітінді / раствор;
- solvent - еріткіш / растворитель;
- conductivity - өткізгіштік / проводимость;
- electric current - ток күші / электрический ток;
- vinegar - сірке суы / уксус;
- observation - бақылау / наблюдение;
- electrolyte - электролит;
- dissociation - диссоциация.

Facts

Arrhenius is a Swedish chemist. In 1903 he won the Nobel Prize for his work with solutions. He explained why some solutions conduct electricity. In this theory,
Arrhenius concluded the ‘molecule’ breaks apart into a positive fragment and a negative fragment, called ions. He also explained weak and strong electrolytes according to the ratio of the ions in solutions.

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1.2 DISSOCIATION OF ACIDS, BASES, AND SALTS.

What would happen if we replace citric acid in a lemon with a base or salt?

You will:

-
- write electrolytic dissociation reactions of acids, bases and salts;
- identify the acidity and the basicity of solutions.

Acids

Acids produce H3O+ (simply H+) ions in water. Dissociation of nitric acid is shown below:

$$HNO_3 + H_2O \rightleftarrows H_3O^+ + NO_3^-$$

Simplified equation:

$$HNO_3 \rightleftarrows H^+ + NO_3^-$$

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Dissociation of polyprotic acids (acids which have more than one hydrogen atoms) occurs stepwise. For example, dissociation of sulfuric acid occurs in 2 steps:

$$H_2SO_4 \rightleftarrows H^+ + HSO_4^-$$

$$HSO_4^- \rightleftarrows H^+ + SO_4^{2-}$$

Sum of these steps:

$$H_2SO_4 \rightleftarrows 2H^+ + SO_4^{2-}$$

The common element for all acids is hydrogen, which is responsible for common properties of acids. Therefore, according to the electrolytic dissociation, an acid can be defined as substance that produce H+ in aqueous solution.

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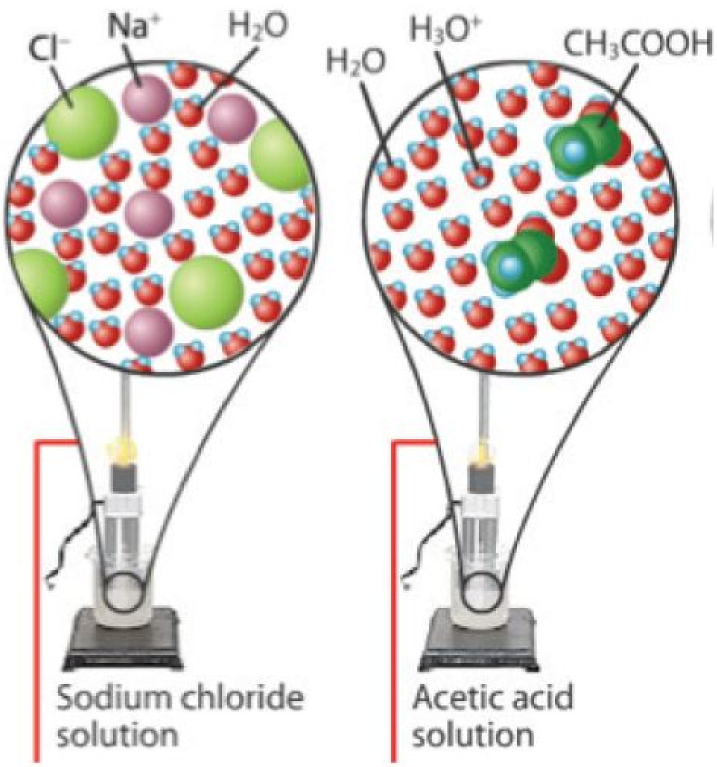

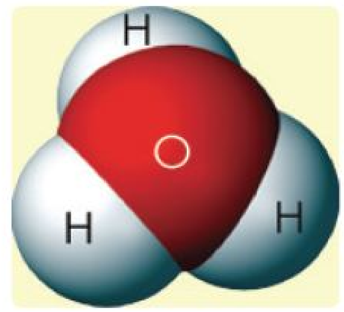

H_3O^+ – *Hydronium ion*

Bases

Dissolution (dissociation) of a base produces hydroxide ions. Dissociation equations of NaOH and Ca(OH)2 are shown below:

$$NaOH \rightleftarrows Na^+ + OH^-;$$

$$Ca(OH)_2 \rightleftarrows CaOH^+ + OH^-; \qquad CaOH^+ \rightleftarrows Ca^{2+} + OH^-$$

Sum of the steps for the dissociation of Ca(OH)2:

$$Ca(OH)_2 \rightleftarrows Ca^{2+} + 2OH^-$$

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Ammonia NH3 does not have hydroxide (OH-) ion in its structure. However, it accepts an H+ (proton) ion from water and produces OH– ion as shown below:

$$\underset{\text{Ammonia}}{NH_3} + H_2O \rightleftarrows \underset{\text{Ammonium ion}}{NH_4^+} + \underset{\text{Hydroxide ion}}{OH^-}$$

As we see, H2O molecule can accept and donate a hydrogen ion. According to this property, we can say that H2O can act as an acid or a base:

$$H_2O + H_2O \rightleftarrows H_3O^+ + OH^-$$

Simplified equation:

$$H_2O \rightleftarrows H^+ + OH^-$$

H+ and OH– ions are produced equally, so, water shows neither acidic nor basic properties. It shows neutral medium.

Salts

All salts dissociate into ions as shown below:

$$Ca(NO_3)_2 \rightleftarrows Ca^{2+} + 2NO_3^- \qquad NaHSO_4 \rightleftarrows Na^+ + H^+ + SO_4^{2-}$$

$$MgOHCl \rightleftarrows Mg^{2+} + OH^- + Cl^-$$

Neutral salt is a type of salt which dissociates into cations and anions in aqueous solution.

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Laboratory work

№1. Determination of pH of acid-base solutions

The pH of acids and bases can be found by dissolving a small amount of substance in distilled water and adding few drops of universal indicator solution (or by using indicator paper). The colour produced is compared with the pH scale.

Materials:

universal indicator (paper or solution), acid solutions (vinegar CH3COOH, hydrochloric acid HCl), base solutions (sodium hydroxide NaOH, ammonia NH3), distilled water, test tubes.

Procedure

1. Add few drops of acid and base solutions (separately) intothe test tubes.

2. Add 2-3 drops of universal indicator to the test tubes.

3. Write the colours in the table below. Compare colours with the pH scale (page 19).

Ammonia gas has a sharp odour. Prepare a table for your results

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Solutions	Colours with universal indicator	pH
NaOH solution		
Ammonia solution		
HCl solution		
Vinegar		

Keep in mind

Electrolytic dissociation is a reversible process for weak electrolytes. Therefore “↔” sign can be written instead of “→”.

Facts

Citrus fruits have a sour taste because they contain acids

Keep in mind

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The most important acids

Formula	Name
HCl	Hydrochloric acid
HNO_3	Nitric acid
H_2S	Hydrosulfuric acid
H_2SO_4	Sulfuric acid
H_3PO_4	Phosphoric acid
CH_3COOH	Acetic acid

Keep in mind

Base – a substance that produces OH– (hydroxide) ions in aqueous solution.

Name “ammonium” is composed in similar manner according to the “hydronium”.

Literacy

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1. Why do some substances dissociate into ions in water?

2. Which of the following compounds produce a metal cation and hydroxide anion?

a) calcium hydroxide ($Ca(OH)_2$)

b) hydrochloric acid (HCl)

c) magnesium bromide ($MgBr_2$)

3. Write the dissociation processes of the following compounds:

a) sodium chloride ($NaCl$)

b) sulfuric acid (H_2SO_4)

c) potassium hydroxide (KOH)

d) acetic acid (CH_3COOH)

Terminology

- to donate - беру / отдавать;
- to accept - қабылдау / принимать;
- dissolution - еру / растворение;
- universal indicator - әмбебап индикаторы / универсальный индикатор;
- pH scale - pH көрсеткіш / шкала pH;
- aqueous - сулы / водный;
- polyprotic - көп негізді / многоосновной;
- hydronium ion - оксоний ионы / ион оксония;
- neutral medium - бейтарап орта / нейтральная среда;
- reversible - қайтымды / обратимый.

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1.3 THE DEGREE OF DISSOCIATION. STRONG AND WEAK ELECTROLYTES

Why some acids are more corrosive than others?

You will:

- know what dissociation degree is;
- know whether an electrolyte is strong or weak;
- calculate a degree of dissociation of compounds.

The degree of dissociation, or α, is a way of representing the strength of an electrolyte, often represented by the Greek letter alpha. It is defined as the ratio between the number of ionized molecules and the number of molecules dissolved in water. It is represented as a percentage:

$$\alpha = \frac{N_i}{N_{tot}} \cdot 100\ \%$$

Ni - the number of molecules dissociated into ions;

Ntot - total number of molecules.

According to the degree of dissociation electrolytes can be classified as strong electrolytes, electrolytes of medium strength and weak electrolytes.

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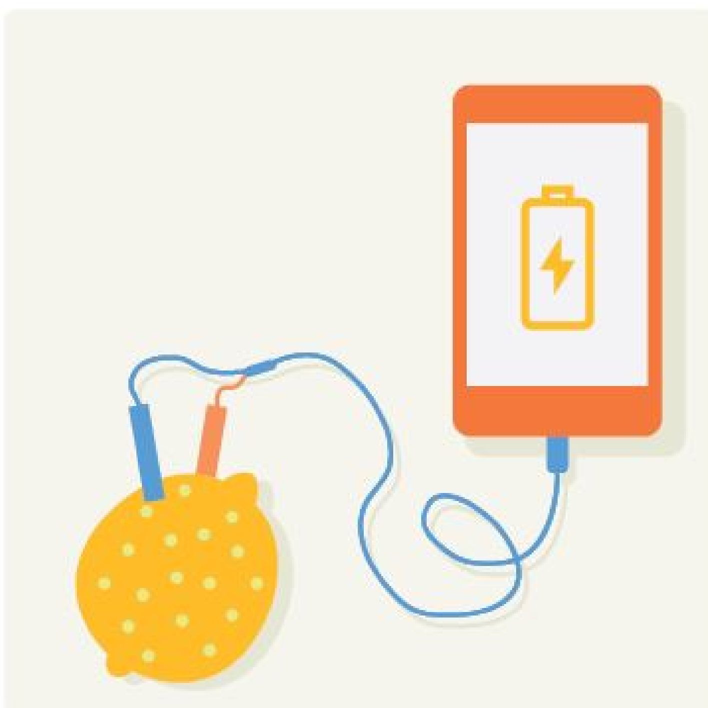
Strong electrolytes strength	Electrolytes of medium strength	Weak electrolytes strength
$\alpha > 30$ %	$3\% \le \alpha \le 30$ %	$\alpha < 3$ %
HNO_3 – 91 % HCl – 92 % NaCl - 84 % KOH - 84 % NaOH - 84 %	H_3PO_4 - 26 % HNO_2 – 6.5 %	CH_3COOH (acetic acid) – 1.3 % $NH_3 \cdot H_2O$ (NH_3) – 1.3 % H_2CO_3 – 0.17 % H_2S – 0.07 %



Lemon conducts electricity because it contains some ions

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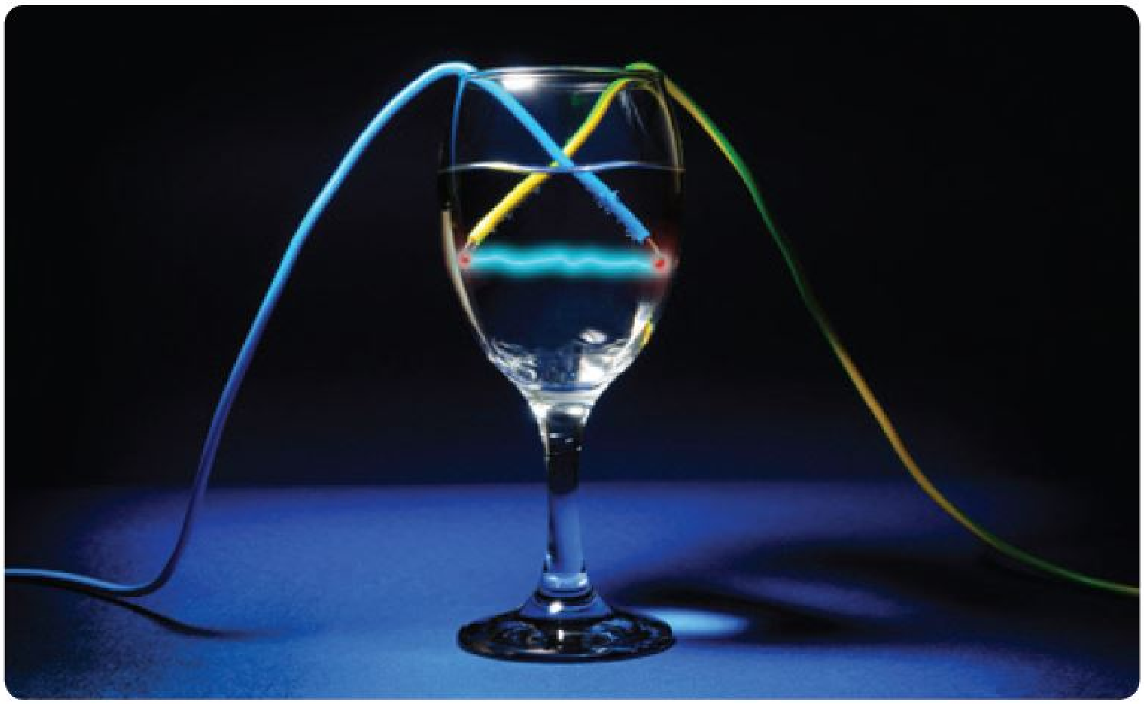
Solutions with a good electrical conductivity are known as strong electrolytes. Sodium chloride, hydrochloric acid, and potassium hydroxide solutions are examples of strong electrolytes. Solutions with poor conductivity are called weak electrolytes. Vinegar, tap water, and lemon juice are examples of weak electrolytes.



Tap water is a poor conductor of electricity

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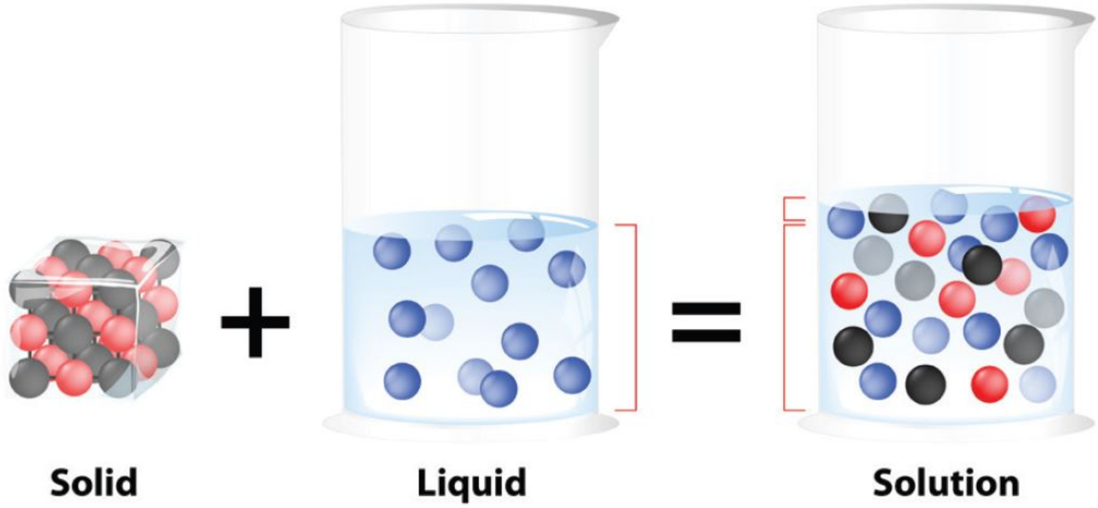

Complete dissociation of solid electrolyte in a liquid.

Literacy

1. Lemon contains citric acid. Is it a strong or weak electrolyte?

2. Dissociation degree of a compound A is 70 %. Is it a strong or weak electrolyte?

3. 200 molecules were placed in the solution. Determine the degree of dissociation if dissociated 40 molecules.

4. Determine strong electrolytes from the followings, and write their dissociation reactions: H_2S, H_2SO_4, HNO_2, $NH_3 * H_2O$.

Activity

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Homemade pH indicator solution

Red cabbage juice contains a natural pH indicator that changes colour according to the acidity of the solution.

Materials:

- red cabbage
- boiling water
- filter paper
- glass containers
- ammonia (NH3) solution
- baking soda (NaHCO3)
- lemon juice
- vinegar (CH3COOH)

Procedure:

1. Cut the cabbage into small pieces.
2. Place the cabbage in a large glass container and add boiling water.
3. Wait about 10 minutes.
4. Filter the plant material to obtain a blue-green coloured liquid.
5. Pour about 50-100 mL of your red cabbage indicator into each glass container.

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6. Add solutions to your indicator until the colour is changed.

**Use separate containers for each solution*

Red cabbage

Facts

Acids which are used in daily life are mainly weak.

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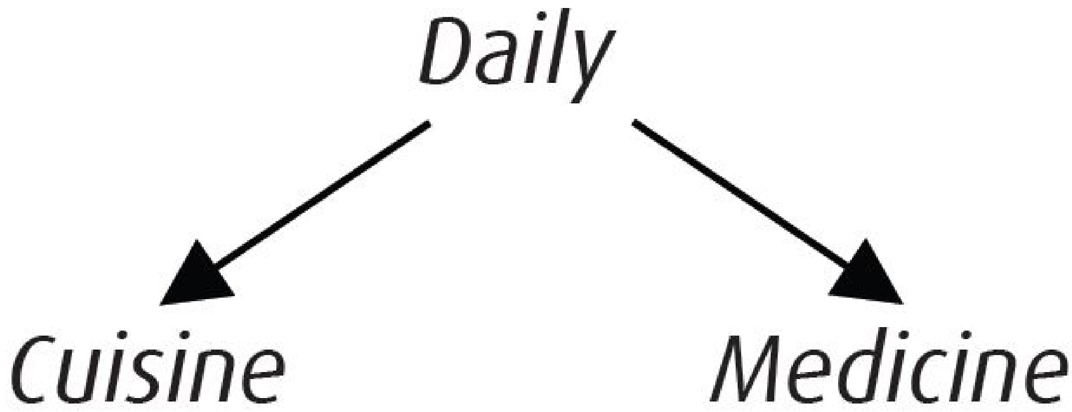

Cuisine	Medicine
Acetic acid (vinegar)	Acetylsalicylic acid (aspirin)
Citric acid	Boric acid
Malic acid	Ascorbic acid (vitamin C)

Keep in mind

Strong electrolytes are good conductors of electricity.

Poor conductors of electricity are known as weak electrolytes.

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Solving problems

1. What mass of iron (III) oxide is produced when 8 g of iron metal reacts completely with oxygen gas?

2. What volume of hydrogen gas is produced when 14 g of zinc metal reacts with sulfuric acid solution?

3. If 62 g of phosphorus are burnt, what mass of P_2O_5 is produced?

4. If 24 g of carbon are burnt, what mass of CO_2 is produced?

5. Calculate the mole number of zinc sulfate formed when 250 ml of 0.2 M sulfuric acid is added to zinc carbonate.

6. Calculate the volume of CO_2 gas which is produced by burning 5 L of methane CH_4 in excess oxygen.

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

Terminology

- degree - дәреже / степень;
- citric acid - лимон қышқылы / лимонная кислота;
- malic acid - алма қышқылы / яблочная кислота;
- tap water - құбыр суы / водопроводная вода;
- determine - анықтау / определять;
- red cabbage - қызыл орамжапырақ / краснокочанная капуста.

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1.4 IONIC DOUBLE DISPLACEMENT REACTIONS

Why do gas bubbles form when you mix baking soda with vinegar?

You will:

- write reactions in molecular and ionic forms;
- explain why ionic displacement reactions occur.

1. Precipitation

When aqueous solutions of two water-soluble compounds are mixed, there may be a reaction between the ions of these solutions. If one of the products is insoluble, a solid will precipitate out of the solution. This solid product is called a precipitate.

Let’s take a reaction between lead (II) nitrate Pb(NO3)2 and potassium iodide KI. The products of this reaction are KNO3 and PbI2. According to solubility table, potassium nitrate is soluble in water, but lead (II) iodide is not. That's why yellow precipitate of lead (II) iodide forms at the bottom of the solution:

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$$Pb(NO_3)_{2(aq)} + 2KI_{(aq)} \rightarrow 2KNO_{3(aq)} + PbI_{2(s)}$$

Now let's see which ions are involved in the formation of the precipitate. To find it out, first, we separate all soluble salts into ions:

$$Pb^{2+}_{(aq)} + 2NO_3^-{}_{(aq)} + 2K^+_{(aq)} + 2I^-_{(aq)} \rightarrow 2K^+_{(aq)} + 2NO_3^-{}_{(aq)} + PbI_{2(s)}$$

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Then, we cancel the same ions present on both sides of the equation:

$$Pb^{2+} + \cancel{2NO_3^-} + \cancel{2K^+} + 2I^- \rightarrow \cancel{2K^+} + \cancel{2NO_3^-} + PbI_{2(s)}$$

This gives the net ionic equation and shows the ions which were involved:

$$Pb^{2+} + 2I^- \rightarrow PbI_{2(s)}$$

Such a net ionic equation tells us that Pb2+ and I– ions cannot both be found as ions in the same solution.

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Formation of $Cu(OH)_2$ precipitate

2. Gas releasing

Sulfuric acid solution is added to sodium carbonate solution:

$$Na_2CO_{3(aq)} + H_2SO_{4(aq)} \rightarrow Na_2SO_{4(aq)} + H_2CO_{3(aq)}$$

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But H2CO3 is an unstable acid, it quickly decomposes to CO2 and H2O:

$$Na_2CO_{3(aq)} + H_2SO_{4(aq)} \rightarrow Na_2SO_{4(aq)} + CO_{2(g)} + H_2O_{(l)}$$

Let's separate all soluble salts into ions:

$$2Na^+_{(aq)} + CO_3^{2-}{}_{(aq)} + 2H^+_{(aq)} + SO_4^{2-}{}_{(aq)} \rightarrow 2Na^+_{(aq)} + SO_4^{2-}{}_{(aq)} + CO_{2(g)} + H_2O_{(l)}$$

Let's cancel the same ions:

$$\cancel{2Na^+}_{(aq)} + CO_3^{2-}{}_{(aq)} + 2H^+_{(aq)} + \cancel{SO_4}^{2-}{}_{(aq)} \rightarrow \cancel{2Na^+}_{(aq)} + \cancel{SO_4}^{2-}{}_{(aq)} + CO_{2(g)} + H_2O_{(l)}$$

The net ionic equation:

$$CO_3^{2-}{}_{(aq)} + 2H^+_{(aq)} \rightarrow CO_{2(g)} + H_2O_{(l)}$$

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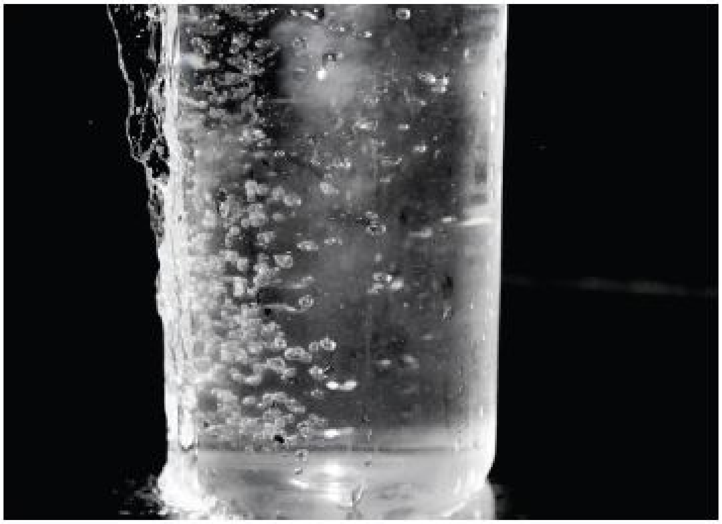

Gas evolution

Baking soda and vinegar

3. Formation of water or a weak electrolyte

Let's mix sodium hydroxide with hydrochloric acid:

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$$NaOH_{(aq)} + HCl_{(aq)} \rightarrow NaCl_{(aq)} + H_2O_{(l)}$$

Let’s separate all soluble salts into ions:

$$Na^+_{(aq)} + OH^-_{(aq)} + H^+_{(aq)} + Cl^-_{(aq)} \rightarrow Na^+_{(aq)} + Cl^-_{(aq)} + H_2O_{(l)}$$

Let’s cancel the same ions:

$$\cancel{Na}^+_{(aq)} + OH^-_{(aq)} + H^+_{(aq)} + \cancel{Cl}^-_{(aq)} \rightarrow \cancel{Na}^+_{(aq)} + \cancel{Cl}^-_{(aq)} + H_2O_{(l)}$$

The net ionic equation:

$$OH^-_{(aq)} + H^+_{(aq)} \rightarrow H_2O_{(l)}$$

Practice work

№1. Ionic displacement reactions

Materials:

1M solutions of iron (III) chloride FeCl3, sodium hydroxide NaOH, hydrochloric acid HCl, sodium carbonate Na2CO3, test tubes.

Procedure:

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1. Mix iron (III) chloride and sodium hydroxide solutions.

2. Mix sodium carbonate Na2CO3 and hydrochloric acid HCl solutions.

3. Mix sodium hydroxide NaOH and hydrochloric acid HCl solutions.

4. Write your observations.

Write the net ionic equation for each reaction described above.

Keep in mind

A net ionic equation is an equation that includes only the actual participants in a reaction.

Keep in mind

A precipitate is shown by subscript “(s)” in reactions which means “solid”. And releasing of gas is shown as “(g)” which means “gaseous”.

Terminology

- double displacement - алмасу реакциясы / реакция обмена;
- neutralization - бейтараптану / нейтрализация;
- precipitate - тұнба / осадок;

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- soluble - еритін / растворимый;
- insoluble - ерімейтін / нерастворимый;
- net ionic equation - қысқартылған иондық теңдеу / сокращенное ионное уравнение;
- reactant - реагент / реагент;
- solubility table - ерігіштік кестесі / таблица растворимости.

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1.5 CHEMICAL PROPERTIES OF ACIDS, BASES, SALTS IN TERMS OF THE ELECTROLYTIC DISSOCIATION THEORY

Why sodium hydroxide NaOH is so effective as a drain cleaner?

You will:

- learn chemical properties of acids, bases and salts according to the electrolytic dissociation through an experiment;
- write chemical equations that show chemical properties of acids, bases, salts in molecular and ionic forms

Chemical properties of acids

a. Acids react with active metals to produce salts and hydrogen gas:

Acid + Active Metal → Salt + Hydrogen

For example:

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$$2HCl(aq) + Zn(s) \rightarrow ZnCl_2(aq) + H_2(g)$$

$$2H^+(aq) + 2Cl^-(aq) + Zn(s) \rightarrow Zn^{2+}(aq) + 2Cl^-(aq) + H_2(g)$$

$$2H^+(aq) + Zn(s) \rightarrow Zn^{2+}(aq) + H_2(g)$$

b. Acids react with basic oxides to form salts and water:

Acid + Basic Oxide → Salt + Water

For example:

$$H_2SO_4(aq) + MgO(s) \rightarrow MgSO_4(aq) + H_2O(l)$$

$$2H^+(aq) + SO_4^{2-}(aq) + MgO(s) \rightarrow Mg^{2+}(aq) + SO_4^{2-}(aq) + H_2O(l)$$

$$2H^+(aq) + MgO(s) \rightarrow Mg^{2+}(aq) + H_2O(l)$$

c. Acids react with bases to give salts and water. This reaction is called a neutralization reaction:

Acid + Base → Salt + Water

For example:

$$NaOH(aq) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l)$$

$$Na^+(aq) + OH^-(aq) + H^+(aq) + Cl^-(aq) \rightarrow Na^+(aq) + Cl^-(aq) + H_2O(l)$$

$$H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$$

d. Acids react with metal carbonates to give salts, carbon dioxide and water:

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Acid + Carbonate → Salt + Carbon dioxide + Water

For example:

$$2HCl(aq) + Na_2CO_3(aq) \rightarrow 2NaCl(aq) + CO_2(g) + H_2O(l)$$

$$2H^+(aq) + 2Cl^-(aq) + 2Na^+(aq) + CO_3^{2-}(aq) \rightarrow 2Na^+(aq) + 2Cl^-(aq) + CO_2(g) + H_2O(l)$$

$$2H^+(aq) + CO_3^{2-}(aq) \rightarrow CO_2(g) + H_2O(l)$$

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Concentrated solution of hydrochloric acid

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Formation of CO_2 gas in soda drinks

Chemical properties of bases

Bases react with acidic oxides to produce salts and water:

Base + Acidic Oxide → Salt + Water

$Ca(OH)_2(aq) + CO_2(g) \rightarrow CaCO_3(s) + H_2O(l)$

$Ca^{2+}(aq) + 2OH^-(aq) + CO_2(g) \rightarrow CaCO_3(s) + H_2O(l)$

Chemical properties of salts

Solutions of salts react with some metals. Products of these reactions are salt of a metal and a displaced metal:

Salt of 1st Metal + 2nd Metal → Salt of 2nd Metal + 1st Metal

$Pb(NO_3)_2(aq) + Zn(s) \rightarrow Zn(NO_3)_2(aq) + Pb(s)$

$Pb^{2+}(aq) + 2NO_3^-(aq) + Zn(s) \rightarrow Zn^{2+}(aq) + 2NO_3^-(aq) + Pb(s)$

$Pb^{2+}(aq) + Zn(s) \rightarrow Zn^{2+}(aq) + Pb(s)$

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Result of the reaction between Zn with lead (II) nitrate

Activity

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How many reactions can you write in 5 minutes?

To play this game, you need to make 2 or 3 groups.

1. Form a line with your group. Groups need to be parallel.

2. The fi rst member of a group will write an example on board for one of the reactions that you learned in class.

3. Then he/she will go to the end of the group line.

4. Next student needs to repeat the actions.

5. You have only 5 minutes. After checking reactions calculate points.

6. Give 1 point for each right example. The winner is group with maximum points.

Facts

Fizzy drinks contain carbonic acid. It is unstable compound. The bubbles of carbon dioxide are formed in the drink due to this acid.

Literacy

1. Finish and balance the following equations:

a) HCl + K2CO3 →

b) KOH + H2SO4 →

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c) $Mg + HBr \rightarrow$

2. Identify which of the following reactions produce salt and release gas. Write the products and the net ionic equations.

a) $Fe + H2SO4 \rightarrow$

b) $Cu + HCl \rightarrow$

c) $Al + H3PO4 \rightarrow$

Terminology

- to displace - орынбасу / заменить;
- fizzy drink - газды сулар / газировки;
- bubbles - көпіршіктер / пузыри;
- to release - бөліп шығару / выделять.

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1.6 HYDROLYSIS OF SALTS

Does pH of soil affects the colour of flowers?

You will:

- identify the medium of salt solutions experimentally;
- predict reaction medium of salt solutions;
- write molecular and ionic equations of salt hydrolysis.

When salt is dissolved in water, it dissociates into a cation and an anion. Some of these ions may react with water and change the medium of water. Hydrolysis is a chemical reaction of a compound with water. Not all ions undergo a hydrolysis reaction.

– The cations of strong bases (Li^+, Na^+, K^+, Ca^{2+}, Ba^{2+}) and anions of strong acids (SO_4^{2-}, Cl^-, Br^-, I^-, NO_3^-) do not react with water (solution is neutral).

– The cations derived from weak bases (NH_4^+, Cu^{2+}, Fe^{2+}) react with water to produce hydronium ion, H_3O^+, (solution is acidic).

– The anions derived from weak acids (F^-, CH_3COO^-, CO_3^{2-}, CN^-) react with water to produce hydroxide ion, OH^-, (solution is basic).

Now, let us classify $NaCl$, K_2CO_3, and NH_4Cl solutions as acidic, basic, or neutral. $NaCl$, when sodium chloride dissolves in water, it produces sodium and chloride ions.

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$$NaCl + H_2O \leftrightarrow Na^+ + Cl^- + H_2O \quad pH \approx 7$$

Na^+ is a cation of a strong base, NaOH, and Cl^- is an anion of a strong acid, HCl. So, both ion do not hydrolyze. Therefore, sodium chloride solution is neutral. K_2CO_3, potassium carbonate solution contains potassium and carbonate ions. K^+ is derived from a strong base, KOH, and CO_3^{2-} is derived from a weak acid, H_2CO_3. Thus, only carbonate ions (CO_3^{2-}) react with water to produce hydroxide ion:

$$K_2CO_3 + H_2O \leftrightarrow KHCO_3 + KOH \; 2K^+ + CO_3^{2-} + H_2O \leftrightarrow 2K^+ + HCO_3^{2-} + OH^-$$

$$CO_3^{2-} + H_2O \leftrightarrow HCO_3^- + OH^- \qquad pH > 7$$

The resulting hydroxide OH^- ion shows that the potassium carbonate solution is basic. It will turn litmus paper to blue. NH_4Cl, ammonium chloride solution contains ammonium and chloride ions. Since Cl^- is an anion of a strong acid, HCl, it does not undergo a hydrolysis reaction. NH_4^+ is a cation of a weak base, NH_4OH. Therefore, it hydrolyzes to produce a hydronium ion:

$$NH_4Cl + H_2O \leftrightarrow NH_4OH + HCl$$

$$NH_4^+ + Cl^- + H_2O \leftrightarrow NH_4OH + H^+ + Cl^- \qquad pH < 7$$

The resulting hydronium ion (H_3O^+) shows that the ammonium chloride solution is acidic and turn litmus paper to red.

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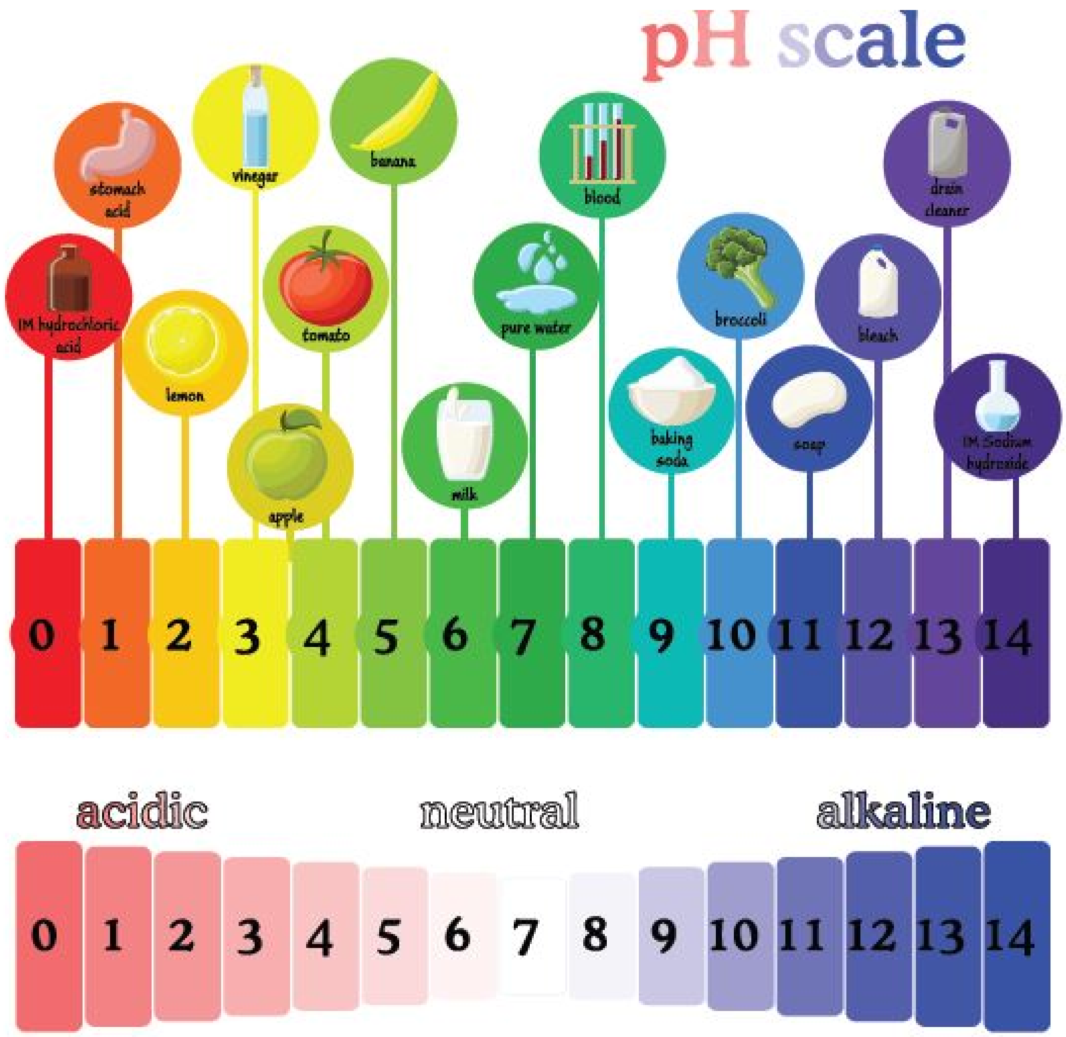

The pH value of some substances

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Handmade soap

Soap gives basic medium

Laboratory work

№2. Hydrolysis of salts

Materials:

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beakers, stirring rod, universal indicator, 1M solutions of sodium chloride, sodium carbonate, ammonium sulfate, lead (II) nitrate, sodium phosphate.

Procedure:

1. Pour aqueous solutions of each salt in a different beakers.

2. Then, check, whether hydrolysis occurred in each solution by using universal indicator.

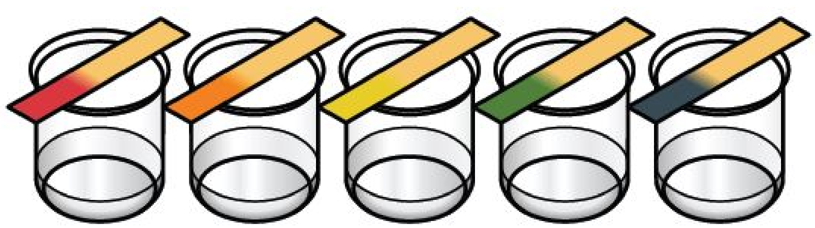
Observation and questions:

1. Which salts do not hydrolyze? Why?

2. Which of the hydrolyzed salts is/are acidic, basic?

3. Write all hydrolysis reactions for given salts.

Safety: Solutions of lead compounds are toxic.



Keep in mind

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Examples of molecular equations of salt hydrolysis

1. $CuSO_4 + 2HOH \leftrightarrow Cu(HSO_4)_2 + Cu(OH)_2$

$Cu(HSO_4)_2 + 2HOH \leftrightarrow Cu(OH)_2 + 2H_2SO_4$

2. $K_2S + HOH \leftrightarrow KHS + KOH$

$KHS + HOH \leftrightarrow KOH + H_2S$

3. $Pb(NO_3)_2 + H_2O \leftrightarrow PbOHNO_3 + HNO_3$

4. $Al_2S_3 + 6HOH \rightarrow 2Al(OH)_3 + 3H_2S$

Facts

The flowers of a hydrangea bush are blue when grown in acid soil and pink when the soil pH is alkaline.

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Flowers of hydrangea

Literacy

1. What does hydrolysis of salts mean?

2. Write hydrolysis reactions for solutions of the following salts: FeCl3, K2CO3, Na2S.

3. Predict whether the solutions of the following salts are acidic, basic or neutral:

a. CuCl2

b. NaNO3

c. LiCN

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Terminology

- hydrolysis - гидролиз;
- pH value - pH көрсеткіш / значение pH;
- medium - орта / среда;
- soil - топырық / почва;
- hydronium - гидроксоний;
- to derive - алу / получить;
- undergo - жүру / пройти;
- to reduce - азайту / уменьшить;
- hydrangea - гортензия гүлі / цветок гортензия.

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Problems: Electrolytic dissociation

1. Decide whether the following statements are true (T) or false (F).

a. The solute in a solution is always a solid. ....

b. The precipitation is the formation of gas............

c. Water is an example of a weak electrolyte............

d. Solutions are homogeneous mixtures............

e. An accumulator is a device in which sulfuric acid is used as an electrolyte. ....

2. Classify each of the following substances as a strong electrolyte, weak electrolyte or nonelectrolyte:

a. Acetic acid solution b. Sugar solution

c. Ammonia solution d. Sodium chloride solution

e. Alcohol solution f. Hydrochloric acid solution

g. Sodium hydroxide solution

3. In three different beakers, solutions of table salt, sugar, and acetic acid are given. How can you identify them without tasting?

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4. Write the dissociation processes of the following compounds:

a. potassium chloride, KCl

b. nitric acid, HNO3

c. lithium hydroxide, LiOH

d. acetic acid CH3COOH

5. 300 molecules were placed in the solution. Determine the degree of dissociation if dissociated 75 molecules.

6. Calculate concentration of ions in 0.01 molar solution of barium hydroxide, if α=85%.

7. Characterize each of the following compounds

Compound	Acid, Base or Salt	Electrolyte (strong, weak, non-)	Products of dissociation
$CaSO_4$		strong	
KOH	Base		

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NaCl			Na^+, Cl^-
H_2SO_4			
H_2CO_3			
HF			
$C_6H_{12}O_6$ (glucose)			
NH_3			
C_2H_5OH (alcohol)			

8. Predict whether the solutions of the following salts are acidic, basic, or neutral. Write all possible reactions.

a. KF   b. NH4I   c. Cu(NO3)2   d. NH4Br   e. KI f. Na3PO4

9. Calculate the molar concentration of Al3+ and SO42– in the solution, if the molar concentration of aluminum sulfate is 0.001 mol/L and degree of dissociation is 80 %.

10. In two different test tubes there are two solids, sodium chloride and silver chloride. How can you identify them?

11. We have 6 test tubes with magnesium chloride. Add to each test tube following solutions.

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1. $NaOH$

2. K_2SO_4

3. Na_2CO_3

4. $Zn(NO_3)_2$

5. K_3PO_4

6. Na_2SO_4

Write the chemical and net ionic equations for the possible reactions.

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CHAPTER 2: QUALITATIVE ANALYSIS OF INORGANIC COMPOUNDS

2.1 QUALITATIVE REACTIONS FOR CATIONS

How can we use a flame to identify the presence of metal in a compound?

You will:

- know how to determine metal ions by using a flame test;
- carry out qualitative analysis to identify iron(II), iron(III), and copper(II) ions.

The analysis of cations

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Tested Cation	Reagent	Result
Ag^{+}	Cl^{-}, SO_4^{2-}	White precipitate,white precipitate
Cu^{2+}	OH^{-} S^{2-}	Blue precipitate Black precipitate
Mg^{2+}	OH^{-}	White precipitate
Fe^{2+}	OH^{-}	Green precipitate
Fe^{3+}	OH^{-}	Reddish-brown precipitate
Zn^{2+}	OH^{-} S^{2-}	White precipitate (soluble in excess OH^{-}) White precipitate
Pb^{2+}	S^{2-}	Black precipitate
NH_4^{+}	OH^{-}	Formation of ammonia gas with sharp odour
Ba^{2+}	SO_4^{2-}, CO_3^{2-}	White precipitate, white precipitate
Al^{3+}	OH^{-}	White precipitate (soluble in excess OH^{-})

Laboratory work

№3. Determination of Li+, Na+, K+, Ca2+, Sr2+, Ba2+, Cu2+ cations by means of flame test

Different metal ions give different colours in a flame test. Therefore, flame test is useful in identification of metal ions. In this experiment, we will observe characteristic colours of different metal ions.

Materials:

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salts of sodium, potassium, lithium, calcium, barium, copper and strontium, watch glass, 100 ml beakers, burner, wood stick.

Procedure:

1. Prepare 1M salt solutions.

2. Light a burner.

3. Put wood sticks in salt solutions.

4. Take a wet wood stick of sodium salt solution and slowly pass the wooden splint back and forth through the flame.

5. Observe colours of the flame and write in the table below.

6. Repeat previous steps for other metal salt solutions and write the colour of the flame in the table below.

7. Carry out a fl ame test for an unknown sample given to you and try to determine a metal ion in it.

Observation and questions:

1. Which elements give the similar colour in the flame test?

2. Can we use a fl ame test to determine different metals in one sample? Explain.

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Metallic ion	Li^{+}	Na^{+}	K^{+}	Ca^{2+}	Ba^{2+}	Sr^{2+}	Cu^{2+}
Flame colour							

Laboratory work

№4. Qualitative analysis of Fe2+, Fe3+, Cu2+ cations: reactions with alkalis

Metal hydroxides have different solubilities in water. For example, soluble transition metal salts give coloured precipitates with alkali solutions. The difference in colours of metal hydroxides can be used in analytical chemistry for determining of unknown metals.

Materials:

test tubes, droppers, test tube rack, 1M solutions of iron (III) chloride, iron (II) sulfate, copper (II) chloride/sulfate, potassium/sodium hydroxide.

Procedure:

1. Place 3 test tubes in the test tube rack.

2. Pour about 10 ml of iron (III) chloride, iron (II) sulfate, copper (II) chloride/sulfate solutions into the test tubes (separately).

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3. Then add 7-10 drops of the base with a dropper to each test tube.

4. Write your observations (colour of precipitate) in the table.

Observation and questions:

1. Write net ionic equations.

2. Suggest other ways of determining of copper and iron containing compounds.

	Fe^{3+}	Fe^{2+}	Cu^{2+}
Base solution			

Keep in mind

Each ion reacts in its characteristic way.

Keep in mind

Fe(OH)2 - green

Fe(OH)3 - reddish brown

Cu(OH)2 - blue

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Science in context

Display of fireworks are also a chemical reaction. Different colours of fireworks are produced by pyrotechnic ‘stars’. The ‘stars’ contain five basic ingredients:

- red – Sr^{2+} ion,
- orange – Ca^{2+} ion,
- yellow – Na^{+} ion,
- green – Ba^{2+} ion,
- blue-green – Cu^{2+} ion.

Fireworks

Literacy

1. Complete the reactions, write net ionic equations:

a. $H_2SO_4 + BaCl_2 \rightarrow$

b. $FeCl_3 + AgNO_3 \rightarrow$

c. $CuSO_4 + NaOH \rightarrow$

2. Which of the following compounds will react with iron (II) chloride? Write molecular and net ionic equations.

a) $Cu(NO_3)_2$ b) $NaOH$ c) Na_2SO_4 d) HCl

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3. Suggest molecular equation for the following net equations:

a. Ba2+ + CO32- → BaCO3   b. H+ + OH– → H2O

Terminology

- qualitative - сапалық / качественный;
- several - бірнеше / несколько;
- flame - жалын / пламя;
- analysis - талдау / анализ;
- precipitate - тұнба / осадок;
- wood stick - ағаш кесінді / деревянная палочка.

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2.2 QUALITATIVE REACTIONS FOR ANIONS

How can you prove a sample of mineral water contains certain anions?

You will:

- carry out qualitative reactions for some anions.

The analysis of anions

Tested Anion	Reagent	Result
Cl^-	Ag^+, Pb^{2+}	White precipitate, white precipitate
Br^-	Ag^+	Greyish-yellow precipitate
I^-	Ag^+	Yellow precipitate
SO_4^{2-}	Ba^{2+}	White precipitate
PO_4^{3-}	Ag^+	Yellow precipitate
S^{2-}	Cu^{2+}, Pb^{2+}, Ag^+ Cd^{2+}	Black precipitate Yellow precipitate
CO_3^{2-}	H^+	Formation of carbon dioxide that turns limewater milky
OH^-	Indicator	Colour change

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As you could understand from the previous lesson, to indicate an ion you need to find a reaction that will work only for it. The most common reaction for identification is precipitation. Tests for most common anions are given in Table. For example, silver nitrate forms a white precipitate with chloride ion:

$$AgNO_3(aq) + NaCl(aq) \rightarrow AgCl(s) + NaNO_3(aq)$$

Also, silver nitrate is used to identify bromide and iodide ions. All bromides produce a cream precipitate (AgBr) while all iodides give a yellow precipitate (AgI) with silver nitrate:

$$AgNO_3(aq) + KBr(aq) \rightarrow AgBr(s) + KNO_3(aq)$$

$$2AgNO_3(aq) + CaI_2(aq) \rightarrow 2AgI(s) + Ca(NO_3)_2(aq)$$

In addition to reactions above, silver nitrate can be used to determine phosphate ions. It will form a yellow precipitate:

$$3AgNO_3(aq) + Na_3PO_4(aq) \rightarrow Ag_3PO_4(s) + 3NaNO_3(aq)$$

Ba^{2+} ions are used for the precipitation of sulfate ions. Both of them form a white precipitate of barium sulfate ($BaSO_4$):

$$Ba(NO_3)_2(aq) + K_2SO_4(aq) \rightarrow BaSO_4(s) + 2KNO_3(aq)$$

However, another option for identifying ions is gas release. For example, addition of hydrochloric acid to carbonate compounds produces carbon dioxide gas, which then is tested with limewater:

$$K_2CO_3(aq) + H_2SO_4(aq) \rightarrow K_2SO_4(aq) + H_2O(l) + CO_2(g)$$

$$CO_2(g) + Ca(OH)_2(aq) \rightarrow CaCO_3(s) + H_2O(l)$$

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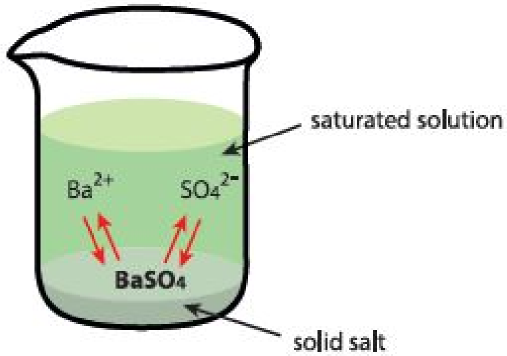
Chlorine test in blood



Determination of sulfate-ion

Keep in mind:

There are no two anions behave identically in all chemical reactions.

Facts

Barium sulfate BaSO4 is one of the components of “Lego” constructors.

LEGO toys

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Literacy

1. Given three solutions: Na_2CO_3, KI, Na_2SO_4. Which cations and anions should be used to indicate them.

2. Write the total and the net ionic equations for the following compounds. Water solutions of:

a. copper (II) sulfate and sodium hydroxide

b. sodium carbonate and calcium chloride

c. zinc hydroxide and nitric acid

3. You suspect a sample of tap water contains sulfate and iodide anions. How can you identify them?

Activity

"Golden rain" experiment

The reaction of potassium iodide and lead nitrate gives an insoluble precipitate. The formed lead iodide is more soluble in hot water. That property can be used to identify Pb^{2+} and I^- ions. We will conduct an experiment called "golden rain". Remember that lead compounds are toxic and should be used with appropriate safety rules.

Procedure:

1. Prepare an aqueous solution of potassium iodide (1 g per 150 ml of water).

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2. In the second beaker prepare hot solution of lead (II) nitrate (1 g per 150 ml of water).

3. Add 7-10 drops of hot lead (II) nitrate solution to potassium iodide. A yellow precipitate will form. Mix solution and precipitate will dissolve. After cooling of the solution, dissolved lead iodide recrystallizes by forming golden-yellow crystals.

SAFETY: Wear disposable gloves. Avoid skin contact. Solutions of lead compounds are toxic. Wash hands after the experiment.

Laboratory work

№5. Qualitative analysis of inorganic compounds

Carbonate test for calcium cation

Materials:

Ca(OH)2, Na2CO3 solutions, test tubes.

Procedure:

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1. Pour 6-8 drops of the limewater $Ca(OH)_2$ solution in a test tube.

2. Add 1-2 drops of sodium carbonate Na_2CO_3 solution. Look for a white precipitate.

3. Write chemical reactions.

Test for ammonium cation

Materials:

NaOH, $(NH_4)_2SO_4$ solutions, test tubes.

Procedure:

1. Pour 5-6 drops of the ammonium sulfate $(NH_4)_2SO_4$ solution in a test tube.

2. Add 1-2 drops of sodium hydroxide NaOH solution. You may notice the smell of ammonia gas. Test the ammonia gas with wet litmus indicator paper.

3.Record the results.

Terminology

- to suspect - сезіктену / подозревать;
- to behave - істеу / вести себя (поведение);
- constructor - құрастырғыш / конструктор;

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- recrystallization - қайта кристалдандыру / перекристаллизация.

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2.3 QUALITATIVE ANALYSIS OF UNKNOWN SALT SOLUTION

If you find unlabeled mineral, how would you identify it?

You will:

- know how to plan and carry out an experiment on an identification of cations and anions.

Sometimes we have a compound without any label and we need to find out what it is. In such cases, we can use many tests to identify the compound. These tests are based on reactions that indicates a particular ion. The chosen reaction must work only for the specific ion. This type of analysis is called as qualitative analysis.

Formation of precipitate and production of gas are some of the options to analyze an unknown chemical.

As we said before, there can be many ways to identify an unknown ion but we will show only some simple examples that you can use. There are two schemes as a strategy for identification of ions.

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Chemical analysis conducted by a girl in lab

Keep in mind

You can identify any cation or anion by using specific reactions.

Science in context

Qualitative analysis is used in food quality analysis, in medicine, in identifying soil composition, in water purity analysis, etc.

Water purity analysis

Practice work

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№2. Identifying of an unknown compound

Materials:

beaker 250 ml, distilled water, unknown substance, test tubes, test tube rack, pipette.

Procedure:

1. Take a sample of unknown substance(s) from a teacher.

2. Put it into a beaker and add water. Mix it.

3. Divide your solution into two parts.

4. The first part of the solution will be used to identify unknown anion (use the scheme for anion test).

5. The second part of the solution will be used for experiments on cation (use the scheme for cation test).

6. Record your observations and make a conclusion.

SAFETY: Some unknown substances may be toxic or corrosive. Wear disposable gloves. Avoid skin contact. Wash hands after use.

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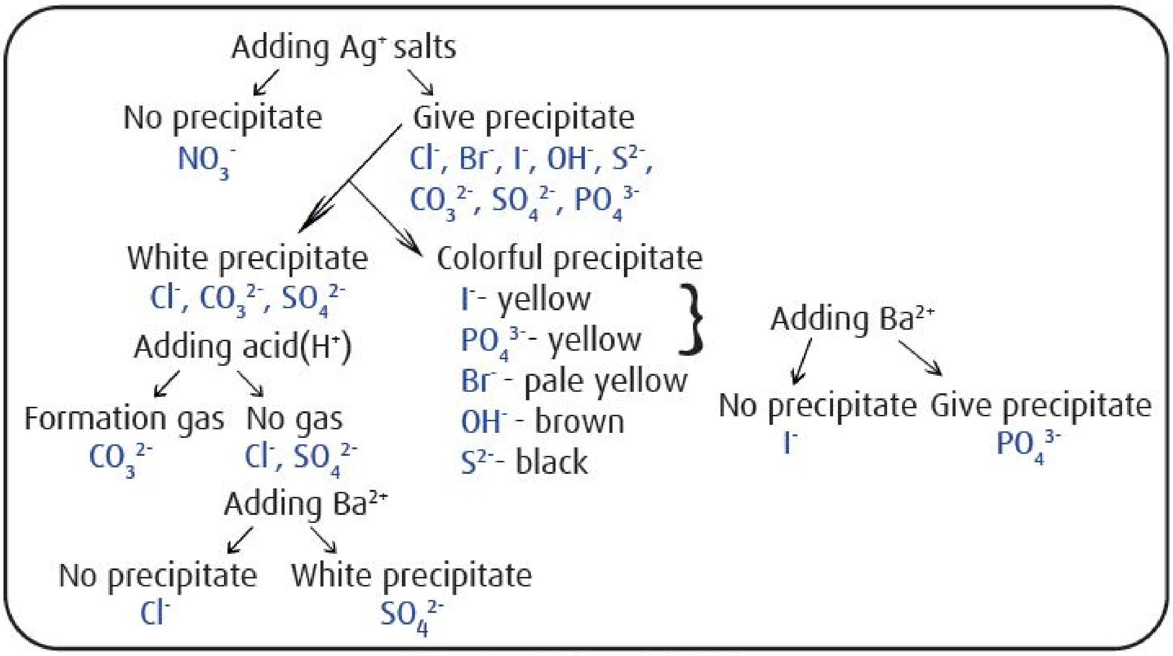
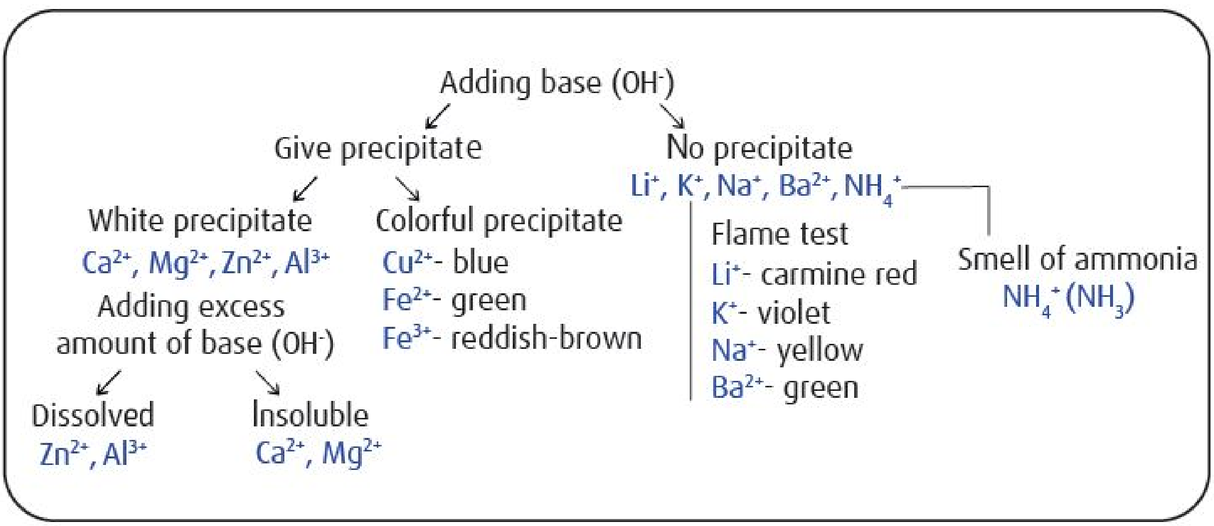


Scheme for qualitative analysis of anions



Scheme for qualitative analysis of cations

Terminology

- unlabeled - аты белгісіз / без этикеток;
- qualitative - сапалық / качественный;
- identifi cation - сәйкестендіру / идентификация;

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- confirm - растау / подтвердить;
- certain - мүмкін / определенный.

Literacy

1. What analysis types are used in medicine?

2. How can we identify calcium chloride ($CaCl_2$) in a solution?

3. How can you identify the composition of tap water in your home?

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2.4 CHEMICAL CALCULATIONS ON LIMITING REAGENT PROBLEMS

Assume you have 5 letters to send, but you have only 3 stamps. How many messages can you post?

You will:

- solve problems with limiting/excess of reactants.

Although you have three letters, the number of stamps determines the number of letters that you can send. In this case, we have limited number of stamps and an excess number of letters. That is why the answer is one letter.

Letter stamps

Keep in mind

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The mole number of a substance can be found through mass, volume or number of particles.

Example 1

4 moles of hydrogen gas reacts with 2 moles of chlorine gas to produce hydrogen chloride.

a. Calculate the amount of HCl produced (in moles).

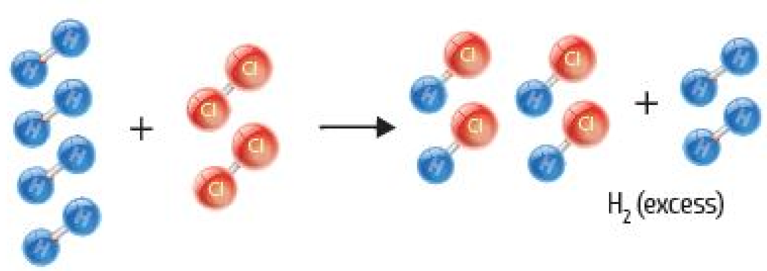
b. Calculate the amount of unused reagent (in moles).

Solution:

a.

	$H_2(g)$	+	$Cl_2(g)$	→	$2HCl(g)$
Initial :	4 mol		2 mol		—
Change :	-2 mol		-2 mol		+4 mol
Final :	2 mol (excess)		— (limiting)		4 mol

b. In this reaction, hydrogen is in excess. Two moles of hydrogen is used in the reaction and two moles remain.



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Example 2

Carborundum, SiC is used as an abrasive. It is formed by the combination of SiO2 and carbon, according to the reaction:

$$SiO_2(s) + 3C(s) \rightarrow SiC(s) + 2CO(g)$$

What mass of SiC is formed from 6 grams of SiO2 and 6 grams of C?

Solution.

We must find which reactant is limiting.

Step 1. Balanced equation of this reaction:

$$SiO_2(s) + 3C(s) \rightarrow SiC(s) + 2CO(g)$$

Step 2. The mole numbers of the reactants are:

6 g SiO2; n(SiO2) = n/M = 0.1 mol and 6 g C; n=(6 g)/(12 g/mol) = 0.5 mol

Step 3.

Let's divide mole numbers of reactants by their coefficients:

(n(SiO2))/1 =(0,1 mol)/1 = 0.1 mol,

(n(C))/3 = (0,5 mol)/3 = 0.167 mol

Step 4.

Now we need to compare these two numbers and as you can see silicon dioxide is a limiting reactant.

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	$SiO_{2(s)}$	+	$3C_{(s)}$	$\rightarrow$	$SiC_{(s)}$	+	$2CO$
Initial :	0.1 mol		0.5 mol				
Change:	- 0.1 mol		- 0.3 mol		+ 0.1 mol		
Final :	- (limiting)		0.2 mol (excess)		0.1 mol		

Step 5.

The mass of 0.1 mol SiC is:

m(SiC) = n(SiC) • Mr(SiC) = 0.1 mol • 40 g/mol = 4 g

Keep in mind

Mole formulas:

$$n = \frac{m}{M} \qquad n = \frac{V}{22,4}$$

$$n = \frac{N}{N_A}$$

Science in context

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You might not notice that you use limiting problems in your daily life. As an example, you want to prepare 20 bauyrsaqs, you need:

500 g of wheat + 100 ml of milk + 50 g of sugar + 200 ml of vegetable oil. How many bauyrsaqs can you prepare if you have 800 g of wheat, 150 ml of milk, 40 g of sugar and 500 ml of vegetable oil?

Frying of bauyrsaqs

Literacy

1. The mixture of 2 moles of H_2 and 2 moles of O_2 gases react to produce water. Which reactant is in excess and which one is limiting? What is the mass of produced water?

2. Given: $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$.

20 L of N_2 and 15 L of H_2 gases react. Which gas is in excess? What is the mass of excess gas?

3. Equal masses of sodium and chlorine gas react in a closed container to give 0.1 mol of sodium chloride. Which element is

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in excess? Calculate the mass of the element which remains.

Terminology

- limiting - жетіспейтін, шектеулі / недостаток;
- excess - артық / избыток;
- stamp - марка / марка;
- initial - бастапқы / начальный;
- to remain - өзгермеу / оставаться;
- carborundum - карборунд / карборунд;
- behind - артынан / сзади.

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Problems: Qualitative analysis of inorganic compounds

1. Consider the following reaction:

$Fe(s) + 2HCl(aq) \rightarrow FeCl_2(aq) + H_2(g)$

a. When 2.2 moles of Fe reacts with 4.5 moles of HCl, how many moles of H_2 are formed?

b. What is the limiting reactant?

c. For the reactant in excess, how many moles are left at the end of the reaction?

2. Consider the following reaction:

$CuCl_2(aq) + 2KOH(aq) \rightarrow Cu(OH)_2(s) + 2KCl(aq)$

a. 0.56 moles of $CuCl_2$ reacts with 0.64 moles of KOH. What is the mole number of produced KCl?

b. Which one is the limiting reactant?

c. For the reactant in excess, how many moles are left at the end of the reaction?

3. Given the following reaction (the reaction is not balanced):

$CH_4(g) + O_2(g) \rightarrow CO_2(g) + H_2O(l)$

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a) If you start with 12.8 g of CH_4 and 64 g of O_2, determine the limiting reagent;

b) determine the number of moles of carbon dioxide produced;

c) determine the mass of produced water;

d) determine the mass left of excess reagent.

4. Which element is in excess when 7.2 grams of Ca is ignited in 9.6 grams of pure oxygen? What mass is in excess? What mass of CaO is formed?

5. How many grams of Li_2S are formed when 14.7 grams of lithium is heated with 22.4 grams of sulfur?

6. Write the balanced net ionic equation for the reaction occurred between

a) Pb^{2+} and SO_4^{2-};

b) Pb^{2+} and Cl^-.

Suggest molecular equations.

7. Write the balanced net ionic equation for the reaction occurred between

a) Ag^+ and Cl^-;

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b) Ag^+ and Br^-.

Suggest molecular equations.

8. Write a balanced molecular and net ionic equations between silver nitrate $AgNO_3$ and sodium phosphate Na_3PO_4 solutions.

9. Answer the question below for each of these pairs of solutions.

I. NaCl and $AgNO_3$ solutions

II. NaI and $AgNO_3$ solutions

III. $MgCl_2$ and NaOH solutions

IV. $BaCl_2$ and H_2SO_4 solutions

V. NaCl and KI solutions

a. Write the equations for the reactions that take place between the given pairs. If you think that the pairs do not give a reaction, give your reasoning.

b. Write the net ionic equations for the reactions you wrote in question a.

10. Given two ionic solutions: sulfate and chloride of sodium. What is the scheme for identifying of each salt? Draw an identification scheme.

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11. In three different test tubes, there are the solutions of potassium chloride, potassium iodide and potassium sulfide solutions. How can you identify them by using only one reagent?

12. In which of the following does a reaction not occur? (Use the solubility table)

A) MgCl2(aq) + NaOH(aq) →

B) BaCl2(aq) + H2SO4(aq) →

C) KI(aq) + AgNO3(aq) →

D) NaCl(aq) + AgNO3(aq) →

E) LiNO3(aq) + NH4Cl(aq) →

13. How would you test a sample for presence of calcium ions?

14. How would you test a sample for presence of phosphate and chloride ions?

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CHAPTER 3: THE RATE OF CHEMICAL REACTION

3.1 THE RATE OF REACTIONS. FACTORS AFFECTING THE RATE OF REACTION

Why some types of milk sour in a week and some of them do not sour for a month?

You will:

- define the rate of chemical reactions;
- learn factors that can affect the rate of reactions.

Rates of reaction

You know that the speed of any object (for example car) is the change of distance (Δd) in a defi nite period of time (Δt). Or "speed" = Δd /Δt. We can defi ne the rate of reaction as change in amount (concentration, mass, volume, mole) Δx over a definite period of time (second, minute, hour etc.) Δt. Or

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$$r = \frac{\Delta x}{\Delta t}$$

where x can be mass m, volume V, mole n.

Factors affecting the rate of reaction

Scientists studied many reactions to understand which factors affect the rate of reactions. It was discovered that there are five main factors which affect reaction rate:

- The surface area of any solid reactant

The rate of a reaction increases when we increase the surface area of a solid.

- The concentration of reactant

The rate of a reaction increases when we increase the concentration of a reactant in solution.

- The temperature at which the reaction happens

The rate of a reaction increases when we increase the temperature of the reaction mixture.

- Use of catalyst

The rate of a reaction increases when the catalyst is added in the reaction.

- Light, also, can infl uence some reactions.

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Examples of slow and fast speeds

Corrosion is slow process

Powder has got greater surface area than normal solid substance

Demonstration

№2. The rate of reaction. "Iodine clock" reaction.

Materials:

starch, sodium acetate, potassium iodide, sodium thiosulfate (Na2S2O3), acetic acid 30% solution, hydrogen peroxide 20% solution, two 100 ml beakers, stirring rod, analytical balance.

Procedure:

Solution A

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1. Dissolve about 0.1 g of starch in 80 ml of hot water, use 100 ml beaker
2. Add 0.41 g of sodium acetate, 5 g of potassium iodide and 0.94 g of sodium thiosulfate. Stir the solution and wait until it cools.
3. Pour water into the beaker to make up to 100 ml.

Solution B
1. To 100 ml beaker solution pour 50 ml of hydrogen peroxide solution
2. Add 30 ml of acetic acid. Pour water into the beaker to make up to 100 ml.

The demonstration
Mix about 20 ml of Solution A and Solution B. Stir the resulting solution. After a while, you will see that solution suddenly turn to dark blue.

NOTE: The time for blue colour to appear can be changed by changing amount of thiosulfate in Solution A.

Laboratory work

№6.1. The rate of reaction – the effect of temperature.

When hydrochloric acid reacts with zinc, hydrogen gas and zinc chloride are produced. By changing the temperature of the solutions we can change the time for the reaction needed to be completed.

Materials:

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1M of hydrochloric acid solution, zinc pellets, burner, ice cubes (or snow), two thermometers, two beakers.

Procedure:

1. Prepare two solutions of acid: cold and hot (use ice cubes (or snow) and burner)

2. Record the maximum and minimum temperatures.

3. Fill beaker for a ¼ of its volume with cold solution of hydrochloric acid. Do the same with hot solution.

4. Drop a pellet of zinc into beakers.

5. Record what happens.

Observation and questions:

- Which reaction occurred faster?

- Write chemical equation for this reaction.

- Why does increasing the temperature, usually, increases the rate of reaction?

Keep in mind

Catalyst – a substance that increases the rate of a chemical reaction. The catalyst does not change chemically at the end of the reaction.

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Catalysts are used in car. Cross sections of a car catalyst

Literacy

Imagine two types of a potato: whole and sliced. Which of these potatoes will fry faster? And why?

Sliced potatoes

Terminology

- rate of reaction – реакция жылдамдығы / скорость реакции;
- to rate – өлшеу, бағалау / оценивать;
- collision – соқтығысу / столкновение;

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- suffi cient – жеткілікті / достаточный;
- surface area – беттік аудан / площадь поверхности;
- catalyst – өршіткі / катализатор;
- infl uence – әсері / влияние.

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3.2 TEMPERATURE AND CONCENTRATION EFFECTS

Why some plants and insects live in summer and “die” in winter?

You will:

- understand how temperature affects on the rate of reactions;
- know the effect of concentration on the rate of reaction.

Temperature

We can change temperature to make reactions faster or slower. And you know that the rate of a reaction increases when we increase the temperature of the reaction. It is often stated an increase in temperature of 10°C doubles the reaction rate.

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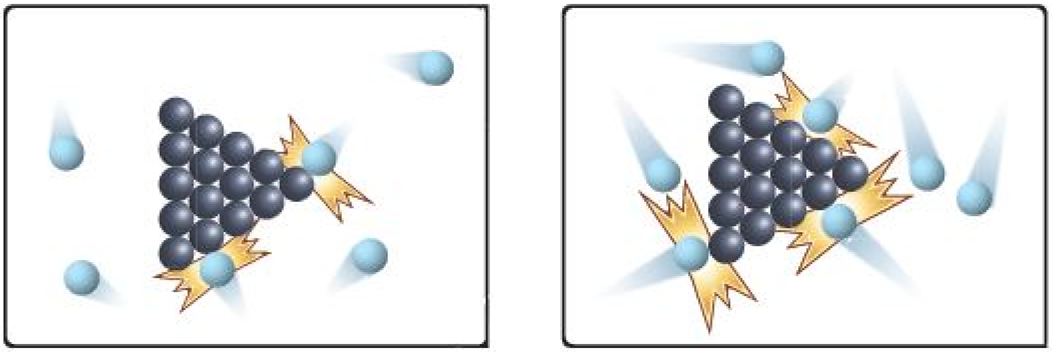

Temperature. More collisions and particles collide with more energy

The energy that is set not only increases the collision, but is also needed to break old bonds and to form a new bond in the reaction product.

In other words, the molecules will start moving faster as the mixture is heated. It mean that there will be more collisions per second and the collisions will involve more energy. Numbers of molecules that collide with sufficient kinetic energy for the reaction to take place will increase. Therefore, the overall rate of reaction will increase.

Concentration of reactants

The rate of a reaction is directly proportional to the concentration of reactants: the higher the concentration of reactants, the faster the reaction occurs. As concentration increases, particles of reactants start to collide more often, so the possibility of successful collision increases too. As the concentration of reactants falls, the rate of reaction decreases. Reactions that produce gases are useful in studying the effect of solution concentration on the reaction rate.

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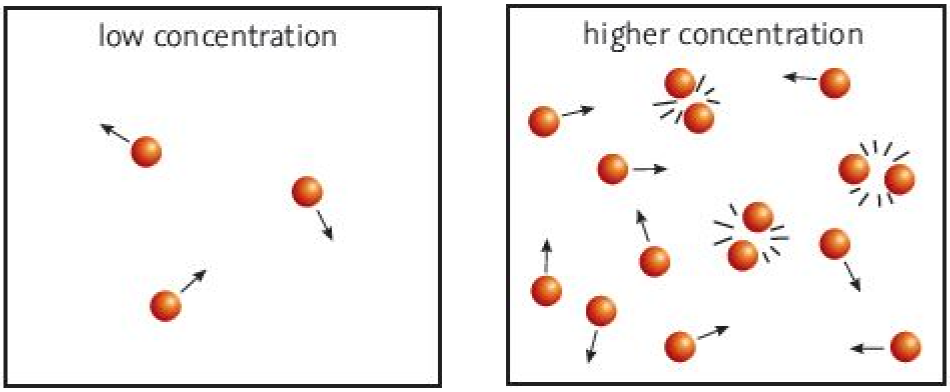

Concentration. When particles are closer together they have a greater chance of reacting

A refrigerator keeps food at a certain temperature, and slows down the rate of the reactions that cause spoilage.

Laboratory work

№ 6.2. The rate of reaction – the effect of concentration and interacting area.

Materials:

concentrated and diluted solutions of HCl, chalk powder, solid chalk, two test tubes.

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Procedure:

1. Take a small piece of chalk, break it into two equal parts, wipe one of pieces of chalks into powder.

2. Pour 5 ml of HCl (conc.) into fi rst test tube and 5 ml of HCl (diluted) into the second.

3. Put chalk into the test tubes with solutions of HCl.

4. Record the start and the end time for each reaction.

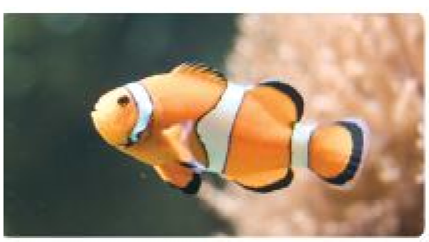
Observation & questions:

• Write chemical reaction between chalk and the acid, if chemical formula of chalk is CaCO3.

• Reaction in which test tube took less time to complete? Why?

Facts

When the temperature drops, most fish stop normal activities and their whole system slows down.



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Keep in mind

Collision theory in the rate of reaction

Collision theory says that chemical reactions occur by the collisions between atoms and molecules, so the more collisions the faster the rate of the chemical reactions. It follows that if the molecules collide more often that this will increase the rate of reaction. The higher the temperature the more kinetic energy molecules and atoms have. The more kinetic energy the molecules have the faster they move and the more collision will occur increasing the rate of the reaction.

Terminology

- to disappear - жоғалу / исчезнуть;
- concentration - концентрация / концентрация;
- to increase - өсу / повышать;
- to collide - соқтығысу / сталкиваться;
- marble – мәрмәр / мрамор;
- dilute – сұйытылған / разбавленный;
- wipe into - ұнтақтау / стереть в порошок.

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3.3 PRESSURE EFFECTS. CATALYSTS AND INHIBITORS

What is the difference between boiling point of water on mountains and boiling point of water underground? Why?

You will:

- explain the effect of pressure on the rate of reaction;
- understand the difference between catalyst and reactant;
- explain effect of inhibitors on the rate of the reaction.

Pressure

For reactions involving gases, increasing pressure increases the rate of reaction. It happens because the higher pressure compresses the gas, effectively increasing its concentration. That's why the frequency of collision increases.

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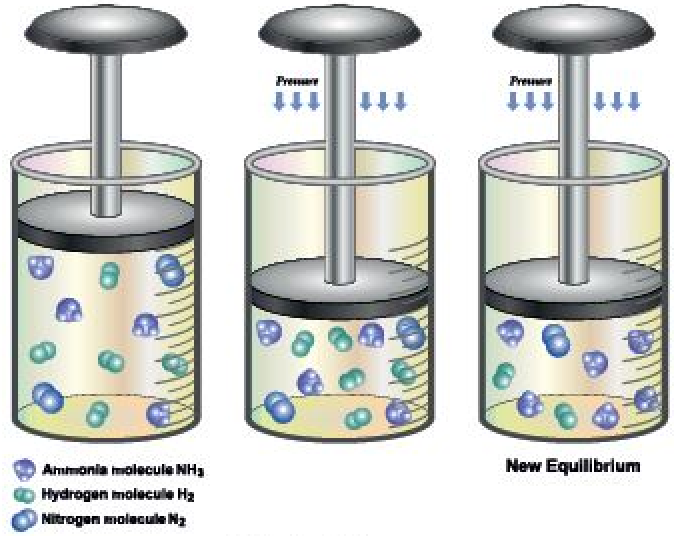

Effect of Pressure

Cleaning car with high-pressure water

Catalyst and inhibitors

A catalyst is a substance that increases the rate of a reaction without being consumed during it. Catalyst changes the reaction path by decreasing the activation energy. Catalysts have the following properties.

1. They remain unchanged after the reaction.

2. The energy of activation for the reaction, EA, is lowered by a catalyst.

3. It does not make an impossible reaction possible.

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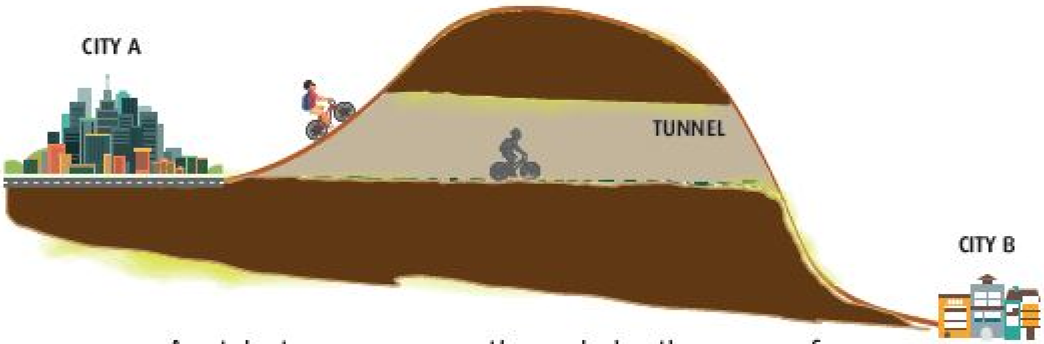

A catalyst opens a new pathway during the course of a reaction

Industrial process	Catalyst
Ammonia manufacture (Haber process)	Iron
Sulfuric acid manufacture (Contact process)	Vanadium (V) oxide
Margarine production (hydrogenation of fats)	Nickel
Nitric acid manufacture (oxidation of ammonia)	Platinum-Rhodium
Conversion of methanol to hydrocarbons	Zeolite ZSM-5

List of catalysts used in industry

Sometimes slow reactions can be benefi cial. A substance that slows down a reaction is called an inhibitor. Inhibitors act oppositely to catalysts and increase activation energy. Inhibitors include preservatives, such as the ones found in food products to prevent spoilage. There are different kinds of chemical preservatives commonly used in foods. They can both inhibit the activity of bacteria or kill the bacteria. These chemicals include benzoates (sodium benzoate), nitrites (sodium nitrite), sulfi tes (sulfur dioxide) and sorbic acid.

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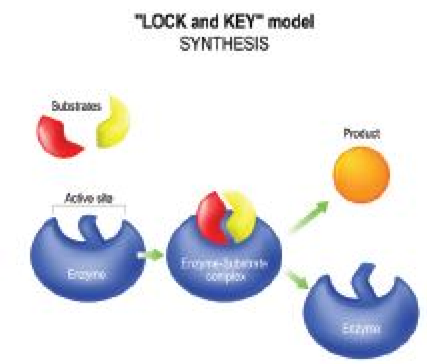
Facts

Pollutants also can act as catalyst, for example, CFC. The depletion of the ozone layer increases by chlorofl uorocarbon (CFC), which have been widely used in refrigeration and air conditioners.

Facts

Enzymes are organic catalysts that speed up reactions in living cells.



Keep in mind

Activation energy is a minimum energy required to start a reaction. Activation energy is represented by EA.

Facts

A catalytic converter works by filtering exhaust gases produced by a car. It coated with precious metals such as

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platinum, palladium and rhodium that act as a filtering agents for harmful gases.


Catalysts in daily life

Practice work

№3. Effect of a catalyst on the rate of decomposition of hydrogen peroxide H2O2.

Introduction:

When manganese (IV) oxide MnO2 is added to hydrogen peroxide, an exothermic and rapid chemical reaction takes place. This reaction produces water, oxygen and heat. Without the catalyst, the decomposition of hydrogen peroxide will occur, but the reaction will take more time to be completed.

Materials:

manganese (IV) oxide, hydrogen peroxide solution, beaker.

Procedure and questions:

1. Pour 50 ml of hydrogen peroxide into the beaker.
2. Add a small amount of MnO2 by using a spatula.

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3. Record your observations.

Terminology

- pressure - қысым / давление;
- catalyst - катализатор;
- inhibitor - тежегіш / ингибитор;
- activation energy - активтену энергиясы / энергия активации;
- frequency - жиілік / частота;
- to spoilage - бұзылу / портиться;
- exhaust – шығыс газдар / выхлопные газы;
- depletion - бұзылу / портить.

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Problems: The rate of chemical reaction

1. Which of the following has a higher rate of reaction?

a.

1	piece of chalk + 100 ml hydrochloric acid
2	powdered chalk + 100 ml hydrochloric acid

Affecting factor: ....

b.

1	10 g lump of iron metal + 200 ml hydrochloric acid (diluted)
2	10 g powdered iron metal + 200 ml hydrochloric acid (concentrated)

Affecting factor: ....

c.

1	5 g lump of iron metal + 200 ml hydrochloric acid at 25ºC
2	5 g lump of iron metal + 200 ml hydrochloric acid 80ºC

Affecting factor: ....

d.

1	10 g lump of calcium carbonate + 100 ml hydrochloric acid
2	10 g lump of calcium carbonate + 100 ml hydrochloric acid + 40 ml water

Affecting factor: ....

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2. Place the following reactions according to their rates:

I. Photosynthesis

II. Rusting of iron

III. Sparking of a match

IV. Digestion of food

V. Spoiling of fruit

3. Which of the criteria below must be supplied in order to result in a reaction?

I. Activation energy

II. Collision with a proper geometry

III. Catalyst

4. $CaCO3(s)$ + heat → $CaO(s) + CO2(g)$

What should be done to complete the given reaction in a shorter time?

I. The volume of the container should be increased.

II. The temperature should be increased.

III. CaCO3 must be granulated.

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5. $A_2(g) + B_2(g) + heat \rightarrow 2AB(g)$

Which of the following does not increase the rate of the reaction?

A) Addition of catalyst

B) Increasing the volume of the container

C) Addition of A2

D) Addition of B2

E) Increasing temperature

6. Which of the following statement does not apply to catalysts?

A) They may change the reaction mechanism.

B) They do not affect the heat of the reaction.

C) They always decrease the rate of the reaction.

D) They change the activation energy.

E) They remain unchanged after the reaction

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CHAPTER 4: CHEMICAL EQUILIBRIUM

4.1 CHEMICAL EQUILIBRIUM

Why do we sweat when we are hot?

You will:

- know about reversible and irreversible reactions;
- understand that equilibrium is a dynamic process;
- understand the chemical equilibrium in terms of kinetic theory.

In the stoichiometry of chemical reactions, it is assumed that the reaction goes till one of the reactants is consumed or we can say - to completion. However, many reactions do not go to completion, but rather establish an equilibrium.

Physical equilibrium

Water evaporates at all temperatures above 0OC. Let's describe evaporation of water in a closed container. Evaporation of liquid water forms water gas. The gas molecules of water can't escape the container. So, they start to collide with each other and with the water's surface then they turn back into liquid water. Therefore, evaporation and condensation are reversible processes in a closed container.

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Reversible processes are represented by " ⇔". Irreversible processes are represented by "→".

$$H2O(l) \Leftrightarrow H2O(g)$$

In the beginning, the rate of evaporation of water is higher than the rate of water formation. However, the rate of evaporation of water and the rate of condensation of water becomes equal after a while. At this time, the system is at equilibrium.

At equilibrium, the amounts of water vapor and liquid water remain constant, but evaporation and formation of water occur continuously on a microscopic scale. Therefore, we say that equilibrium is a dynamic process.

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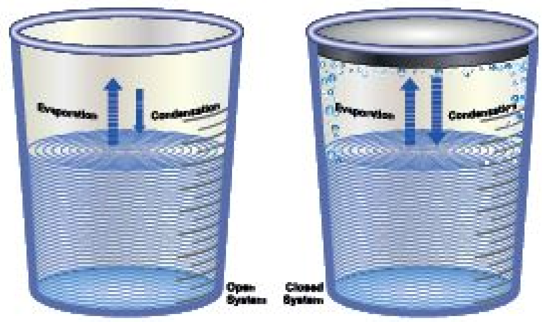
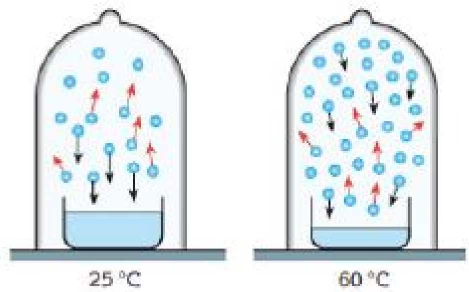
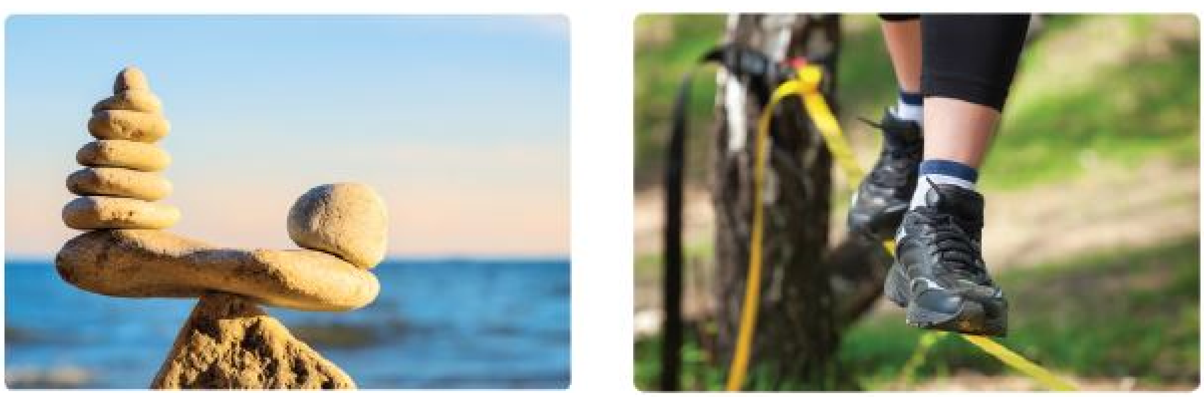


Evaporation of water in open and closed container



At a temperature of 60 °C, the amount of vapor produced is much greater than the amount of liquid at equilibrium.



Examples of dynamic equilibrium

To sum up, here are some characteristics of a chemical equilibrium state:

1. Forward and reverse reactions occur continuously, equilibrium is dynamic.

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2. It can be assumed that there is no visible evidence of change.

3. It can be reached through both forward and backward reactions.

4. It can be reached in a closed system.

5. Concentrations of reactants and products remain constant

Laboratory work

№7. Simple reversible reactions

Materials:

1M solutions of iron (III) nitrate and potassium thiocyanate (KNCS), 0.1M solutions of silver nitrate and sodium hydrogen phosphate (Na2HPO4), spot plate, three test tubes, beaker, hot water, ice.

Procedure:

Experiment A

1. Pour 25 ml of distilled water into a beaker and add one drop of 1M Fe(NO3)3 and 1M of KNCS.

2. Add a few drops of resulted solution to fi ve wells of spot plate. Use one well as colour standard. You will compare other wells with this one.

3. Add one drop of 1M of Fe(NO3)3 to 2nd well, mix.

4. Add one drop of 1M of KNCS to 3rd well, mix.

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5. Add one drop of 0.1M of AgNO3 to 4th well and mix.

6. Add one drop of 0.1M of Na2HPO4 to 5th well and mix.

7. Write down your observations.

Experiment B

1. Pour 4-5 ml of iron-thiocyanate solution from Experiment A to three test tube.

2. 1st test tube will be colour standard. You will compare other test tubes with this one.

3. Heat 2nd test tube with hot water. Do not boil the solution.

4. Cool 3rd test tube with ice water.

5. Write down your observations.

Note: Your observation will be explained in next chapter. You will understand how equilibrium can be shifted.

Keep in mind

When two opposing chemical reactions occur at the same rate, the system is in a state of dynamic equilibrium. Concentrations of reactants and products do not change with time.

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Facts

Equilibrium in human body (homeostasis)

Did you know that many different characteristics of human body remain in balance? For example, body temperature and blood sugar level. These features remain very nearly constant despite a change of environment, level of activity or diet. Arterial blood pressure, blood oxygen content, the volume of body water, etc among these controlled systems. That's why homeostasis is so essential for regular human activity.

Proper work of homeostatic mechanism is essential for human health

Terminology

- reversible – қайтымды / обратимый;
- dynamic process – динамикалық үрдіс / динамический процесс;
- equilibrium – тепе-теңдік / равновесие;
- continuously – үзіліссіз / непрерывно;
- condensation – конденсация / конденсация;

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- simultaneously – бір уақытта / одновременно;
- spontaneously – аяқ астынан / спонтанно;
- forward – алға қарай / вперед;
- to exhibit – қою / выставлять;
- homeostasis – гомеостаз;
- adjusted – қалпына келтірілген / отрегулированный;
- spot plate - тамшылық тақтайша/ точечная пластина.

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4.2 FACTORS AFFECTING EQUILIBRIUM

Which factor has the biggest influence on chemical reaction?

You will:

- predict the shifts of the chemical equilibrium by Le Chatelier's principle;
- understand and distinguish the effect of changing conditions on a rate of chemical reactions and shift of chemical equilibrium.

As you could notice from Laboratory work №7, from the previous lesson, chemical equilibrium can be shifted. In the lab you were changing a concentration of reactants and products, changing a temperature of a system. In this lesson, you will understand how these changes affect the chemical equilibrium. You will learn Le Châtelier's principle, which explains the effect of a change in conditions on a chemical equilibrium.

Effect of concentration changes

In the given reaction,

$$2SO2(g) + O2(g) 2SO3(g)$$

if some amount of SO2 or O2 is added to the equilibrium mixture, the equilibrium will be disturbed. Since the addition

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of SO_2 or O_2 increases the concentration of reactants, the equilibrium will be shifted to the right side to decrease the concentration of reactants.
However, If some amount of product, SO_3 is added to the system, the concentration of the product increases. Therefore, the reaction shifts to the reactants side to decrease the amount of products and to establish a new equilibrium state.

Effect of pressure

Change in pressure changes the concentrations of gas reactants and gas products. When the pressure of the system increases, the reaction shifts to the side having the smaller total amount of gases. When the pressure of the system decreases, the reaction shifts to the side where the total amount of gas is larger. Consider the effect of increase in a pressure for the following reaction:

$$N_2(g) + 3H_2(g)\ 2NH_3(g)$$

When the pressure of the system is increased, the equilibrium shifts toward the NH_3, because the total amount of gases is smaller on the right side. But if the pressure of the system is decreased, the equilibrium shifts toward the N_2 and H_2. The equilibrium reactions in which the total numbers of the coeffi cients of gases in reactants and products are equal are not infl uenced by pressure changes. For example, the following reactions are not affected by changing the pressure:

$H_2(g) + Cl_2(g) \Leftrightarrow 2HCl(g)$
$N_2(g) + O_2(g) \Leftrightarrow 2NO(g)$

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Pressure change has opposite effect on volume change. When the volume of gas increases, the pressure of the gas decreases. When the volume of a gas decreases, the pressure of the gas increases. Therefore, change in pressure at constant temperature affects the equilibrium reaction conversely to volume change. The change in pressure and volume of a system that involves only liquids and solids can be ignored.

Effect of temperature

For the following reaction, the forward reaction is endothermic, and the reverse reaction is exothermic:

$$N2O4(g) + 58\ kJ \Leftrightarrow 2NO2(g)$$

If we change the temperature of the system, it will shift in a way that will decrease the effect of the change, according to the Le Châtelier's principle. If the temperature of the system is raised, the equilibrium will proceed to the right side to decrease the temperature. If the reaction mixture is cooled down, the equilibrium will shift to the left side to increase the temperature.

The equilibrium shifted to left side

The effect of temperature. NO_2 gas has reddish-brown colour while N_2O_4 is yellow.

Demonstration

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№3. Dehydration copper sulfate.

Materials:

copper sulfate pentahydrate, evaporating dish, dropper, distilled water, burner

Procedure:

1. Place 10 g of $CuSO_4 \times 5H_2O$ into the evaporating dish.

2. Heat the salt gently.

3. Observe the color changing of salt.

4. Add 5-6 drops of distilled water to the salt powder.

5. Write down your observations.

Literacy

1. For the following reactions, predict the direction of the reaction if the pressure is increased:

$$S(s) + 3F_2(g) \Leftrightarrow SF_6(g)$$

$$Cl_2(g) + I_2(g) \Leftrightarrow 2ICl(g)$$

2. What will happen, if we increase concentration of products in reactions above?

3. In which direction will an equilibrium be shifted, if we decrease temperature for the reactions below:

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$$N_2(g) + 3H_2(g) \Leftrightarrow 2NH_3(g) + 92.2kJ$$

$$H_2O(l) \Leftrightarrow H_2O(g)$$

Facts

Le Chatelier's principle

If a chemical reaction is at equilibrium and experiences a change in pressure, temperature, or concentration of products or reactants, the equilibrium shifts in the opposite direction to offset the change. Le Chatelier's principle is widely used in chemical industry. One example of this principle use is the Haber process. By use of the Haber process, about 500 million tons of fertilizer is produced every year. This fertilizer has a great impact on the food production for half of the world's population.

Facts

When water is frozen into ice, it becomes more spacious. Ice crystals occupy more volume. Ice floats on water.

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Glasses with ice cubes

Terminology

- shift - ауысу / сдвиг;
- Le Chatelier’s principle – Ле Шателье принципі / принцип Ле Шателье;
- to increase – өсу / увеличивать, повышать;
- to decrease – кему / уменьшать, понижать;
- disturb – бұзылу / нарушать;
- to consider – қарастыру / рассматривать;
- conversely - керісінше / наоборот;
- infl uenced – осының әсерімен / под влиянием.

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Problems: Chemical equilibrium

1. Why do reversible reactions occur?

2. Give examples of dynamic equilibrium from daily life.

3. Define Le Châtelier's principle.

4. Which factors can affect an equilibrium system?

5. Which features are essential for the system to establish equilibrium?

6. Classify the following processes as reversible and irreversible:

a) Explosion

b) Formation of ammonia gas from H2 and N2

c) Burning

d) The decay of leaves

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e) $N_2(g) + O_2(g) \leftrightarrow 2NO(g)$

f) Evaporation-condensation of water.

7. Give examples of the following transformations.

- solid ↔ gas
- gas ↔ liquid
- solid ↔ liquid
- gas + gas ↔ gas

8. Find whether the following reactions can reach equilibrium or not:

a. $N_2O_4(g) \rightarrow 2NO_2(g)$ ....

b. $2Al(s) + 6HCl(aq) \rightarrow 2AlCl_3(aq) + 3H_2(g)$ ....

c. $2NH_3(g) \rightarrow N_2(g) + 3H_2(g)$ ....

9. The following reaction at equilibrium is given (T = 250C)

$CO(g) + H_2O(g) \leftrightarrow CO_2(g) + H_2(g)$.

Try to predict how the system will respond to the following changes:

- Addition of CO gas;
- Addition of H_2 gas;

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- Removal of H_2O gas;
- Removal of CO_2 gas.

10. For the following reaction:

$2NH_3(g) \leftrightarrow 3H_2(g) + N_2(g)$

try to predict how the system will respond to the following changes:

- Increasing volume;
- Decreasing volume;
- Increasing pressure.

11. Consider the reaction:

$CaCO_3(s) \leftrightarrow CO_2(g) + CaO(s)$

To which side will shift the reaction to reestablish equilibrium, if the following changes are applied:

- Increasing pressure;
- Decreasing volume;
- Increasing volume.

12. Consider the reaction:

$2NH_3(g) \leftrightarrow 3H_2(g) + N_2(g) - Q$ kcal

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Try to predict how the system will respond to the following changes:

- Increasing temperature;
- Decreasing temperature

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CHAPTER 5: OXIDATION-REDUCTION REACTIONS

5.1 OXIDATION STATES. OXIDATION AND REDUCTION PROCESSES

Antioxidants are substances that inhibit oxidation process. Why are they so important in the food industry?

You will:

- know what an oxidation state is;
- know how to find oxidation states;
- understand that oxidation and reduction processes are interrelated.

Oxidation state

The oxidation state (number) of element shows the tendency of atoms to donate or accept electrons to stabilize their last electron level.

Atoms or molecules in their elemental state have an oxidation number (or charge) of 0. It is shown as Al, Mg, Fe, H2, P, O2,N2, Cl2.

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Finding the oxidation state of an element in a compound

Oxidation states of some common ions

+1	+2	+3	-1	-2
H^{+}	Mg^{+2}	Al^{+3}	F^{-}	O^{-2}
Na^{+}	Ca^{+2}		Cl^{-}	
K^{+}	Ba^{+2}		Br^{-}	
Ag^{+}	Zn^{+2}			
Hg^{+}				
NH_4^{+}				

Example 1

Find the oxidation state of carbon C in potassium carbonate K2CO3.

Solution

The oxidation states of K and O are +1 and -2, respectively (given in a table). Also, we need to take into account the quantities of each atom in the compound.

The sum of the charges in a compound should be zero. As a result,

2·(K) + 1·(C) + 3·(O) = 0.

2·(K+1) + 1·(Cx) + 3·(O-2)= 0.

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$2\cdot(+1) + x + [3\cdot(-2)] = 0$

$x = +4$

Example 2

Find the oxidation state of sulfur in hydrogen sulfate ion (HSO_4^-):

Solution

In this case, the sum of the oxidation states of atoms is not equal to zero. Because hydrogen sulfate ion is negatively charged. So, the sum will be equal to -1.

$1\cdot(H) + 1\cdot(S) + 4\cdot(O) = -1$

$1\cdot(+1) + 1\cdot(x) + 4\cdot(-2) = -1$

$1 + x + (-8) = -1$

$x = -1 -1 +8$

$x = +6.$

Oxidation and reduction processes

The term oxidation was initially used to name reactions in which an element reacts with oxygen.

As an example,

$$2Cu + O_2 \rightarrow 2CuO \text{ - oxidation of copper}$$

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In the reaction above, each atom of copper loses two electrons to form an Cu^{+2} ion. This process is called oxidation.

$$Cu \rightarrow Cu^{+2} + 2e^-$$

In the same time, each atom of oxygen gains two electrons to form O^{-2} ion. Respectively, the molecule of oxygen gains four electrons. This process is called reduction.

$$O_2 + 4e^- \rightarrow 2O^{-2}$$

To conclude, oxidation is a process in which an atom loses electrons, and reduction is a process in which an atom gains electrons. Oxidation and reduction processes occur simultaneously. One reaction cannot take place without the other.

Literacy

1. What are the oxidation states of sulfur in sulfuric acid H_2SO_4, hydrogen sulfi de H_2S and calcium sulfi de CaS?

2. Find the oxidation states of nitrogen in the following compounds: nitric acid HNO_3, ammonia NH_3 and nitrogen dioxide NO_2.

3. Sulfur and oxygen react to form sulfur dioxide SO_2.

$$S(s) + O_2(g) \rightarrow SO_2(g)$$

Which of the elements above undergoes oxidation and which reduction?

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Keep in mind

The sum of the oxidation numbers of atoms in a compound should be equal to zero.

Keep in mind

Oxidation is a process in which an atom loses electrons.

Reduction is a process in which an atom gains electrons.

Lose Electrons ---- Oxidation
Gain Electrons ---- Reduction

Science in context

Oxidation process has damaging effects on metals. For example, rusting is an oxidation process when iron or steel slowly corrode in humid air. Rusting weakens structures of car bodies, railings, ships and bridges.

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Terminology

- oxidation state - тотығу дәрежесі / степень окисления;
- oxidation - тотығу / окисление;
- reduction - тотықсыздандыру / восстановление;
- to damage - зиян келтіру / наносить ущерб;
- to corrode - жеп қою / разъедать;
- to undergo - душар болу / подвергаться.

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5.2 OXIDATION-REDUCTION REACTIONS

Is there any substance that can oxidize and reduce at the same time?

You will:

- know what oxidationreduction reactions are;
- know what oxidizing and reducing agents are.

As we learned from previous lessons, many chemical reactions involve electron transfers from one atom to another. These types of reactions are called oxidation-reduction reactions or redox reactions. Let's examine an example:

$$2Cu(s) + O2(g) \rightarrow 2CuO(s)$$

As you know oxidation and reduction take place at the same time. In the given reaction copper oxidizes. What has been reduced during the reaction above? If you look at charges of substances in the reaction you will notice that several changes took place:

- The charge of copper during the reaction changes from 0 to +2.
- The charge of oxygen during the reaction changes from 0 to -2.

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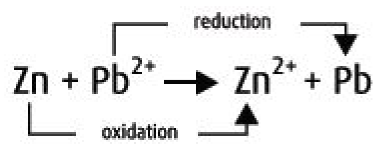
The copper atom lost its electrons while oxygen molecule has gained them. Example

$$Zn(s) + Pb(NO3)2(aq) \rightarrow Zn(NO3)2(aq) + Pb(s)$$

In ionic form it will be easier to understand the process of transferring electrons:



Zinc loses two electrons and lead gains them.


Formation of lead (Pb) on zinc (Zn) plate

Redox agents

Let us look at the following reaction:

$$Mg + ½\ O2 \rightarrow MgO$$

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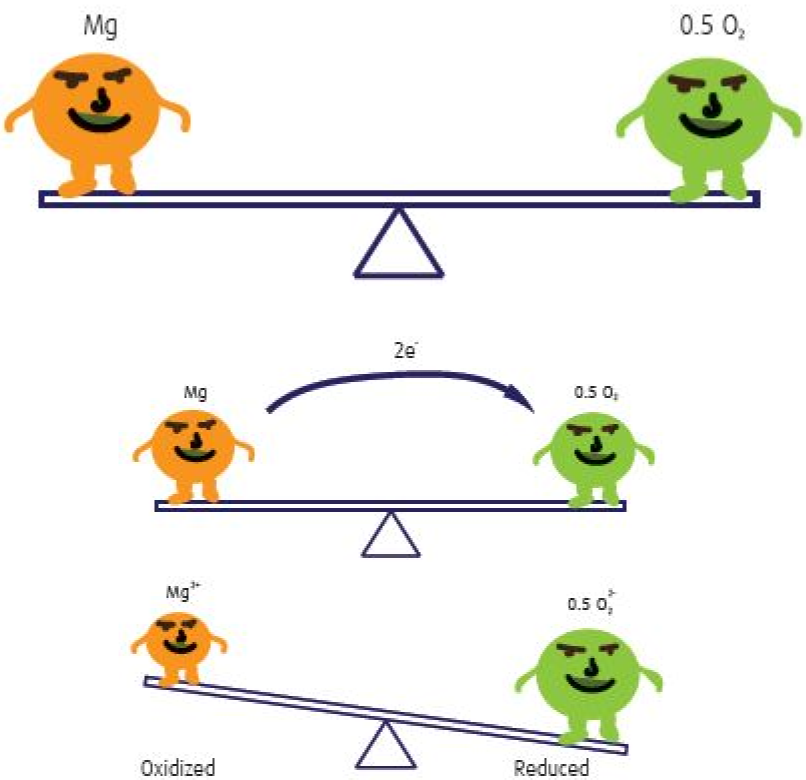
Burning of magnesium

During a reaction, magnesium atom loses electrons and oxygen atom gains electrons. The substance that gives off electrons is called a reducing agent because it reduces the other substance. On the other side, the substance that gains electrons is called an oxidizing agent because it oxidizes the other substance.



In this example, Mg is a reducing agent, as it gives electrons to oxygen and O is the oxidizing agent, as it takes electrons

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from magnesium.

Spoiling

Oxidation or chemical decomposition of food is called spoiling. The spoiling process gives an unpleasant odour and taste. To prevent oxidizing of food products people add substances called antioxidants.

Expired moldy bread

Homemade antioxidant fruits

Keep in mind

Reducing agent (reducer) - an element or a compound that loses electrons.

Oxidizing agent (oxidizer) - an element or a compound that gains electrons.

Activity

Redox reactions

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Materials:

solutions of 1 M iron (II) sulfate, 1 M sodium hydroxide and 3% hydrogen peroxide H_2O_2, beakers.

Procedure:

1. Pour 10 ml of 1 M iron (II) sulfate solution into the beaker.

2. Pour 5 ml of 1 M sodium hydroxide to iron (II) sulfate solution. You will observe the formation of the dirty-green precipitate.

3. Add 8-10 drops of 3% hydrogen peroxide solution to the precipitate. The reddish-brown precipitate will form.

Safety: Wear eye protection. Care with hydrogen peroxide.

Conclusion:

Complete and balance chemical equations:

$$FeSO_4(aq) + NaOH(aq) \rightarrow ...$$

$$Fe(OH)_2(s) + O_2(g) + H_2O(l) \rightarrow ...$$

Literacy

1. How did people prevent food spoiling in ancient times?

2. In the following example, sodium and chlorine react to form sodium chloride, NaCl.

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$$2Na(s) + Cl_2(g) \rightarrow 2NaCl(s)$$

Which one is oxidizer and which one is reducer?

3. How many electrons do transfer in the following reaction?

$$2CO(g) + O_2(g) \rightarrow 2CO_2(g)$$

Terminology

- to involve - қатыстыру / включать в себя;
- to transfer - ауыстыру, аудару / переносить;
- to take place - орын алу / происходить;
- to prevent - болдырмау / предотвратить;
- moldy bread - көгерген нан / заплесневелый хлеб;
- spoiling - бүліну / порча (продукта).

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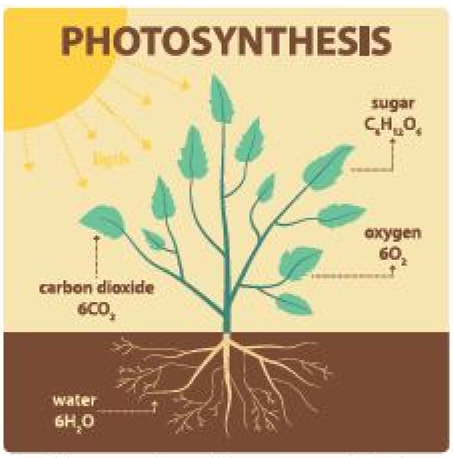
5.3 BALANCING REDOX REACTIONS

Photosynthesis is a redox reaction and is the most important process that produces oxygen. Which other methods can you think of?



Photosynthesis is an example of a redox reaction

You will:

- balance redox reactions using the oxidation-number method.

Balancing oxidation-reduction reactions are similar to balancing other types of reactions.

First, balance the number of atoms; then, balance all of the transferred electrons. However, these simple rules are often

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difficult to apply in oxidation-reduction reactions (redox reactions). So, some methods are widely used.

Balancing Redox Reactions by the oxidation-number method

Oxidation and reduction always occur together in a chemical reaction. Therefore, the total number of electrons gained and lost must be equal to each other.

In this method, the reaction is broken down into two halfreactions, oxidation and reduction half-reactions. Each halfreaction is balanced separately so that the same number of electrons appear in each half-equation. Then, the two halfreactions are summed up to get a balanced net equation.

Let us balance the following equation:

$$Fe^{+2}(aq) + Cl_2(g) \rightarrow Fe^{+3}(aq) + Cl^-(aq)$$

1. The oxidation half-reaction is:

$$Fe^{+2} \rightarrow Fe^{+3} + e^-$$

The reduction half-reaction is:

$$Cl_2 + 2e^- \rightarrow 2Cl^-$$

2. The total of gained and lost electrons must be equal. The oxidation half-reaction must be multiplied by 2 to balance the electrons.

$$2Fe^{+2} \rightarrow 2Fe^{+3} + 2e^-$$

When the two half-reactions are summed up, the overall reaction is obtained.

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Oxidation : 2Fe+2 → 2Fe+3 + 2e-

Reduction : Cl2 + 2e- → 2Cl-

———————————————

Overall : 2Fe+2 + Cl2 → 2Fe+3 + 2Cl-

Facts

Preparation of qymyz is based on redox reactions

Kazakh dishes and qymyz

Example 1

Balance the following reaction using half-reaction method:

Al(s) + Cl2(g) → AlCl3(s)

Solution

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First, the oxidation number of each atom in the reactants and products are indicated to fi nd the total number of transferred electrons.

The half reactions are:

Al → Al3+ + 3e– (oxidation)

2e– + Cl2 → 2Cl– (reduction)

The final equation is obtained by summing up the two halfreactions, as follows:

Al → Al3+ + 3e– / 2

2e– + Cl2 → 2Cl– / 3

2Al + 3Cl2 → 2Al3++ 6Cl-

So, the balanced equation should be:

2Al(s) + 3Cl2(g) → 2AlCl3(s)

Example 2

Balance the following reaction using oxidation-number method:

KMnO4(aq) + HCl(aq) → MnCl2(aq) + Cl2(g) + KCl(aq) + H2O(l)

Solution

$$K\overset{+7}{Mn}O_4 + H\overset{-1}{Cl} \rightarrow \overset{+2}{Mn}Cl_2 + \overset{0}{Cl_2} + KCl + H_2O$$

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First, the equation must be divided into two partial equations, showing the atoms that change their oxidation states.

$Mn^{7+} + 5e^- \rightarrow Mn^{2+}$ (reduction)

$2Cl^- \rightarrow Cl_2^0 + 2e^-$ (oxidation)

To balance the reaction the half-reactions must be multiplied by the least common multiple of 10, which are 2 and 5:

$Mn^{7+} + 5e^- \rightarrow Mn^{2+}$ / 2

$2Cl^- \rightarrow Cl_2 + 2e^-$ / 5

$2Mn^{7+} + 10Cl^- \rightarrow 2Mn^{2+} + 5Cl_2$ (overal skeleton reaction)

The coefficients are transferred into a complete reaction:

$2KMnO_4(aq) + 16HCl(aq) \rightarrow 2MnCl_2(aq) + 5Cl_2(g) + 2KCl(aq) + 8H_2O(l)$

Literacy

1. What is the unknown substance in the following balanced redox reaction?

$$4Ca + 10HNO_3 \rightarrow 4Ca(NO_3)_2 + X + 5H_2O$$

2.Balance the following equations by using the oxidation number method:

$$S(s) + HNO_3(conc) \rightarrow SO_2(g) + NO_2(g) + H_2O(l)$$

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$$Cu(s) + HNO_3(dil) \rightarrow Cu(NO_3)_2(aq) + NO(g) + H_2O(l)$$

3. Which of the following change(s) is/are redox reaction(s)? (Each arrow is a reaction)

$$Ca_3P_2 \rightarrow PH_3 \rightarrow P_2O_5 \rightarrow H_3PO_4$$

Terminology

- photosynthesis - фотосинтез / фотосинтез;
- oxidation-number method - электрондық баланс тәсілі / метод электронного баланса;

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Problems: Oxidation-Reduction Reactions

1. Determine which element is oxidized and which element is reduced in each reaction. Identify the oxidizing agent and the reducing agent:

- $2Ca(s) + O_2(g) \rightarrow 2CaO(s)$
- $2Na(s) + S(s) \rightarrow Na_2S(s)$
- $2K(s) + Br_2(l) \rightarrow 2KBr(s)$

2. Find the oxidation number of each atom in following ions:

- nitrate NO_3^-
- ammonium NH_4^+
- CO_3^{2-}

3. Calculate the oxidation number of manganese in each of the following compounds:

- Mn_2O_3
- $KMnO_4$
- $MnSO_4$
- Mn_2O_7
- K_2MnO_4

4. Use the changes in oxidation numbers to determine which elements are oxidized and which are reduced in these reactions:

- $C(s) + HNO_3(conc) \rightarrow CO_2(g) + NO_2(g) + H_2O(l)$
- $Cu(s) + HNO_3(conc) \rightarrow Cu(NO_3)_2(aq) + NO_2(g) + H_2O(l)$
- $H_2S(g) + O_2(g) \rightarrow SO_2(g) + H_2O(l)$

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5. Determine the oxidation number of the elements in each of the following compounds:

- H_2SO_3
- F_2
- $Zn(OH)_2$
- KNO_2
- KH
- Fe_2O_3

6. What are oxidation states of nitrogen in the following compounds respectively?

HNO_2, NH_4Cl, NO

7. What are oxidation states of sulfur respectively in the given compounds?

Na_2S, Na_2SO_4, $Na_2S_2O_3$

8. What is the sum of all coefficients in the following balanced redox reaction?

___FeS_2 + ___O_2 → ___Fe_2O_3 + ___SO_2

9. What is the substance X in the following balanced redox reaction?

$4Ca + 10HNO_3 \rightarrow 4Ca(NO_3)_2 + ...X + 5H_2O$

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10. In which of the following schemes there is no change in oxidation state?

A) $H_2S \rightarrow SO_2$ B) $H_2SO_3 \rightarrow H_2SO_4$ C) $PH_3 \rightarrow P_2O_5$ D) $N_2O_3 \rightarrow HNO_2$ E) $CrO_3 \rightarrow H_2CrO_4$

11. In which compound sulfur has oxidation state -2?

A) Na_2S B) Na_2SO_3 C) Na_2SO_4 D) $Na_2S_2O_4$ E) $Na_2S_2O_3$

12. What is the change in oxidation state of sulfur in the following redox reaction?

$H_2S(g) + 8HNO_3(conc) \rightarrow H_2SO_4(aq) + 8NO_2(g) + 4H_2O(l)$

A) $S^{2+} \rightarrow S^{4+}$

B) $S^0 \rightarrow S^{4+}$

C) $S^{2-} \rightarrow S^{4+}$

D) $S^{2-} \rightarrow S^{8+}$

E) $S^{2-} \rightarrow S^{6+}$

13. Balance the following reactions using oxidation-number method:

A) $FeCl_3(aq) + KI(aq) \rightarrow FeCl_2(aq) + I_2(s) + KCl(aq)$

B) $Cu_2S(s) + O_2(g) \rightarrow CuO(s) + SO_2(s)$

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C) $KMnO_4(aq) + FeSO_4(aq) + H_2SO_4(aq) \rightarrow Fe_2(SO_4)_3(aq) + MnSO_4(aq) + K_2SO_4(aq) + H_2O(l)$

D) $FeS(s) + O_2(g) \rightarrow Fe_2O_3(s) + SO_2(g)$

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CHAPTER 6: METALS AND METAL ALLOYS

6.1 GENERAL PROPERTIES OF METALS

Melting points of iron, tungsten, and mercury are 1538°C, 3422°C, and -39°C respectively. Why metals have different melting points?

You will:

- explain what the metallic bond and metallic lattice are;
- describe physical and chemical properties of metals.

Metallic bond

Metal atoms have a small number of valence electrons. Metals more likely to lose electrons to achieve more stable electron arrangement. Metals are solid at room temperature, except for mercury.

The valence electrons of metal atoms can easily move between formed ions. These electrons that can move freely between atoms form an “electron sea.” This phenomenon is called the metallic bond.

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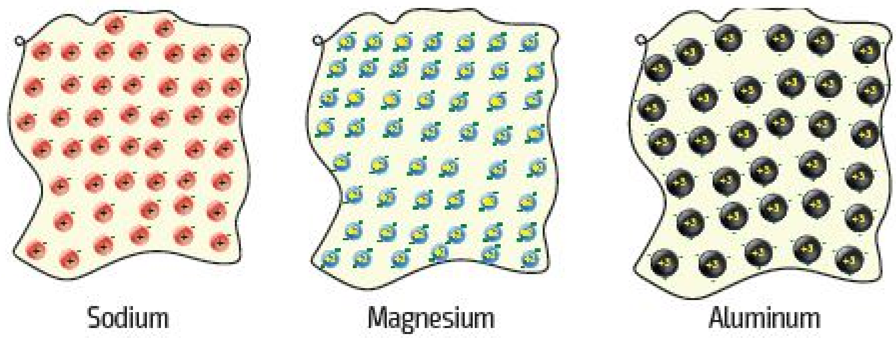
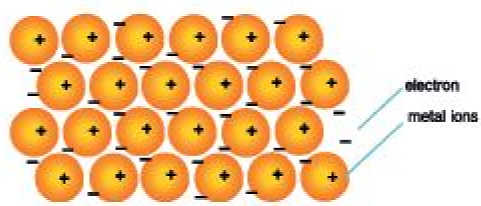
These freely moving electrons in the electron sea make metals good conductors of heat and electricity. Because the free moving electrons can move through the structure, they can carry the electric current. Also, metals are shiny, can be drawn into wires and can be hammered into shape easily.

Strength of the metallic bond increases with some valence electrons that can contribute to electron sea.



The metallic bonding in aluminum is the strongest, and the weakest in Na. Sodium, magnesium and aluminum melt at 98°C, 650°C and 660°C respectively.

Titanium and steel parts, ball-bearings



The free movement of electrons in metals makes it easy for metals to be shaped and drawn into wires

Metallic lattice

About 80 % of elements in the Periodic Table are metals. All of them are solids, but they are different in melting point hardness and malleability. All these properties depend on the

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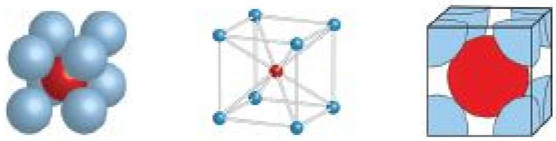
structure of metallic lattice or the way they combine. There are three main types of lattices or crystal structures:

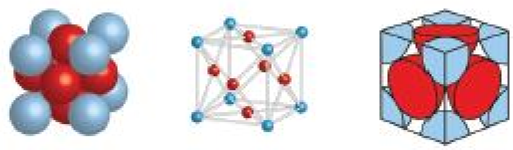
- body-centered cubic (bcc),
- face-centered cubic (fcc)
- and hexagonal closest packing (hcp).

Body-centered cubic is a cube with atoms at the edges and an atom in the center of every cube. Some metals have bcc lattice such as Pb, K, Na, Li, W, V, Ba, etc.



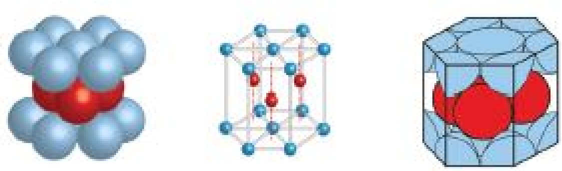
cubic body-centered (bcc)

Face-centered cubic is a cube with one atom at each of the corners of the cube and one at the center of each face. Some metals have fcc lattice such as Ni, Ag, Au, Pd, Pt, Cu, etc.



cubic face-centered (fcc)

In hexagonal closest packing atoms are arranged at the edges and the center of the hexagonal prism, and three atoms - in the middle of the prism. Some metals have hcp lattice such as Mg, Cr, Os, Zn, Be, Ca, etc.



hexagonal (hcp)

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Chemical properties of metals

Metals mostly have a small number of valence electron. Therefore, during a chemical reaction, they often act as reducing agents and donate electrons to other reactants in order to obtain a full outermost shell. They usually undergo reduction process.

$$Na \rightarrow Na^+ + e^-$$

$$Mg \rightarrow Mg^{2+} + 2e^-$$

Following chemical properties are general of metals:

1. React with oxygen:

Magnesium +oxygen → magnesium oxide

$$2Mg(s) + O_2(g) \rightarrow 2MgO(s)$$

2. Active metals react with water:

Sodium + water → sodium hydroxide + hydrogen

$$2Na(s) + 2H_2O(l) \rightarrow 2NaOH(aq) + H_2(g)$$

3. React with acids:

Zinc + sulfuric acid → zinc sulfate + hydrogen

$$Zn(s) + H_2SO_4(dil.) \rightarrow ZnSO_4(aq) + H_2(g)$$

Demonstration

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№4. 3D models of a crystal lattices of metals

Materials:

periodic table, metal samples, models of crystal lattices of metals.

Procedure:

1. Observe the crystal lattices

2. Compare and make conclusions

Science in context

Tungsten W has the highest melting point, 3422°C. Tungsten and its alloys are used extensively for filaments for electric lamps, electron and television tubes, and for metal evaporation work.

Literacy

1. Where are chromium and zinc used?

2. Write main physical properties of metals.

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3. What type of metals are used in headphones?

4. Determine the types of crystal lattices for following metals: Au, Fe, Ca, Cr.

5. What is the difference between metals and nonmetals?

6. Predict which metal has following properties:

- X element is a ductile and excellent conductor of electricity. It has red-orange metallic luster and is used for wire production.

Terminology

- electron sea - электрон газы / электронный газ;
- crystal lattice - кристалдық тор / кристаллическая решетка;
- wire - сым / провод;
- ductile - иілімді / пластичный;
- malleable - созылымды, иілімді / тягучий, ковкий;
- filaments - жіптер / нити;
- body-centered cubic - көлемді орталықтанған кубтық / объемноцентрированная кубическая;
- face-centered cubic - бүйірлі орталықтанған кубтық / гранецентрированная кубическая;
- hexagonal - гексогональді / гексагональная.

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6.2 METAL ALLOYS

Steel is one of the world's most important engineering and construction material. Why does stainless steel not corrode?

You will:

- know what are alloys and what are their benefits;
- compare properties of iron alloys: steel and cast iron;
- learn about the production of metals in Kazakhstan.

Alloys

Pure metals have different useful properties, such as electrical conductivity, high strength, hardness, and corrosion resistance. However, not all of them perfect for industrial use. Therefore, metals are usually combined with other metals. These combinations of metals are called alloys. Making alloys is one of the most common ways of changing the properties of metals. The aim to obtain alloys that are more suitable for industrial use than the original metals.

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Some important alloys

Alloy	Typical composition	Particular properties
brass	copper ~70% zinc ~30%	harder than pure copper, "gold" coloured
bronze	copper ~90% tin ~10%	harder than pure copper
cast iron	iron ~97% carbon ~2-4%	harder than iron
steel	iron ~98 carbon ~0.1-2%	harder and stronger than iron
stainless steel	iron ~70% chromium ~20% nickel ~10%	harder than pure iron; does not rust

Bronze vintage teapot

Steel and cast iron

Steel is an alloy of iron with carbon (less than 2%). Steel properties depend on the amount of carbon. It is usually malleable, hard. When it is cooled fast, it becomes hard. But when it is cooled slowly it becomes soft. Stainless steel differs from carbon steel by the amount of chromium present.

Steel is the most widely used metal material in the world. Steel comes in a variety of forms, has relatively low-cost production and exhibits incredible strength. Main steel applications are used in construction, transport, packaging, energy, and appliances.

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Cast iron is the composition of iron with carbon (2-4%) and other elements (S, Mn, P). It is one of the first products of ferrous metallurgy.

Cast iron has excellent resistance to corrosion. Hardness is constant against time and is retained up to relatively high temperatures.

Cast iron is used in a large variety of structural and ornamental applications. It is relatively inexpensive, durable and easily cast into a variety of shapes.


Tanks and railways made from steel


Cast iron pots on a kitchen working


Decorative cast iron fence

Production of metals in Kazakhstan

Scientists say that all elements of the Periodic Table are found in some form in our country. For example, Kazakhstan part of Altay mountains contains about 900 polymetal ore deposits. In Zhezkazgan region there are metal ores of

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copper, lead, zinc, nickel, cobalt, aluminum, manganese and many others. Qaratau ridge contains a signifi cant amount of deposits of lead, zinc, vanadium, and iron. Expensive metals (gold, silver, and platinum) and rare metals (uranium, molybdenum, rhenium, etc.) are also produced in Kazakhstan.

Steel production in Temirtau

Environmental effects

Mining factories are one of the largest consumers of natural resources and environmental pollutants. Wastes from mining and metallurgical industries occupy huge areas and are a source of environmental risk due to harmful substances entering the atmosphere, soil, and water. In this regard, the problems of environmental protection and safe living in the zone of action of factories have acquired a multifaceted nature, affecting the interests of hundreds of thousands of people, production, and nature in general.

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Demonstration

№5. Metals and alloys.

Observe and compare samples of metals and their alloys.

Facts

The Palace of Peace and Reconciliation in Astana city is designed to withstand expansion and contraction due to temperature variations of over 80°C, from -40 to over 40°C - leading to an expansion of the building of up to 30 cm.

Exterior of the Palace of Peace and Reconciliation building

Literacy

1. Write names for alloys of copper.

2. Why are pure copper, gold, and aluminum often alloyed?

3. Where can we find stainless steel materials in our daily life?

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Terminology

- durability - төзімділік / прочность;
- hardness - беріктік / твердость;
- tensile strength - беріктік шегі / предел прочности;
- stainless steel - тот баспайтын болат / нержавеющая сталь;
- ferrous metallurgy - қара металлургия / черная металлургия;
- non-ferrous metallurgy - түсті металлургия / цветная металлургия;
- environmental effect - экологиялық әсер / экологический эффект;
- alloy - құйма, қорытпа / сплав.

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6.3 PRODUCTION OF METALS

Iron metal is known from ancient times. How has humankind produced first iron products?

You will:

- know about the process of metal production.

Metals are so common that we can mistakenly believe that they are found in the ready-made form in nature. In fact, production of metals is a complicated process. Metal production refers to all of the processes included in the change of raw material, such as a metallic ore, to a final metallic form. In some cases, the metal production involves just a few steps since the metal already occurs in an elemental form in nature. For instance, gold, silver, platinum and other so-called inert metals. Therefore, they can be put to different commercial uses with little additional treatment.

However, in most cases metals occur in nature as compounds, such as the oxides or the sulfides, and must first be converted to their elemental state. Then they can be treated in a wide variety of ways to make them usable.

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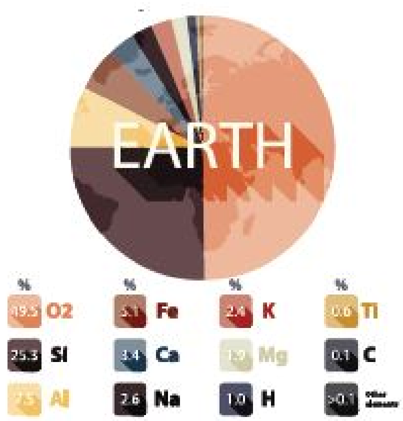

Chemical composition of the Earth`s crust

Metallurgy

Metallurgy deals with the production of metals from ores. Metallurgy is the branch of science and technology related to the properties of metals and their production and purification. Metallurgy is classified as ferrous and non-ferrous metallurgy. Ferrous metallurgy (black metallurgy) is the metallurgy of iron and its alloys. Ferrous metallurgy in Kazakhstan is introduced by the metallurgical combines in Temirtau, Aktobe, Sokolov-Sarybai and Lisakovsk.

Non-ferrous metallurgy (coloured metallurgy) involves processes and alloys based on other metals. Coloured metallurgy plants are found in Oskemen, Ridder, Shymkent, Pavlodar, Balkhash and Zhezkazgan cities.

Production of metals

There are several steps in the production of a metal from its ore.

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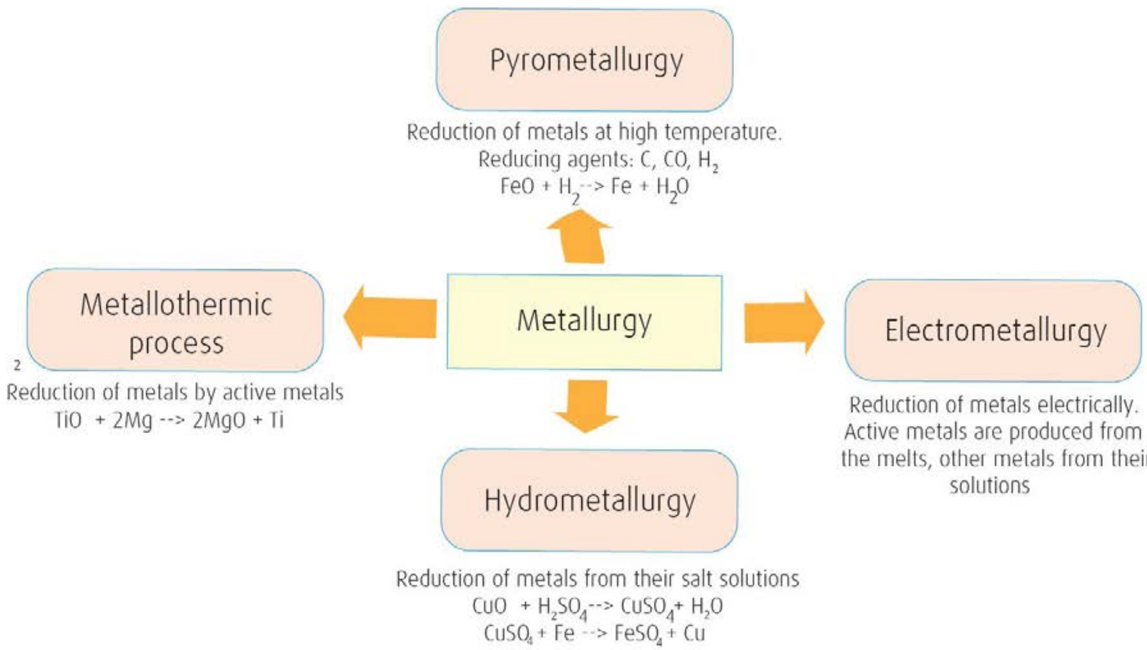

The structure of Modern Metallurgy

Preparation of the Ore

In the initial treatment of an ore, the mineral is separated from waste materials - usually clay and silicate minerals. One useful method for carrying out such a separation is called flotation. Another physical separation process makes use of the magnetic properties of certain minerals. Metals that are attracted to magnets (Fe, Co, Ni) called ferromagnetic.

Production of Metals

Because metals in their combined forms always have positive charges, the production of an elemental free metal is a reduction process. The higher activity of the metal, the harder is to extract it from the ore.

Preliminary operations are necessary to convert the ore to a chemical state more suitable for reduction.

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Currently, the major metallurgical processes are conducted at high temperatures in a procedure known as pyrometallurgy. The reduction in these procedures can be carried out either chemically or electrically.)

Literacy

1. Which deposits of metals are placed near your city?

2. Metal production is important for the economy but has some bad environmental effects. Do you think it is worth to open a factory near your house?

3. How many grams of magnesium are produced from reduction of its oxide by 80 g of carbon?

$$MgO(s) + C(s) \text{ [heating]} \rightarrow Mg(s) + CO(g)$$

4. Iron metal can be produced from its ore by heating it to high temperatures with carbon.

$$Fe2O3(s) + C(s) \text{ [heating]} \rightarrow Fe(s) + CO2(g)$$

If there are 10% of impurities, how many grams of iron oxide Fe2O3 are required to produce 56 kg of iron metal?

Activity

Students throw a ball to each other. Students that got the ball have to say one sentence about metallurgy. The winner is that who will say more sentences.

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Keep in mind

The higher activity of the metal, the harder is to extract it from the ore.

Flotation – a process for separating the different minerals in a mass of powdered ore based on their tendency to sink in, or float on, a given liquid.

Facts

Non-ferrous metallurgy factories produce a large amount of waste. About 100 tons of ore are processed to produce 1 ton of copper

Terminology

- impurities - қоспалар / примеси;
- ore deposit - рудалық кен орны / месторождение руды;

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- treatment - өңдеу / обработка;
- purification - тазарту / очистка;
- waste - қалдықтар / отходы;
- preliminary - алдын ала / предварительный;
- fl otation - флотация / флотация.

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6.4 SOLVING EXERCISES WITH IMPURITIES

Sometimes the efficiency of obtaining metals can drop to 1%. For example, from 1 ton of ore, only 10 kg of metal is produced. Where does other 99% go?

You will:

- solve problems with impurities.

Exercise 1

How many grams of aluminum can be obtained from electrolysis of 34 kg of molten Al2O3? The mass percentage of impurities in initial reactant is 40%.

Solution

Step 1. Write reaction and balance it:

$$Al_2O_{3(molten)}\ _{[electrolysis]}\rightarrow Al_{(s)} + O_{2(g)}$$
$$2Al_2O_{3(molten)}\ _{[electrolysis]}\rightarrow 4Al_{(s)} + 3O_{2(g)}$$

Step 2. Calculate the mole number of given compound. Given that mass of Al2O3 which contain 40% of impurities. It means that there is 60% of pure Al2O3:

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$$m(Al_2O_3) = \frac{m(total) \cdot w(Al_2O_3)}{100} = \frac{34 \cdot 60\%}{100} = 20.4kg$$

$$m(Al_2O_3) = \frac{m(Al_2O_3)}{M(Al_2O_3)} = \frac{20.4kg}{102g/mol} = 0.2kmol$$

Step 3. Find the mole number of aluminum using coefficients:

$$2Al2O3(molten) \rightarrow 4Al(s) + 3O2(s)$$

if 2 mol of Al2O3 gives ---- 4 mol of Al

then 0.2 kmol of Al2O3 gives ---- 0.4 kmol of Al

n(Al) = 0.4 kmol

Step 4. Calculate mass of aluminum: m(Al) = n(Al) · M(Al) = 0.4 kmol · 27 g/mol = 10.8 kg

Exercise 2

Calculate the mass of corundum, which contains 30% impurities that is needs obtain 37.8 g of aluminum.

Solution

Step 1. Write the reaction and balance it:

$$Al_2O_{3(molten)\ [electrolysis]} \rightarrow Al_{(s)} + O_{2(g)}$$
$$2Al_2O_{3(molten)\ [electrolysis]} \rightarrow 4Al_{(s)} + 3O_{2(g)}$$

Step 2. Calculate mole of given compound.

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Mass of aluminum is given. Mole number of aluminum:

n(Al) = m(Al) / Ar(Al) = 37.8 kg / 27 g/mol = 1.4 kmoles

Step 3. Find mole of aluminum oxide in reaction using coefficients:

$$2Al2O3(molten) \rightarrow 4Al(s) + 3O2(s)$$

Let's make proportion:

if 2 moles of Al2O3 gives 4 moles of Al

then x kmoles of Al2O3 gives 1.4 kmoles of Al

x = n(Al2O3) = (2 · 1.4) / 4 = 0.7 kmoles

Step 4. Calculate the mass of aluminum oxide:

m(Al2O3) = n(Al2O3) · Mr(Al2O3) = 0.7 kmoles · 102 g/mol = 71.4 kg

71.4 kg is the mass of pure aluminum oxide. In the last step we need to calculate mass of corundum which contain 70% of Al2O3 (because of 30% of impurities):

Step 5. Calculate mass of corundum:

70% of Al2O3 in 100% of corundum

71.4 kg of Al2O3 in x kg of corundum

x = m(corundum) = (71.4 · 100) / 70 = 102 kg

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Literacy

1. How many liters of carbon dioxide (at STP) can be obtained from 119 grams of limestone containing 16% of impurities?

$$CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$$

2. Calculate the volume of gas (at STP) produced by treatment of 10 g of marble containing 5% of impurities with hydrochloric acid.

$$HCl(aq) + CaCO_3(s) \rightarrow CaCl_2(aq) + CO_2(g) + H_2O(l)$$

3. Saltanat has a gold necklace with 585 gold content. Calculate the mass of pure gold in the jewelry if the mass of the necklace is 3 grams.

4. Azamat brought to the laboratory 2 kg of ore containing iron (II) carbonate $FeCO_3$. To fi nd the mass percentage of the salt, Azamat suggested treating 100 g of ore with excess hydrochloric acid. He collected released gas into a balloon. Volume at STP was about 9 liters. Calculate the mass percentage of the salt. Find the mass of iron carbonate in 2 kg of ore.

Facts

Jewelry golden products are not made of pure gold. The indicator of the quality of a gold product is gold content. For example, if gold content is equal to 585 that says that for 1000 parts of the alloy there are 585 parts of gold, the

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remaining 415 - additives: copper, silver, palladium, zinc, nickel and even platinum, which is in the alloy of white gold. The function of such additives is to make the alloy strong and durable and also to control the colour range of product.

Gold ring proof

Terminology

- to suggest - ұсыну / предлагать;
- additives - қосындылар / добавки;
- corundum - корунд / корунд;
- rock-forming mineral - жыныс түзуші минералдар / породообразующий минерал.

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Problems: Metals and metal alloys

1. What are the most abundant elements in the Earth's crust?

2. Why active metals like sodium and potassium are not found in elemental form in nature?

3. Gold and silver are known as the most expensive metals from ancient times. Why are they so precious?

4. Metals are malleable and ductile. Give examples from the daily life of the benefits of this qualities.

5. Why is pure aluminum not used in airplane body production?

6. Research gold-copper alloys and find the different names of these alloys.

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7. Try to find meaning of words such as ounce, carat.

8. Research which noble metal is more expensive than the others?

9. Explain the thermite process and write the equation for this reaction.

10. Which regions of Kazakhstan have factories of both ferrous and non-ferrous metallurgy?

11. Silver is the best conductor of electricity among metals. However, copper is used in production of wires. Why?

12. Consider the reaction:

$$Mg(s) + HCI(aq) \rightarrow MgCI2(aq) + H2(g)$$

How many grams of magnesium sample that is 40% pure are needed to fill a 44,8 L balloon with hydrogen gas at STP?

13. When 30.93 g of ore containing iron (II) carbonate reacts with an excess amount of hydrochloric acid, 4.48 liters of carbon dioxide were released. Determine the mass percentage of impurities in the ore.

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14. A sample of silver oxide is found to contain 20% impurities. Calculate the volume of oxygen at STP that is released from the decomposition of 29 g of this sample.

15. A sample of iron ore contains 75% Fe_3O_4 by mass. Calculate the volume of hydrogen that is needed to reduce all the iron from 23.2 g of this ore at STP.

(Clue: Remember that at high temperatures hydrogen reacts with many metal oxides to give pure metal and water vapor.)

16. After heating 400 g of sodium nitrate, 33.6 liters of oxygen were obtained. What is the mass percentage of impurities in the saltpeter?

$$NaNO_3(s) \rightarrow NaNO_2(s) + O_2(g)$$

17. Calculate the percentage yield of copper in the following reaction where 230 g of copper oxide CuO produces 160 g of copper.

$$CuO + C \rightarrow Cu + CO$$

18. Calculate the percentage yield of iron metal in the following reaction where 720 kg of hematite Fe_2O_3 produces 490 kg of pure iron.

$$Fe_2O_3 + 3C \rightarrow 2Fe + 3CO$$

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19. Calculate the percent yield of copper oxide in the following reaction where 10 g copper sulfide CuS produces 5.9 g of copper oxide.

$$2CuS + 3O2 \rightarrow 2CuO + 2SO2$$

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CHAPTER 7: 1, 2, 13 GROUP ELEMENTS AND THEIR COMPOUNDS

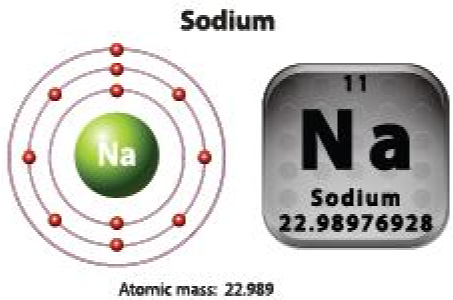
7.1 ALKALI METALS AND THEIR COMPOUNDS.

What unites table salt, soap, and soda?

You will:

- know which metals are called alkali metals;
- know properties of alkali metals according to their atomic structure;
- know that oxides and hydroxides of alkali metals are bases.

The elements of group 1, except hydrogen, are called alkali metals.




Pure sodium

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Lithium (Li), sodium (Na), potassium (K), rubidium (Rb), cesium (Cs) and francium (Fr) show common metallic properties. Their electron confi gurations end with ns1; it means that they have one valence electron and form +1 charged ions. All alkali metals are soft and can be cut with a knife.

The activity of metals increases from top to bottom and francium is expected to be the most active metal in the periodic table. But francium is very rare and radioactive element. That is why chemists consider cesium as the most active metal.

Alkali metals are the most active metals. They are not found in a free metallic form. Alkali metals are found only in the form of compounds. Pure alkali metals produced by chemical methods oxidize easily, so they need to be stored under oil or kerosene.

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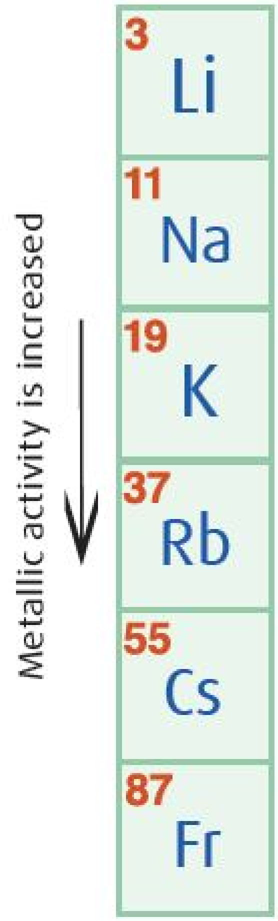
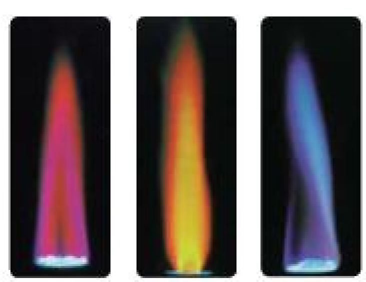


Chemical properties of alkali metals

Compounds of alkali metals can be identifi ed by use of the flame test. The characteristic flame colour is given in a table.

Flame tests of alkali metals

Metal	Flame colour
Lithium	red
Sodium	yellow
Potassium	lilac
Rubidium	red-violet
Cesium	blue



Flame tests of alkali metals: Li, Na, K

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Since they are alkali, they do not react with bases but react with acids. The oxides of alkali metals have basic properties and the aqueous solutions of their oxides give bases.

1. Reaction with oxygen

They may form oxides, peroxides or superoxides by reacting with oxygen in the air. As a result of reactions with excess oxygen, lithium forms oxide, Li_2O, sodium forms peroxide Na_2O_2 and potassium, rubidium and cesium form superoxides, such as KO_2, RbO_2, CsO_2:

$$4Li(s) + O_2(g) \rightarrow 2Li_2O(s)$$

$$2Na(s) + O_2(g) \rightarrow Na_2O_2(s)$$

$$K(s) + O_2(g) \rightarrow KO_2(g)$$

2. Reaction with halogens

All of them react with halogens to form alkali halides (salts of alkali metals):

$$2Na(s) + Cl_2(g) \rightarrow 2NaCl(s)$$

3.Reaction with sulfur

They form sulfides in reaction with sulfur:

$$2Na(s) + S(s) \rightarrow Na_2S(s)$$

4. Reaction with water

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They react with water and produce bases:

$$2Na(s) + 2H_2O(l) \rightarrow 2NaOH(aq) + H_2(g)$$

Basic oxides and hydroxides

Oxides and hydroxides of alkali metals are basic. They react with acids and form salts:

$$Na_2O(s) + 2HCl(s) \rightarrow 2NaCl(s) + H_2O(s)$$

$$2KOH(aq) + H_2SO_4(aq) \rightarrow K_2SO_4(aq) + 2H_2O(l)$$

Compounds of alkali metals

Common names and uses of some alkali metal compounds

Formula	Common Name	Uses
Li_2CO_3	Lithium carbonate	Ceramics, glasses
$NaOH$	Caustic soda	Soap, paper, textile, dye
$NaCl$	Table salt	Nutrition, soap, glass, pottery
$NaHCO_3$	Baking soda	Baking powder, neutralization of HCl in stomach
KOH	Potassium hydroxide	Soap
K_2CO_3	Potash	Production of glass and soap

Demonstration

№6. Reaction of sodium with water.

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Materials:

sodium metal, phenolphthalein indicator, water, beaker 250 ml.

Procedure:

1. Pour 100 ml of water into the beaker. Add 3-4 drops of indicator.

2. Carefully add 2-3 g of sodium to the water.

3. Observe change of colour.

4. Conclude and write a reaction.

Care: Sodium is a highly reactive metal.

Safety: Wear eye protection.

Reaction of potassium with water

Literacy

1. Alkali metals can not be found in elemental form in nature. Why?

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2. Why is it diffi cult to take second outermost electron from an alkali metal?

3. How many grams of hydrogen gas H2 are produced when 0.7 g of lithium react with water ?

Keep in mind

Sodium comes from the word “soda” and potassium comes from the word “potash”.

Keep in mind

Alkali metals tarnish in air.

Alkali metals can be easily cut with a knife

Burning of lithium

Facts

The name "alkali" comes from the Arabic word "alqaly" meaning basic.

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Terminology

- alkali metals - сілтілік металдар / щелочные металлы;
- nutrition - тағам / питание;
- pottery - керамика / керамика;
- Chile saltpeter - Чили селитрасы / Чилийская селитра;
- fertilizer - тыңайтқыш / удобрение;
- potash - поташ / поташ;
- to tarnish - қараю / тускнеть;
- gunpowder - оқ-дәрі / порох

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7.2 ALKALINE EARTH METALS AND THEIR COMPOUNDS

What connects alkaline earth metals and colours of fireworks?

You will:

- know which metals are called alkaline earth metals;
- compare properties of 1st and 2nd groups;
- know basic properties and uses of calcium oxide and calcium hydroxide.

The metals in 2nd group are called alkaline earth metals. This group includes beryllium (Be), magnesium (Mg),calcium (Ca), strontium (Sr), barium (Ba) and radium (Ra). The word "earth" was used for the oxides of Group 2 by scientists. Alkaline earth metals have two electrons in their valence shell that occupy the s-orbitals. Therefore, by losing these electrons through a chemical change they gain +2 charge.

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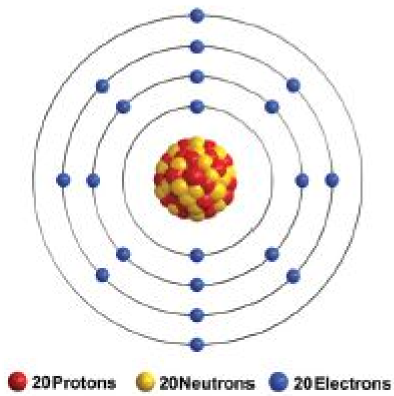


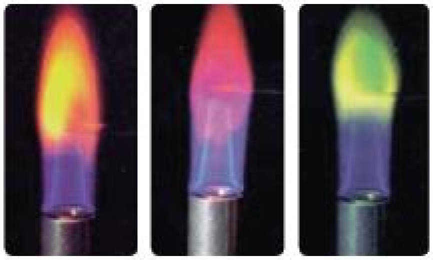
Atom structure of calcium


The limestone hill in Pamukkale

Alkaline earth metals are good conductors of heat. They are malleable and ductile. Since the 2nd group (IIA) elements are relatively active metals, in nature, they occur as compounds. Compounds of alkaline earth metals can be identifi ed with use of the fl ame test. The characteristic colour of flame are given in the table.

Flame tests of alkaline earth metals

Metal	Flame colour
Calcium	orange red
Strontium	red
Barium	pale green


Flame tests of alkalIne earth metals: Ca, Sr, Ba.

Chemical properties of alkaline earth metals

Alkaline earth metals are second most active metals after alkali metals. The activity of the metals increases from Be to Ba. The elements Ca, Sr and Ba react with water easily,

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whereas the reaction of Be and Mg with water is diffi cult to occur.

1. Reaction with water

Ca, Sr and Ba react with water, like alkali metals, at room temperature to produce metal hydroxides and hydrogen gas:

$$Ba(s) + 2H2O(l) \rightarrow Ba(OH)2(aq) + H2(g)$$

Magnesium metal reacts slowly even with boiling water:

$$Mg(s) + 2H2O(l) \rightarrow Mg(OH)2(aq) + H2(g)$$

2.Reaction with halogens

All alkaline earth metals give direct reactions with halogens to produce metal halides:

$$Mg(s) + Cl2(g) \rightarrow MgCl2(s)$$

3.Reaction with oxygen

They form oxides as a result of their reactions with oxygen:

$$2Ca(s) + O2(g) \rightarrow 2CaO(s)$$

These oxides react with water to produce bases, except for MgO and BeO.

Compounds of alkaline earth metals

The compounds of alkaline earth metals are ionic. They have high melting and boiling points. They are thermally stable. Oxide and hydroxide of calcium show basic properties. They react with acids to produce salt:

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$$CaO(s) + 2HCl(aq) \rightarrow CaCl2(aq) + H2O(l)$$

$$Ca(OH)2(aq) + H2SO4(aq) \rightarrow CaSO4(s) + H2O(l)$$

Uses of some compounds of alkaline earth metals

Formula	Common name	Uses
$Mg(OH)_2$	Milk of magnesia	In medicine as antacid
$CaSO_4{\cdot}2H_2O$	Gypsum	In buildings
CaO	Lime	In manufacture of cement and casting
CaC_2	Carbide	In welding
$CaCO_3$	Limestone	In buildings
$BaSO_4$	Barite	In X-ray photography
$Sr(NO_3)_2$	Strontium nitrate	In fireworks (gives red colour)

Facts

Magnesium burns with a brilliant white light and is widely used in making flares and fireworks.

Magnesium powder as a flashlight in photography

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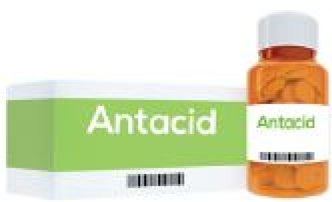
Facts

The magnesium metal is the center of the structure of chlorophyll.

Science in context

Mg(OH)2, milk of magnesia is used as a stomach antacid.



$Mg(OH)_2$, milk of magnesia is used as a stomach antacid.

Literacy

1. State physical properties of alkaline earth metals.

2. Write electron confi guration of strontium.

3. Write a balanced chemical equation for the reaction of calcium with water.

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Terminology

- flare - жарқылдақ / вспышка;
- antacid - антацид / антацид;
- gypsum - ғаныш / гипс;
- barite - барит / барит;
- welding - дәнекерлеу / сварка;
- limestone - әктас / известняк;
- hill - шатқал / холм.

Laboratory work

№8. Reactions of calcium oxide with acids and water.

Basic oxides react with water to produce bases.

Materials:

calcium oxide, 1 M nitric acid HNO3, distilled water,
beaker 250 ml (2), litmus paper.

Procedure:

I. Reaction with acid
1. Pour 100 ml of dilute nitric acid into the beaker.
2. Put a 5-7 g of calcium oxide into the beaker. Mix them.
3. Calcium oxide dissolves in nitric acid.
4. Make conclusions.
5. Note your observations.

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II. Reaction with water

1. Pour 100 ml of water into the beaker.
2. Put a 5-7 g of calcium oxide into the beaker.
3. Calcium oxide dissolves in water to produce lime water Ca(OH)2 which is strong base.
4. Add the indicator and observe changing of colour.
5. Note your observations.

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7.3 ALUMINUM AND ITS COMPOUNDS

Why aluminum dishes became unpopular?

You will:

- know properties of aluminum according to its atomic structure;
- know amphoteric properties of aluminum and its compounds.

Aluminium was first isolated from the mineral alum in 1827 by the German chemist F. Woehler. The name aluminum comes from the word “alumen” meaning bitter taste. Aluminium, after oxygen and silicon, is the third most abundant element in the earth’s crust. Aluminium cannot be found in its free form as it has a great affinity for oxygen. Aluminium is prepared by electrolysis of molten Al2O3 which is obtained from the mineral bauxite. This process was first developed by Charles M. Hall in 1886. With this method, aluminium has been cheaply and easily produced till nowadays.

Chemical properties of aluminium

Aluminium is an amphoteric metal so that it can react with both acids and bases. Also it reacts with some nonmetals and reduces some metal oxides.

1. Reaction with nonmetals:

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$$2Al(s) + 3Br_2(l) \rightarrow 2AlBr_3(s) + heat$$

2. As amphoteric metal aluminium reacts with diluted acids:

$$2Al(s) + 6HCl(aq) \rightarrow 2AlCl_3(aq) + 3H_2(g)$$

It also reacts with strong bases and liberates H_2 gas:

$$2Al(s) + 2NaOH(aq) + 2H_2O(l) \rightarrow 2NaAlO_2(aq) + 3H_2(g)$$

$$2Al(s) + 2NaOH(aq) + 3H_2O(l) \rightarrow 2Na[Al(OH)_4](aq) + 3H_2(g)$$

3. The thermite reaction

Aluminium has a great affi nity for oxygen and it can be used to extract some metals from their oxides:

$$Fe_2O_3(s) + 2Al(s) \rightarrow Al_2O_3(s) + 2Fe(s)$$

During the reaction, the temperature rises to about 2000°C, and the molten iron is produced.

Aluminium has lots of different uses because of its ductility and malleability. It can easily be hammered into wire and plate, even into sheets. Hence, it is frequently used for packaging food. Because it is an excellent conductor of electricity, and it is lighter and cheaper than copper, it is used in high–voltage lines.

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Bauxite mineral


Pavlodar Electrolysis plant


Thermite reaction

Literacy

1. Give two characteristic properties of aluminium that make it very useful for construction.

2. Why does aluminum not corrode like iron?

3. How many liters of H2 gas can be obtained from the reaction of 5,4 g Al and 7,3 g diluted HCl at STP.

Facts

Aluminium was for a long time an expensive metal. D. I. Mendeleev had received a precious gift on one of the

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anniversaries - the balance made of pure aluminium.

Demonstration

№7. Aluminum alloys

Use aluminum alloy samples in your laboratory. Write main physical properties of aluminum alloys.

Science in context

Corundum, an aluminium oxide (Al2O3), a hard compound that is naturally transparent. However, some corundum may naturally mix with chrome and acquire red crystalline structures. These crystals are the precious stones we know as rubies. When corundum is mixed with the element cobalt precious stone sapphire is formed.

Ring with diamonds and large sapphire

Ruby gemstone

Laboratory work

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№9. Reactions of aluminium with acid and bases.

Compounds of Al (aluminum oxide, aluminum hydroxide) also has amphoteric properties. They reacted with acids and bases.

Materials:

aluminum foils, 1 M hydrochloric acid HCl, 1 M sodium hydroxide NaOH, distilled water, beakers.

Procedure:

I.
1. Measure 50 ml of hydrochloric acid and pour it into the beaker. Heat the beaker with acid until it reaches the boiling point.
2. Carefully remove the beaker of acid and stand it on the bench.
3. Add two lumps of aluminium to the beaker.
4. If aluminium totally dissolves in the acid, add two more lumps. Add more aluminium until no more bubbles are formed.
5. Filter the beaker to remove the excess aluminium and transfer the fi ltrate into an evaporating cup.
6. Gently heat the fi ltrate. Dip in a glass rod and hold it up to cool. Stop heating when small crystals form on the glass rod.
7. Pour the solution into a crystallising dish. Label the dish and leave it to crystallize for next lesson.
8. Record your notes.

II.
1. Pour 50 ml of concentrated sodium hydroxide into a beaker.
2. Push the aluminium into the base.

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3. Observe the reaction.
4. Record your results.
Care: Aluminium may highly react with base. The smell of sodium hydroxide is irritant.
Safety: Wear eye protection. Care with acid and base. Wear disposable gloves. Avoid skin contact. Wash hands after use.

	Base, NaOH	Products	Acid, HCl	Products
Aluminium				

Conclusion:

1. Fill the table with your observations on the reactions.
2. Write the formulas and the names of the products produced
in the experiment

Terminology

- affinity - ұқсастық / сходство;
- bauxite - боксит / боксит;
- transparent - әйнектей / прозрачный;
- irritant - тітіркендіргіш / раздражитель.

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7.4 SOLVING EXPERIMENTAL PROBLEMS RELATED TO METALS

How dangerous is to conduct experiments with 1st, 2nd, and 13th group metals in the laboratory?

You will:

- plan and conduct experiments with 1st, 2nd, and 13th group metals.

Practice work

№4. Solving experimental problems related to metals.

Experiment 1. Decomposition of baking soda

Materials:

baking soda, crucible, crucible tongs, balance, spatula, iron ring, stand, burner

Procedure:

1. Take crucible and weigh it on balance. Record this mass in the Data Table.

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2. Go to your lab station and put into crucible some of the baking soda by use of spatula.

3. Use the balance to weigh the crucible with the baking soda. Record this mass in the Data Table.

4. Adjust iron ring on a stand. Put your crucible on iron ring securely, just above the burner.

5. Light the burner and heat the baking soda for 8-10 minutes, while you are waiting, write reaction and calculate masses of products.

6. After you have been heating the crucible, turn off the burner and let the crucible cool for 5-6 minutes.

7. Then weigh your crucible and calculate the mass of product. Use crucible tong to hold crucible.

Data Table:

Mass of crucible	m = ... g
Mass of crucible with baking soda	m = ... g
Mass of baking soda	m = ... g
Mass of crucible with product	m = ... g
Mass of product	m = ... g

Questions:

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1. What is the chemical formula for baking soda?

2. Write the balanced chemical equation for the reaction that took place in the crucible.

3. Use stoichiometry and your balanced equation to calculate the mass of product you should obtain in the crucible. Show your calculations.

4. Use the original mass of baking soda to determine the mass of water produced in this reaction. Show your calculations. What happens with to water?

5. Use the original mass of baking soda to determine the mass of CO_2 produced in this reaction. Show your calculations

6. Compare the masses that you have: mass you have calculated and mass you get by balances.

Crucibles

Crucible tongs

Experiment 2. Reactions of metals with acid, water

Materials:

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calcium, aluminum, lithium metal pieces, 1M sulfuric acid solution, water, test tubes.

Procedure:

I. Reactions of metals with acids

1. Pour 30 ml in three test-tubes with dilute sulfuric acid.

2. Into one test-tube drop a small piece of calcium.

3. Into the other, drop a small piece of aluminum.

4. Into the third, drop a small piece of lithium.

5. Compare the reactivity of the three metals.

6. Record what happens.

Questions:

1. Which is the more reactive, calcium, aluminum and lithium?

2. Write word equations for these reactions.

3. Write formula equations for these reactions.

II. Reactions of metals with water

1. Fill a test tube one-third of the way full of water.

2. Add the calcium strip to the test tube.

3. Check the pH by placing 2-3 drops of the phenolphthalein indicator.

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4. Repeat steps 1-3 using aluminum and lithium in place of calcium.

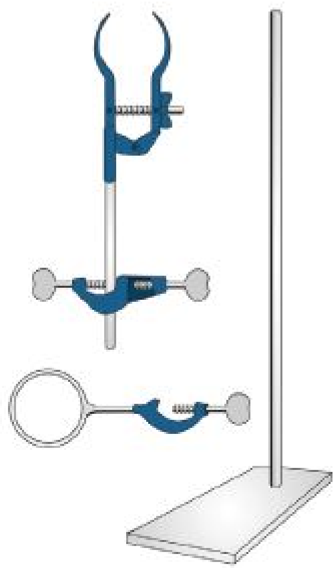
5. Compare the reactivity of those metals.

Questions:

1. Write word equations for these reactions.

2. Write formula equations for these reactions.

Aluminum ignots



Laboratory instruments: stand, clamps and an iron ring

Terminology

- conduct experiment - тәжірибе өткізу / проводить эксперимент;

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- crucible - отбақыраш / тигель;
- crucible tongs - отбақыраштың ұстағыш / тигельные щипцы;
- spatula - қалақша / шпатель;
- iron ring - темір сақина / кольцо;
- stand - тұрғы /штатив.

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Problems: 1, 2, 13 group elements and their compounds

1. Why are alkali metals located in 1st group in the periodic table?

2. What are the common physical and chemical features of alkali metals ?

3. Discuss the general characteristics and gradation in properties of alkaline earth metals.

4. Compare the alkali metals and alkaline earth metals with respect to (i) basicity of oxides and (ii) solubility of hydroxides.

5. Compare the solubility and thermal stability of the following compounds of the alkali metals with those of the alkaline earth metals. (a) Nitrates (b) Carbonates (c) Sulfates.

6. The hydroxides and carbonates of sodium and potassium are easily soluble in water while the corresponding salts of

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magnesium and calcium are sparingly soluble in water. Explain.

7. Explain the significance of sodium, potassium, magnesium and calcium in biological fluids.

8. What are the important aluminum ores?

9. Where do we use aluminum in our daily life?

10. Write the common names of ores that are natural sources of alkali metals.

a. Na2CO3 ....

b. KCl ....

c. NaNO3 ....

d. NaCl ....

11. Fill in the blanks with the appropriate alkali metal.

a. The characteristic colour of .... is yellow, ... is red colour and .... lilac colour in the flame test.

b. .... is the most reactive metal.

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c. .... is radioactive element.

12. Find the alkaline earth metal that has given the properties.

a. All its electrons are found in s orbitals.

b. It is radioactive.

c. Its properties are similar to those of aluminum.

d. It is found in chlorophyll.

e. It is very inert to water.

f. Its compounds are widely used in building.

13. What are the common oxidation numbers of alkali, alkaline earth and earth metals?

14. How many liters of H2 gas can be obtained from the reaction of 30 g Al and excess of diluted HCl at STP.

15. How many grams of hydrogen gas H2 are produced when 17 g of lithium react with water ?

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0CHAPTER 8: 16 ,17 GROUP ELEMENTS AND THEIR COMPOUNDS

8.1 HALOGENS

Why halogens exist in a diatomic form?

You will:

- write electron configuration for halogens;
- identify types of chemical bonds, and crystal lattices of halogens;
- understand how the main properties of halogens change in a group;
- know main chemical reactions of chlorine.

The elements of group 17 produce salts with metals, so they are called halogens, from a Greek word halos – genes, meaning “salt-former”. This group contains fluorine (F), chlorine (Cl), bromine (Br), iodine (I) and astatine (At). Astatine is a radioactive element.

The electron configuration of halogens is ns2np5 and it means that they have 7 valence electrons. Since their atomic numbers are less than that of the following noble gases by one, they have –1 oxidation state in their stable compounds. Fluorine has only –1 oxidation state in all compounds.

Fluorine is the most electronegative element of the periodic table. Within this group the electronegativity

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decreases from fluorine to iodine. Halogens are elements with the highest electronegativity in each period, so halogens are the most active nonmetals of each period.

Chlorine

Bromine

Iodine

Fluoride mineral stone

All halogens are:

- nonmetals, do not conduct electricity;
- poisonous and smelly;
- diatomic molecules: F_2 - pale yellow colour gas, Cl_2 - greenyellow colour gas, Br_2 - reddish-brown colour liquid, I_2 - black colour solid.

Halogens are found as diatomic molecules, such as F_2, Cl_2, Br_2 and I_2. In the diatomic structure of the molecules, each atom shares its single electron that's why the bond between them is nonpolar covalent. The intermolecular attraction between halogen atoms, is one of the factors which affect the state of halogens. For example, in iodine, the intermolecular forces are strong enough to hold the iodine molecules in one place. These type of solids are classified as molecular solids. Other halogens in their solid state (at very low temperatures), are also classified as molecular solids.

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Acids of halogens

Acids - compounds of halogens with hydrogen, turn blue litmus paper into red and their aqueous solutions conduct electricity. There are also halogen oxoacids, represented as HX, HXO, HXO2, HXO3, HXO4 (X denotes halogens).

Chemical properties of chlorine

Chlorine is a very reactive gas. Its most common reactions will be considered.
1. Chlorine is a very reactive gas and can react with metals to form the corresponding chlorides:

$$2Na(s) + Cl_2(g) \rightarrow 2NaCl(s)$$
$$Zn(s) + Cl_2(g) \rightarrow ZnCl_2(s)$$

2.Chlorine has an affi nity for hydrogen so it easily reacts with free hydrogen:

$$H_2(g) + Cl_2(g) \rightarrow 2HCl(g)$$

3.Chlorine can displace any of the halogens (except F_2) from their salts and acid solutions:

$$Cl_2(g) + 2NaBr(aq) \rightarrow 2NaCl(aq) + Br_2(l)$$
$$Cl_2(g) + 2HI(aq) \rightarrow 2HCl(aq) + I_2(s)$$

Uses

The silver halides, especially silver bromide, are very sensitive to light. When they are exposed to sunlight, they reduce to give metallic silver. As a result of this property, they are used to produce photographic fi lms.

Chlorine is used in the manufacture of dyes, explosives, bleaching powder and artifi cial rubber. For its toxic effect, chlorine is also used in the production of insecticides like DDT. Polyvinyl chloride (PVC) is a chlorine-containing plastic used in the production of pipes.

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Teflon pan


PVC plastic materials


Photo in old image

Keep in mind

Hydrochloric acid HCl is an aqueous solution of hydrogen chloride.

Facts

Fluoride ions (F-) are very important for health of teeth, but excess amounts cause darkening and decay of teeth.


Toothpaste on the toothbrush

Science in context

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In industry, the most important polymer of fluorine is known as tefl on, polytetrafl uoroethylene $(CF_2 - CF_2)_n$. Tefl on is used to insulate electric current, to produce heat resistant plastics and non–stick pans. Fluorine is also a constituent of freon (CCl_2F_2), which is widely used in refrigerators. Until recently, such chlorofl uorocarbon (CFC) compounds were used as solvent in sprays because of their low melting points.However, the use of CFC5 in industry has been restricted because of their damage to the ozone layer.

Literacy

1. Which elements are found in group 17th?

2. What are the physical properties of halogens?

3. Where are fl uorine compounds used?

4. Which halogen containing compounds do you use commonly?

5. After the reaction of 7.2 g of H_2 with Br_2 HBr is produced. How many grams of Br_2 are needed?

6. Zinc reacts with hydroiodic acid to produce zinc iodide and hydrogen gas. Find mass of zinc metal that is needed to produce 6.72 L of hydrogen gas at STP?

Terminology

- electronegativity - элекртерістік / электроотрицательность;

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- to insulate - оқшаулау / изолировать;
- sensitive - сезгіш / чувствительный;
- to restrict - шектеу қою / ограничить;
- refrigerator - тоңазытқыш / холодильник;
- insecticide - инсектицид / инсектицид.

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8.2 HYDROCHLORIC ACID

How corrosive properties of hydrochloric acid are used in oil drilling?

You will:

- investigate chemical properties of hydrochloric acid;
- know uses of hydrochloric acid.

Hydrogen chloride

Hydrogen chloride is a gas with an irritating odour. It is formed by the reaction of chlorine with hydrogen:

$$H_2(g) + Cl_2(g) \rightarrow 2HCl(g)$$

It does not conduct electricity in its liquid and gaseous phases, only in aqueous solutions.

A 40 % HCl solution can be prepared with a density of 1.19 g/ml. The concentrated HCl used in the laboratories is 36 %. It is a colourless acid with a sharp odour. It fumes in moist air and hydrogen chloride, gas is evolved.

Chemical properties

1. It reacts with bases to give neutralization reactions:

$$HCl(aq) + KOH(aq) \rightarrow KCl(aq) + H_2O(l)$$

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2. It reacts with $AgNO_3$, and a white precipitate is formed:

$$HCl(aq) + AgNO_3(aq) \rightarrow AgCl(s) + HNO_3(aq)$$

3. HCl reacts with active metals to produce the chloride salts and H_2 gas.

$$2HCl(aq) + Mg(aq) \rightarrow MgCl_2(aq) + H_2(g)$$

4. It reacts with oxidizing agents such as $KMnO_4$ to produce $Cl_2(g)$:

$$16HCl(aq) + 2KMnO_4(aq) \rightarrow 2KCl(aq) + 2MnCl_2(aq) + 5Cl_2(g) + 8H_2O(l)$$

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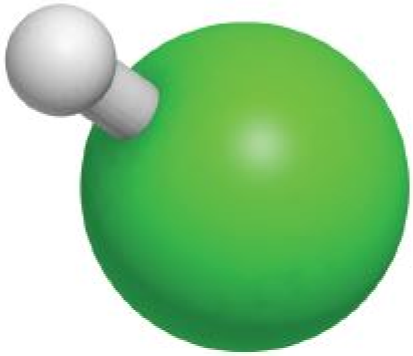
HCl acid is found in our stomach
for digestion

Hydrochloric acid solution



Hydrogen chloride

HCl acid is highly corrosive

Keep in mind

Hydrogen chloride is a colourless gas with an irritating smell. It is highly soluble in water. An aqueous solution of HCl is called hydrochloric acid.

Science in context

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Hydrogen chloride gas is mainly used in the manufacture of HCl acid solutions and polyvinyl chloride (PVC). It is also used in the manufacture of dyes, rubber and medicines.

The rolls of PVC

Laboratory work

№10. Chemical properties of hydrochloric acid

Materials:

Hydrochloric acid HCl, calcium carbonate $CaCO_3$, copper (II) oxide, conic flask, beakers 250 ml, 100 ml, spatula, tripod, burner.

Procedure:

I.

1. Pour 50 ml of acid solution to the 250 ml beaker.

2. Add small portion of carbonate salt to the beaker. Carbonate reacts with acid to give CO_2 gas.

II.

1. Add 30 ml of the hydrochloric acid to the 100 ml beaker. Heat carefully on the tripod with a gentle blue flame

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until nearly boiling.

Safety: Be very careful not to knock the tripod while the beaker is on it.

2. When the acid is hot enough, use a spatula to add small portions of copper (II) oxide to the beaker. Stir the mixture gently for up to half a minute after each addition.

3. When all the copper (II) oxide has been added, continue to heat gently for 1 to 2 minutes to ensure reaction is complete. Acid reacts with CuO, to produce green colour solution

CuCl2.

Safety: Wear eye protection. Care with. Wear disposable gloves.

Conclusion:

Record your observations. Write all chemical reactions.

Literacy

1. What are the physical properties of HCl acid?
2. Write the reactions of hydrochloric acid with iron and Mg(OH)2.
3. What is the number of moles of Cl2 required to produce 146 g HCl?

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4. A 30 g sample of iron reacts with 200 g of 14.6% HCl solution by mass, in order to produce iron (II) chloride and hydrogen gas. What is the percentage of iron in the sample?

Terminology

- gently - ақырын / осторожно;
- to fume - түтеу / дымить;
- moist - ылғалды / влажный;
- manufacture - өндіріс / производство.

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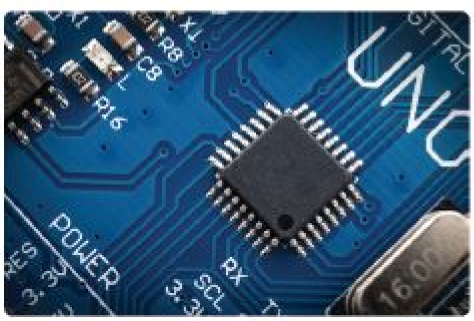
8.3 SULFUR

Is it true that sulfur is the main component of earwax?

You will:

- know main properties of 16th group elements;
-
- know allotropic forms of sulfur;
- know chemical properties of sulfur.

The members of 16th group are oxygen (O), sulfur (S), selenium (Se), tellurium (Te) and polonium (Po). Group 16 is also known as the oxygen group, oxygen family, or chalcogens. Chalcogen means “ore former”.



Selenium was one of the first semiconductors used in the production of photovoltaic cells


Natural sulfur

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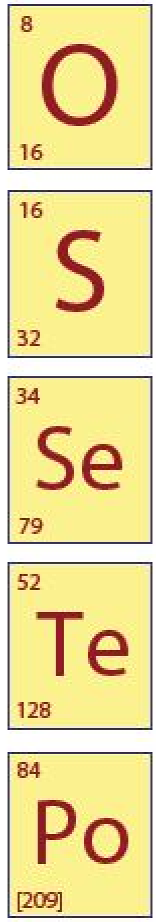

Group 16th is known as the oxygen group, oxygen family, or chalcogens.

They show nonmetallic properties. Nonmetallic character is the strongest in oxygen and sulfur, weaker in selenium and tellurium, while polonium is distinctly metallic. The elements of group 16th have 6 electrons in their valence shell. Their electron configurations end with ns2np4. They try to gain 2 electrons or share electrons to complete the number of electrons in the valence shell. Selenium and tellurium are semiconductors used in the electronics industry. Polonium is a radioactive element formed by the decay of radium.

Sulfur has been known for its medicinal value and its germicidal effect since prehistoric times. However, its

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chemical nature remained unknown until 1787 when A.Lavoisier recognized it is an element. Sulfur is a yellow solid in crystal or powder form. Sulfur is a nonmetal and a poor conductor of heat and electricity. There are three common allotropes of sulfur: rhombic, monoclinic and plastic sulfur.

Rhombic sulfur is a crystal. It is stable below 96°C. The crystals are bright yellow in colour and octahedral in shape, which is why it is called “rhombic”. They are made up of S8 molecules. Its density is 2.07 g/cm3. It is odourless, colourless and solid at room temperature.

Monoclinic sulfur is another crystalline allotrope of sulfur. It is a stable allotrope at temperatures between 96°C and 119°C. The crystals are long, thin and needle-shaped. At room temperature it reverts to rhombic sulfur. Its density is 1.96 g/cm3. It is dissolved in CS2 but can not be dissolved in water.

Plastic sulfur is obtained by heating sulfur to its boiling point. It is insoluble in carbon sulfi de. When it is poured into cold water, it gives dark-brown strings of plastic sulfur. In nature, sulfur exists both in free form and in compounds.

Sulfur miners extracting sulfur inside the crater, Indonesia.

Chemical properties of sulfur

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The sulfur has -2, +4, +6 oxidation states in its compounds. It reacts violently with the metals in the s-block of the Periodic table. It may form compounds with all metals and nonmetals except Au, Pt and noble gases.

1. Reaction with metals

It reacts with active metals at room temperature:

$$2Na(s) + S(s) \rightarrow Na_2S(s)$$

It reacts with other metals when heated:

$$Zn(s) + S(s) \text{ [heating]} \rightarrow ZnS(s)$$

2. It also reacts with nonmetals:

$$H_2(g) + S(s) \rightarrow H_2S(g)$$

$$S(s) + O_2(g) \rightarrow SO_2(g)$$

Sulfur is used in the vulcanization process of rubber. It is also used in dyes, paper and medicine. Some compounds of sulfur are used as fertilizers. The manufacture of sulfuric acid (H_2SO_4) accounts for 80% of sulfur use.


The car tire


Burning match

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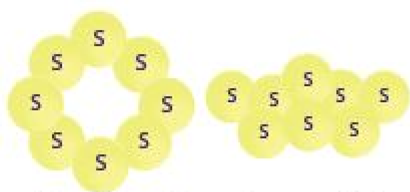
Keep in mind

Allotropes are different forms of the same element.



Rhombic sulfur and monoclinic sulfur contains S_8 units

Literacy

1. How many elements are there in 16th group?

2. How many allotropic forms are there for sulfur?

3. How many electrons are there on outer shell of sulfur atom?

4. What is the percentage by mass of oxygen in H2SO4?

5. How many liters of oxygen (at STP) are required for complete burning 25.6 g of sulfur?

Demonstration

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№8. Allotropes of sulfur.

Materials:

crystalline sulfur, test tube, test tube holder, burner, cold water, beaker 250 ml.

Procedure:

1. Nearly fi ll a 250 mL beaker cold water.

2. Fill test tube about 1/4 full sulfur.

3. Heat sulfur slowly. It will pass through stages:

● melt to yellow liquid (individual S8 atoms)

● red liquid (short chains of S8 atoms)

● dark reddish-brown thick syrup

● dark runny liquid

4. Pour hot sulfur into beaker of water.

Safety: Wear eye protection. Fire hazard. During this activity, the sulfur may catch fi re and burn at the lip of the test tube.

Terminology

- ore - кен / руда;
-
- rubber - резеңке / резина;
- runny - ақпа / текучий;

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- lip - шет / край;
- needle-shaped - ине тәріздес / иглообразный;
- to revert - қайту / возвращаться;
- germicidal - бактерицидті / бактерицидный.

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8.4 COMPOUNDS OF SULFUR

Why silver jewellery tarnishes?

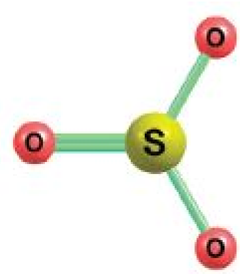
You will:

- know oxides of sulfur;
- know effects of acid rain;
- know properties of hydrogen sulfide.

Oxides of sulfur

Sulfur dioxide (SO_2) is a toxic, colourless gas with a sharp, bad odour.

sulfur dioxide molecule



Sulfur trioxide molecule

It is formed by the combustion reaction of sulfur:

$$S(s) + O_2(g) \rightarrow SO_2(g)$$

It is an acidic oxide, so it reacts with basic substances and dissolve in water:

$$SO_2(g) + CaO(s) \rightarrow CaSO_3(s)$$

$$SO_2(g) + H_2O(l) \rightarrow H_2SO_3(aq) \text{ (sulfurous acid)}$$

Sulfur trioxide (SO_3) is a very active and volatile substance. It is formed by the reaction of SO_2 with excess oxygen:

$$2SO_2(g) + O_2(g) \rightarrow 2SO_3(g)$$

It reacts with basic compounds and dissolve in water:

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$$SO_3(g) + 2NaOH(aq) \rightarrow Na_2SO_4(aq) + H_2O(l)$$

$$SO_3(g) + H_2O(l) \rightarrow H_2SO_4(aq) \text{ (sulfuric acid)}$$

Both sulfur dioxide and sulfur trioxide play major roles in producing acid rain.

Acid rain

Regular rain is slightly acidic. It absorbs some carbon dioxide from the air. However, acid rain is more acidic because of certain pollutants in the air.

It results when sulfur dioxide (SO_2) and nitrogen oxides (NO_X) are emitted into the atmosphere and transported by wind and air currents. . Rainwater is naturally weakly acidic, with a pH of 5.4. pH of acid rain gets between 2.4 and 5.0.

Acid rain can have terrible effects on what it falls on: trees, lakes, buildings and farmland.

The primary sources of SO_2 and NO_X in the atmosphere are:

- Burning of fossil fuels to generate electricity.
- Vehicles and heavy equipment.
- Manufacturing, oil refi neries and other industries.

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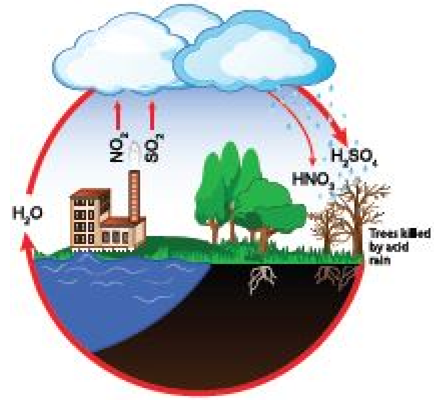
Factories generating toxic air pollution and acid rain



Forming of acid rain

Volcanic crater lake and toxic sulfur fume

Hydrogen sulfi de (H_2S)

It is very poisonous, corrosive, flammable and colourless gas.
It smells like rotten eggs.
In laboratories it is formed by the reaction of iron sulfi de (FeS) with acids:

$$FeS(s) + 2HCl(aq) \rightarrow FeCl_2(aq) + H_2S(g)$$

Qualitative reactions:

1.By adding $Pb(NO_3)_2$:

$$H_2S(g) + Pb(NO_3)_2(aq) \rightarrow PbS(s) + 2HNO_3(aq)$$

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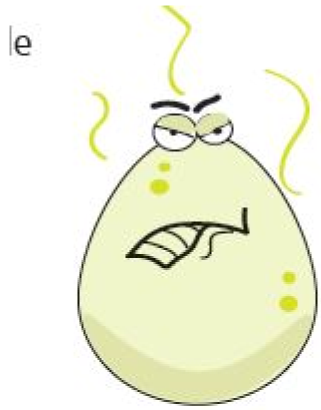
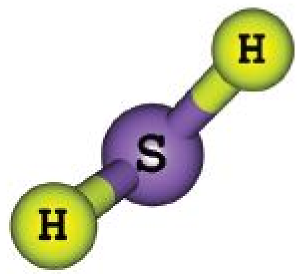
2. H2S in air causes the formation of a black sulfi de layer on silver metal:

$$2Ag(s) + H2S(g) + O2(g) \rightarrow Ag2S(s) + H2O(l)$$



H_2S smells like rotten egg.



Hydrogen sulfide molecule

Science in context

Sulfur dioxide is used for bleaching and as disinfectant.

Facts

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Sulfur dioxide affects human health when it is breathed in. It irritates the nose, throat, and airways to cause coughing, wheezing and shortness of breath. It is also associated with asthma and chronic bronchitis.

Oxides of sulfur are toxic

Literacy

1. How some compounds of sulfur affect human health?

2. Explain how acid rain affects the environment.

3. What are main sources of sulfur oxides and nitrogen oxides in the air?

4. How many grams of sulfur trioxide should be dissolved in water to produce 9.8 g of sulfuric acid?

Facts

H2S is highly toxic. It can enter your body primarily through the air you breathe. Low concentrations of hydrogen sulfi de

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in air may cause headaches, poor memory, tiredness, and balance problems.

Terminology

- acid rain - қышқыл жаңбыр / кислотный дождь;
- environment - қоршаған орта / окружающая среда;
- sharp - өткір / резкий;
- volatile - ұшқыш / летучий;
- poisonous - улы / ядовитый;
- flammable - тез жанғыш / легковоспламеняющийся;
- layer - қабат / слой;
- cough - жөтел / кашель;
- wheez - қырыл / хрип;
- chronic bronchitis -созылмалы бронхит / хронический бронхит;
- heavy equipment - ауыр техника /землеройно-транспортные машины.

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8.5 SULFURIC ACID AND SULFATES

How can we use harmful acid as a fertilizer?

You will:

- investigate physical and chemical properties of sulfuric acid and its salts.

Sulfuric acid, H_2SO_4

Sulfuric acid is a colourless, nonvolatile and hydroscopic liquid. Its melting point is 10.4°C and boiling point is 340°C. In laboratories, a 98% sulfuric acid solution is used. The density of that solution is 1.84 g/ml, and it is 18 M. Sulfuric acid is one of the most important chemical compounds known. It is a strong acid.

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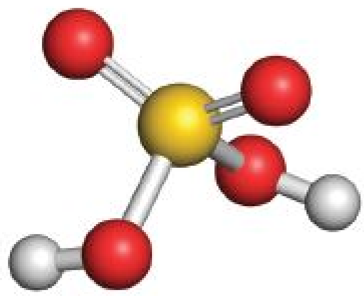
H_2SO_4 (oil of vitroil)

H_2SO_4 is toxic substance



Structural formula of H_2SO_4

Chemical properties

1. It reacts with metals and produces H2 gas:

Zn(s) + H2SO4(aq) → ZnSO4(aq) + H2(g)

2. It may react with inert metals too:

Cu(s) + 2H2SO4(conc) → CuSO4(aq) + SO2(g) + 2H2O(l)

3. It reacts with bases, basic oxides and amphoteric oxides:

H2SO4(aq) + 2NaOH(aq) → Na2SO4(aq) + 2H2O(l)

4. Sulfuric acid reacts with some salts to produce other acids and insoluble sulfate salts form:

H2SO4(aq) + BaCl2(aq) → BaSO4(s)+ 2HCl(aq)

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5. Concentrated sulfuric acid is capable of removing hydrogen and oxygen as water from organic compounds:

$$C_{12}H_{22}O_{11}(s) + H_2SO_4(conc) \rightarrow 12C(s) + H_2SO_4(aq) + 11H_2O(l)$$

Reaction between sucrose and concentrated sulphuric acid.

Preparation (Contact process)

This method was developed by Knietsch in Germany. In principal, it involves the catalytic combination of SO2 and O2 in the form of SO3, which is then dissolved to form sulfuric acid (H2SO4):

$$S + O_2 \longrightarrow SO_2 \xrightarrow{O_2} SO_3 \xrightarrow{H_2SO_4} \underset{\text{oleum}}{H_2S_2O_7} \xrightarrow{H_2O} H_2SO_4$$

Sulfuric acid plant

Sulfates

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Important sulfates salts:
$Na_2SO_4 \cdot 10H_2O$ - Glauber salt,
$MgSO_4 \cdot 7H_2O$ - Epsom salt,
$CaSO_4 \cdot 2H_2O$ - gypsum,
$BaSO_4$- barite,
$KAl(SO_4)_2 \cdot 12H_2O$ - potassium alum,
$CuSO_4 \cdot 5H_2O$ - copper (II) sulfate pentahydrate,
$FeSO_4 \cdot 7H_2O$ - iron (II) sulfate heptahydrate.

Keep in mind

Sulfuric acid is one of the most important chemical. It is a strong, corrosive acid.

Science in context

Sulfuric acid is used in production dyes, paper, soaps and detergents, Sulfates as fertilizers, as an electrolyte in lead accumulators and batteries. It is used as a dehydrating agent in the nitration of compounds from which explosives are made. It is also used in the manufacture of pigments.


Paints and pigments


Detergent with washing powder

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Practice work

№5. Chemical properties of sulfuric acid and sulfates

Materials:

solutions of sulfuric acid H_2SO_4, copper (II) sulfate, iron (II) sulfate, aluminum sulfate, sodium hydroxide, barium nitrate, test tubes.

I variant

1. Find in which tubes contains copper sulfate, iron (II) sulfate, aluminum sulfate.

2. Write reactions between:

- $CuSO_4$ and sodium hydroxide
- $FeSO_4$ and sodium hydroxide
- $Al_2(SO_4)_3$ and sodium hydroxide

II variant

1. Find in which tubes contains sulfuric acid, iron (II) sulfate, aluminum sulfate.

2. Write reactions between:

- H_2SO_4 and barium nitrate
- $FeSO_4$ and sodium hydroxide
- $Al_2(SO_4)_3$ and barium nitrate

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Safety: Solutions of barium compounds is toxic – wash your hands thoroughly at the end of the lesson.

$BaSO_4$ precipitate

Activity

Dehydration of organic compounds.

Materials:

granulated sugar, concentrated H2SO4, beaker, stirring rod.

Procedure:

1. Add 50 g of granulated sugar to the beaker.

2. Insert stirring rod into center of sugar. Add 50 mL of concentrated sulfuric acid to this and stir. The mixture will change from white to yellow to black. At this point the mixture will begin to expand out of the beaker.

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Safety: Sulfuric acid is a very strong acid and is extremely corrosive to skin. Wear gloves and safety goggles.

Literacy

1. Write main properties of sulfuric acid

2. Where is sulfuric acid used?

3. How is sulfuric acid prepared in a chemical plant?

4. How many grams of sulfuric acid should be dissolved in 150 g of water to prepare 30% solution?

5. How many grams of $MgSO_4$ can be produced from 7.2 g of magnesium react with concentrated sulfuric acid?

$$Mg(s) + H_2SO_4(aq) \rightarrow MgSO_4(aq) + H_2(aq)\uparrow$$

Terminology

- capable - қабілетті /способен;
- thoroughly - мұқият / тщательно;
- fertilizer - тыңайтқыш / удобрение;
- stir - араластыру / перемешивать;
- expand - ұлғаю / расширяться;
- hydroscopic - сужұтқыш / водопоглощающий.

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8.6 SOLVING PROBLEMS: PERCENT YIELD

How can we reach effi ciency and yield to 100% in production of sulfuric acid or any other production?

You will:

- understand the meaning of percent yield;
-
- solve problems related with percent yield.

The percent yield (η) is used to relate the amount of product that is actually obtained (the practical amount) to the theoretical amount.

$$\% \text{ Yield} = \frac{\text{Actual Yield}}{\text{Theoretical Yield}} \times 100\%$$

$$\text{Yield} = \frac{n \text{ (practical)}}{n \text{ (theoretical)}} \qquad \text{Yield} = \frac{V \text{ (practical)}}{V \text{ (theoretical)}} \qquad \text{Yield} = \frac{m \text{ (practical)}}{m \text{ (theoretical)}}$$

In the following problems, assume that the yield is 100 % unless stated otherwise.
Silver chloride, AgCl, is a white crystalline solid that is used to make photographic film.
Consider the following reaction yielding silver chloride:

$$AgNO3(aq) + NaCl(aq) \rightarrow AgCl(s) + NaNO3(aq)$$

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Silver chloride

According to this equation, when one mole of silver nitrate reacts with one mole of sodium chloride, one mole of silver chloride is produced. Theoretically this is correct, but if you
perform this experiment in the laboratory and calculate the mole number of silver chloride produced, you will find it smaller than one mole. The reason for this might be that the portions of the reactants do not react or that not all of the product is recovered. In some other reactions, materials may stick to glassware, or an amount of a volatile product may evaporate.

Keep in mind

Reasons for a yield of less than 100% are impurities or personal and instrumental errors.

Literacy

1. A sample of magnesium carbonate is heated and the mass of magnesium oxide produced found to be 80 g. Calculate the mass of decomposed magnesium carbonate if the yield of the reaction is 80%.

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2. What is the percent yield if 121.5 g of silver is produced when 13.5 g of aluminum is reacted with excess silver nitrate solution. The unbalanced reaction equation is:

$$Al(s) + AgNO_3(aq) \rightarrow Al(NO_3)_3(aq) + Ag(s)$$

3. For the balanced equation shown below, if the reaction of 0.112 grams of H_2 produces 0.745 grams of H_2O, what is the percent yield?

$$Fe_3O_4(s) + 4H_2(g) \rightarrow 3Fe(s) + 4H_2O(l)$$

Example 1

When heated, the carbonates of many metals decompose to give oxides of the metals and carbon dioxide gas. Calculate the volume of carbon dioxide gas (at STP) produced from the decomposition of 25 g of calcium carbonate. The yield of the reaction is 75 %.

Solution

We know that calcium carbonate decomposes to give calcium oxide and carbon dioxide:

$$CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$$

Step 1.

Here, we need to calculate the practical volume of CO_2. First, we need to calculate the theoretical volume:

$Mr(CaCO_3) = 40 + 12 + 3 \cdot 16 = 100$ g/mol

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$n(CaCO_3) = m / Mr = 25\ g / 100\ g/mol = 0.25\ mol$

Step 2.

According to chemical equation above, proportion between CO_2 and $CaCO_3$ is 1 to 1. Then:

$n(CO_2) = n(CaCO_3) = 0.25\ mol$

$V(CO_2) = n \cdot Vm = 0.25\ mol \cdot 22.4\ L/mol = 5.6\ L$

Step 3.

5.6 L is the theoretical volume, of CO_2

$$Yield = \frac{V\ (practical)}{V\ (theoretical)}$$

$V_{practical} = yield \cdot V_{theoretical} = 5.6\ L \cdot (75\% / 100\%) = 4.2\ L$

Example 2

Oxygen gas can be obtained from the decomposition of potassium chlorate, $KClO_3$. In a laboratory experiment, the decomposition of 2.45 g of potassium chlorate produces 0.48 g of oxygen. Calculate the percent yield of this reaction.

Solution

The balanced equation for this reaction is

$$2KClO_3(s) \rightarrow 2KCl(s) + 3O_2(g)$$

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In order to fi nd the percent yield of the reaction, we need to have both the practical and theoretical amounts of oxygen. It is stated that the mass of produced oxygen is 0.48 g. This is the practical mass.

Step 1.

Let us calculate the theoretical mass of oxygen:

Mr(KClO3) = 39 + 35.5 + 3 · 16 = 122.5 g/mol

n(KClO3) = n / Mr = 2.45 g / 122.5 g/mol = 0.02 mol

2 mol of $KClO_3$ -------------- 3 mol of O_2
0.02 mol of $KClO_3$ ---------- x mol of O_2

x = (3 ·.0.02) / 2 = 0.03 mol of O_2

m(O2)= n · Mr = 0.03 mol · 32 g/mol = 0.96 g (the theoretical mass of oxygen)

$$\text{Yield} = \frac{\text{m (practical)}}{\text{m (theoretical)}} \text{x}100\% = \frac{0.48\text{ g}}{0.96\text{ g}} \text{x}100\% = 50\ \%$$

Terminology

- percent yield - өнім шығымы /выход продукта реакции;
- volatile - ұшқыш / летучий;
- merely - тек / только.

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Problems: 16, 17 group elements and their compounds

1. What is the formula of the compound that contains 23.35% K, 47.90% Br and 28.75% O?

2. When 16.8 g of Fe and the excess amount of F_2 react to form FeF_3, how many grams of the compound is formed?

3. How many grams of Cl_2 is needed to form 27.5 g of PCl_3?

$$2P(s) + 3Cl_2(g) \rightarrow 2PCl_3(l)$$

4. How many liters of H_2 is produced by the reaction of 39.2 g of iron and sufficient HCl?

$$Fe(s) + 2HCl(aq) \rightarrow FeCl_2(aq) + H_2(g)$$

5. How many liters of fluorine is needed to produce 4.48 liters of O_2?

$$2F_2(g) + 2H_2O(l) \rightarrow 4HF(g) + O_2(g)$$

6. How many grams of HF is produced at the end of the reaction of 2.45 g of XeF_6 with excess water?

$$XeF_6(s) + 3H_2O(l) \rightarrow XeO_3(l) + 6HF(g)$$

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7. How many grams of Cl_2 is produced if 164.25 g of HCl react with MnO_2?

$$MnO_2(s) + 4HCl(aq) \rightarrow Cl_2(g) + MnCl_2(aq) + 2H_2O(l)$$

8. Sulfuric acid H_2SO_4 can be made from sulfur dioxide SO_2, oxygen, and water in high temperature. Suppose you mix 22.4 g of sulfur dioxide with an excess of water and obtain 30 g of sulfuric acid. Calculate the percent yield of sulfuric acid in this reaction.

$$2SO_2(g) + 2H_2O(l) + O_2(g) \rightarrow 2H_2SO_4(aq)$$

9. In an experiment, 150 g of magnesium reacted with excess sulfuric acid forming magnesium sulfate.

$$Mg(s) + H_2SO_4(aq) \rightarrow MgSO_4(aq) + H_2(g)$$

At the completion of the reaction, 711 g of magnesium sulfate was produced. Calculate the theoretical yield and the percent yield.

10. For the balanced equation shown below, if the reaction of 107.88 grams of white phosphorus produces an 81.3 % yield, how many grams of P_4S_7 would be produced?

$$P_4(s) + 7S(s) \rightarrow P_4S_7(s)$$

11. For the balanced equation shown below, if the reaction of 112 grams of PH_3 produced 300 grams of H_3PO_4, what is the percent yield?

$$PH_3(g) + 2O_2(g) \rightarrow H_3PO_4(s)$$

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12. Astatine, the fifth halogen, is little studied because its isotopes are radioactive and short-lived. From your knowledge of the physical and chemical properties of the halogens, predict the physical and chemical properties of the element. Include:

- the colour of the element
- its state at room temperature
- the stability of hydrogen astatide
- its strength as an oxidizing agent
- the nature of the bonding present in its silver salt
- the colour of AgAt.

Element	Colour	Melting and boiling points	Stability of hydrides	Colour of silver salt	Oxidizing ability
F	getting darker →	increasing →	decreasing →	white cream	decreases →
Cl				cream	
Br				pale yellow	
I					

13. Why is oxygen a gas but sulfur a solid?

14. Write balanced equations for the following:

- NaCl is heated with sulphuric acid in the presence of MnO2.
- Chlorine gas is passed into a solution of NaI in water.

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CHAPTER 9: ELEMENTS AND COMPOUNDS OF 14 AND 15 GROUPS

9.1 NITROGEN

Why nitrogen while being an essential element for all living organisms is called “azot” meaning "dead"?

You will:

- learn properties of nitrogen;
- learn nitrogen cycle.

This element has two names. One of them, “azot”, meaning “dead” in Greek, was given by A.Lavoisier. The other, “nitrogen”, means “nitrate former”. The atomic number of nitrogen is 7. Its electron configuration is 1s22s22p3.

Nitrogen has 5 valence electrons. Thus, the element shows oxidation states, such as, –3, +1, +2, +3, +4 and +5. Sometimes it takes three more electrons and sometimes it loses its valence electrons to gain a noble gas electron configuration.

Nitrogen in elemental form (N2) hardly reacts because of strong triple covalent bonds between the N atoms.

$$:N{\equiv}N: + 707.7\ kJ \rightarrow 2N$$

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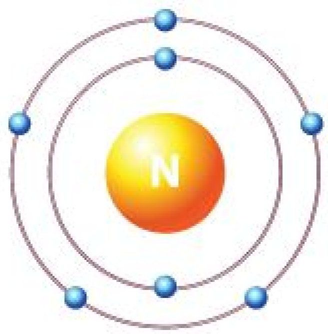
As shown above the bonds between nitrogen atoms (:N ≡ N:) are very strong. Therefore, nitrogen gas does not react with acids, bases, water or halogens at STP.

Nitrogen is a colourless, odourless and tasteless gas that exists as free diatomic molecules in the atmosphere. Nitrogen is an essential element of living organisms.



Nitrogen atom


Liquid nitrogen


DNA molecules contain nitrogen in their structure

Chemical properties of nitrogen

Under proper conditions, nitrogen gas undergoes the following reactions.

1. At high temperatures (2500°C) or in a high electrical current, nitrogen reacts with oxygen to produce NO gas.

$$N_2(g) + O_2(g) \rightarrow 2NO(g)$$

The produced NO gas reacts with O_2 to give other oxides.

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$$2NO(g) + O_2(g) \rightarrow 2NO_2(g)$$

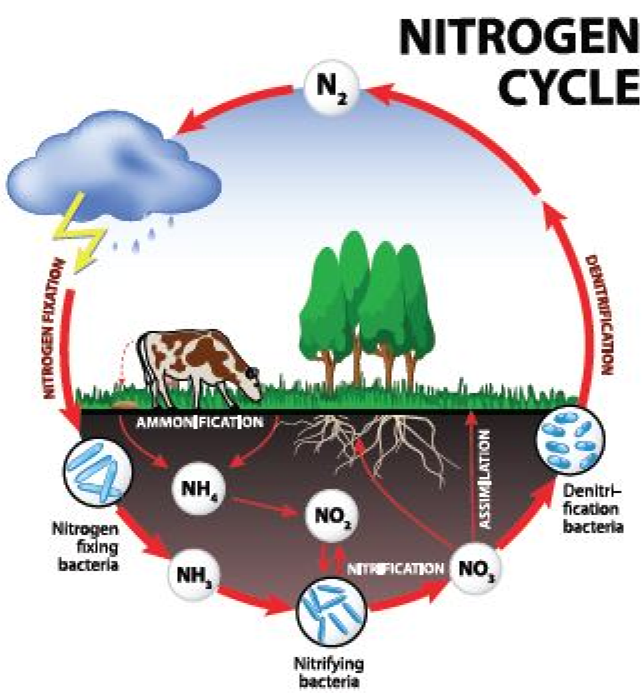
These reactions may be caused by lightning in the atmosphere. 2. At 300 atm pressure and 500°C temperature, nitrogen gas reacts with H_2 in the presence of Al_2O_3 or Fe catalysts (Haber method). Ammonia is obtained as a product.

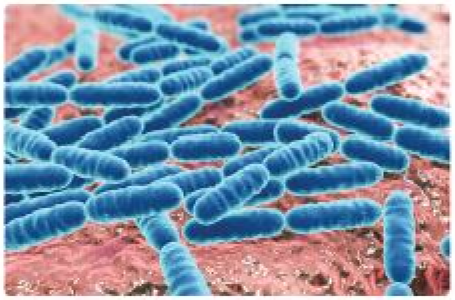
$$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$$

3. At high temperatures, it reacts with metals to produce ionic nitride (N^{3-}) compounds. These compounds are often white crystals. The heat is needed to start the reaction.

$$6Li(s) + N_2(g) \rightarrow 2Li_3N(s)$$

Nitrogen is an essential element for all living organisms. There is a plenty of nitrogen in the atmosphere but it is inert and it is difficult to get it into the soil. So, some plants have nitrogenfixing bacteria which lives in roots and "fix" gaseous nitrogen. The balance of processes which put nitrogen into the air and processes which remove nitrogen from the air is called the nitrogen cycle.





Azotobacter has beneficial effects on crop growth

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Nitrogen oxides

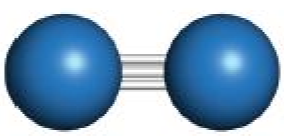
NO gas produced during the ignition of car motors, has very harmful effects. When NO gas is inhaled, it forms NO2 gas by combining with O2 in the lungs. The NO2 gas formed attaches to water molecules in the lungs and causes the formation of nitric acid HNO3.

NO_2 very toxic poisonous gas

Laboratory work

№11. 3D molecular model of nitrogen

Using the 3D molecular model kit, you will understand the structure and properties of nitrogen.



Nitrogen molecule

Literacy

1. How can you explain that nitrogen has got so many different oxidation states?

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2. Why is nitrogen is an inert element?
3. If the percentage of nitrogen gas in the air is 78% by volume and 75% by mass, what will be the average molecular weight of air?
4. How plants get nitrogen from the atmosphere?

Terminology

- nitrogen cycle - азот айналымы / азотный цикл;
- ignition - жану / зажигание;
- inhale - жұту / вдыхать;
- inert - инертті / инертный.

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9.2 AMMONIA

How can ammonia be responsible for both killing millions of people and saving millions of people's lives?

You will:

- explain molecular and structural formula of ammonia
- explain preparation methods, properties and uses of ammonia
- prepare ammonia in laboratory
- describe industrial preparation process of ammonia.

Properties of ammonia

Ammonia is a colourless gas with a characteristic sharp smell. The density of ammonia is less than air. Its boiling point and freezing point are –33.4°C and –77.8°C (at 1 atm) respectively. The chemical formula for ammonia is NH3 and chemical bonds in molecule are covalent. Bonds are made up by sharing three electrons of nitrogen with three atoms of hydrogen. The solubility of ammonia is high: 700 L of ammonia may be dissolved in 1 L of water at 20°C. Ammonia is the most important base in the gaseous phase.

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Ammonia is weak base

Ammonia has sharp, unpleasant smell

Preparation of ammonia

I. In the Laboratory

Small amounts of ammonia can be prepared in the laboratory by heating a solution of an ammonium salt with a strong base, such as NaOH or $Ca(OH)_2$:

$$NH_4Cl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(l) + NH_3(g)$$

Ammonia gas, formed in the reaction, turns wet litmus paper to a blue.

II. In Industry

In industry, ammonia is obtained directly by the Haber process:

Reaction undergoes at 200 atm and 450oC, Al_2O_3 or Fe is used as catalysts (Shown in picture).

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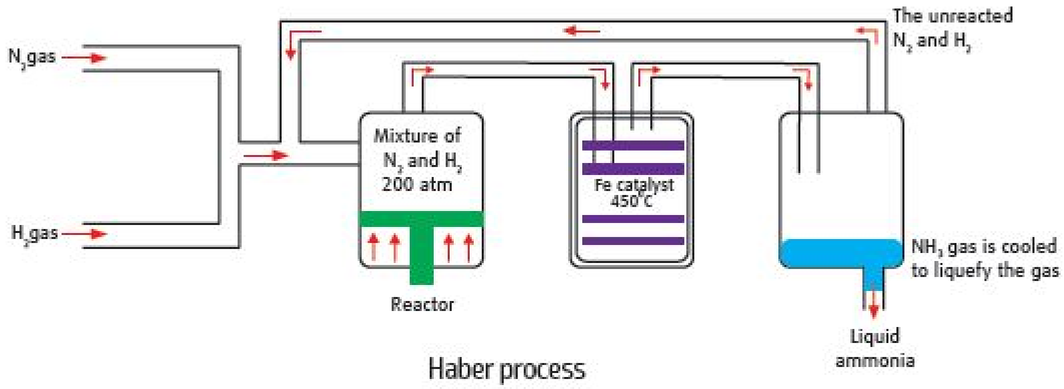
$$N_2(g) + 3H_2(g) \dashrightarrow 2NH_3(g)$$



Haber process

This method is widely used to produce nitrogen fertilizers, so it has a great impact on the food production for half of the world's population. However, ammonia produced by use of this method, also, found its application as a base for production of explosives.

Chemical properties

1. Reactions of ammonia with acids give ammonia salts with durable crystal structures:

$$NH3(g) + HCl(g) \rightarrow NH4Cl(s)$$

$$2NH3(g) + H2SO4(aq) \rightarrow (NH4)2SO4(aq)$$

2. It reacts with pure oxygen:

$$4NH3(g) + 3O2(g) \rightarrow 2N2(g) + 6H2O(l)$$

3. Ammonia is a good reducing agent:

$$2NH3(g) + 3CuO(s) \rightarrow 2Cu(s) + N2(g) + 3H2O(l)$$

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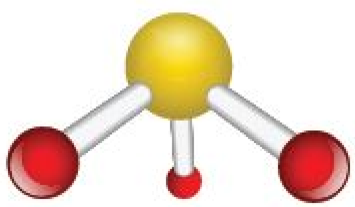
Laboratory work

№12. 3D models of ammonia molecule

Using the 3D molecular model kit, students will understand the structure and properties of ammonia.

Materials:

molecular models.



Structure of ammonia molecule

Practice work

№6. Preparation of ammonia and its properties

Materials:

ammonium chloride NH4Cl, ammonium nitrate NH4NO3, calcium hydroxide, sodium hydroxide NaOH, test tubes, burner, test tube holder, litmus paper.

I variant:

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1. By using ammonium chloride NH_4Cl and calcium hydroxide, you will produce ammonia gas.

2. Test gas by use of wet litmus paper.

3. Write reactions between NH_4Cl and $Ca(OH)_2$.

II variant:

1. By using ammonium nitrate NH_4NO_3 and sodium hydroxide, you will produce ammonia gas.

2. Test gas by use of wet litmus paper.

3. Write reactions between NH_4NO_3 and NaOH.

Facts

Jupiter's atmosphere is made up of 89.8% hydrogen and 10.2% helium with traces of methane and ammonia.

Science in context

Ammonia is used to produce nitric acid in industry. By the reaction of nitric acid with some organic compounds, some explosives are produced, such as nitroglycerin and

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trinitrotoluene (TNT). Ammonia and ammonium salts are used as fertilizer. Another compound of nitrogen, hydrazine (N2H4), is used in the manufacture of rocket fuel and urea. Ammonia is also used in the production of rubber, paper, textile, dye, medicine, and explosives.

Ammonia is used in medicine

Literacy

1. Write main physical properties of ammonia.

2. Write the reaction of nitric acid with ammonia and name the product.

3. Calculate the mass percentages of nitrogen in the following compounds: NH3, NH4Cl.

4. 13.6 g of compound XH3 has volume 8.96 L at STP conditions. What is the atomic mass of element X?

5. How many liters of ammonia can be obtained if 33.6 g of nitrogen reacts with the excess amount of hydrogen?

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Terminology

- impact - әсер /влияние;
- responsible - жауапты /ответственный;
- sharp - өткір /резкий;
- undergo - жүру /проходить;
- population - халық /население;
- application - қолданыс аясы /применение;
- durable - мықты /прочный.

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9.3 NITRIC ACID

Why nitrogen gas is not used as a fertilizer?

You will:

- know molecular and structural formulas of nitric acid;
- explain the formation of chemical bonds in the molecule of nitric acid;
- write preparation reactions of nitric acid;
- learn chemical properties of nitric acid.

The chemical formula for nitric acid is HNO3. It is a toxic substance.

Physical properties

Nitric acid is a colourless, fuming liquid, whose density is 1.35 g/mL. The melting point of nitric acid is –42°C and the boiling point is 82.6°C.

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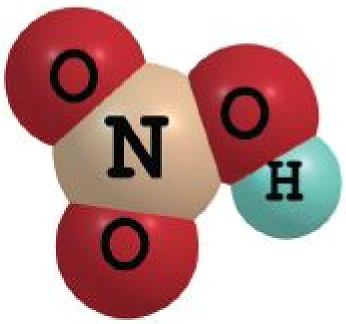

Structure of HNO_3

A bottle of nitric acid

Preparation

Nitric acid was originally prepared by heating a mixture of potassium nitrate and concentrated sulfuric acid:

$$KNO_3(aq) + H_2SO_4(aq) \rightarrow KHSO_4(aq) + HNO_3(aq)$$

Nitric acid is commercially produced by the Ostwald process, which is an industrial preparation of nitric acid starting from the catalytic oxidation of ammonia to nitric oxide:

$$4NH_3(g) + 5O_2(g) \rightarrow 4NO(g) + 6H_2O(l)$$

$$2NO(g) + O_2(g) \rightarrow 2NO_2(g)$$

$$4NO_2(g) + 2H_2O(l) + O_2(g) \rightarrow 4HNO_3(aq)$$

Chemical properties

1. It reacts with metallic oxides:

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$$CuO(s) + 2HNO_3(aq) \rightarrow Cu(NO_3)_2(aq) + H_2O(l)$$

2. Nitric acid reacts with bases and salts:

$$KOH(aq) + HNO_3(aq) \rightarrow KNO_3(aq) + H_2O(l)$$

3. The reaction of the acid with salt:

$$Na_2CO_3(aq) + 2HNO_3(aq) \rightarrow 2NaNO_3(aq) + CO_2(g) + H_2O(l)$$

Chemical structure of nitric acid

Nitrogen atom can have maximum of 4 bonds. It is because of electron structure of nitrogen. Its electron configuration is $1s^22s^22p^3$. There are no 2d orbitals. So there are only four orbitals: one s-orbital and three p-orbitals. Therefore, nitrogen has maximum of four bonds. Three ordinary covalent bonds formed by sharing of three unpaired electrons of nitrogen and one is formed by donor-acceptor mechanism. So we have single bond between nitrogen N and O-H group, double bond between N and one oxygen atom O and there remains only one single bond for nitrogen and its between N and another atom oxygen O. But that oxygen atom is differ from first oxygen atom. It has negative charge and also nitrogen with four bonds of course will be positively charged.

Laboratory work

№13. Chemical properties of nitric acid

Materials:

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nitric acid HNO3(conc.), copper oxide CuO, copper coin, conical fl asks, tweezers.

Procedure:

I.

1. Pour 30 ml of nitric acid to the 250 ml beaker.

2. Add the small portion of copper oxide to the beaker. Oxide

reacts with acid to give the green-blue colour salt solution.

II.

1. Pour 30 ml of conc. nitric acid to the 250 ml beaker.

2. Add one copper coin to the beaker. Coin reacts with conc. nitric acid, to give orange-brown gas NO2.

SAFETY: Take care do not inhale fumes. Conc. nitric acid very toxic. Wear disposable gloves. Avoid skin contact. Wash hands after use.

Conclusion:

Record your observations. Write all chemical reactions.

Keep in mind

The density of concentrated nitric acid (68.4% solution) is 1.41 g/mL and its boiling point is 121°C.

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Literacy

1. Write the physical properties of the nitric acid.

2. Write reactions for the production of nitric acid.

3. What is a chemical formula of ammonium nitrate, calcium nitrate?

4. How many grams of nitric acid should be dissolved in 400 g of water to prepare 22% solution?

5. How many grams of nitric acid can be obtained from 161 g of NO_2 from the following sequence of transformation?

$$4NO_2(g) + 2H_2O(l) + O_2(g) \rightarrow 4HNO_3(aq)$$

Science in context

Nitric acid, HNO_3 is the third most important industrial acid (after sulfuric and phosphoric acids). It is used to prepare fertilizers, explosives, paints, medicals, nylon, and polyurethane plastics.

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Nitric acid production on fertilizer plant

Nylon wire roll

Shooting explosives in a stone quarry

Terminology

- nitric acid - азот қышқылы /азотная кислота;
- fuming - түтіндеген /дымящий;
- industrial - өнеркәсіптік /промышленные;
- explosives - жарылғыш заттар/ взрывчатые вещества;
- nylon - нейлон / нейлон;
- coin - монета / монета;
- sequence - жүйелілік /последовательность.

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9.4 SPECIFIC PROPERTIES OF NITRIC ACID AND NITRATES

Why hydrogen gas is not produced when nitric a acid reacts with metals?

You will:

- know how metals react with nitric acid;
- know products of thermal decomposition of nitrates.

Nitric acid reacts with most metals but the products depend on the concentration of the acid and the nature of the metal. Dilute nitric acid behaves as a typical acid in its reaction with most metals. However, reactions with some metals give products as metal nitrates and nitrogen oxides. Let's consider reactions of copper with dilute nitric acid:

$$Cu(s) + HNO3(dil) \rightarrow Cu(NO3)2(aq) + NO(g) + H2O(l)$$

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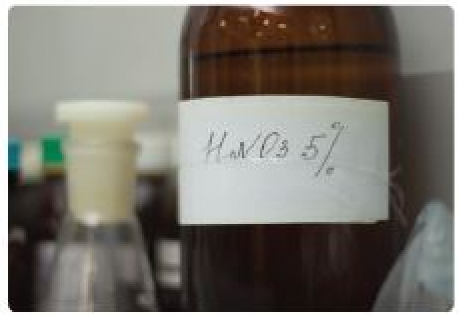
Reaction of nitric acid with copper



Nitric acid solution

As you can see, products are not usual for the reaction of the diluted acid with metal. Now let's balance the reaction by using the change in oxidation state method.

First, the oxidation number of each atom in the reactants and products is indicated to fi nd the total number of transferred electrons.

The half reactions are:

Cu → Cu2+ + 2e– (oxidation)

3e– + N5+ → N2+ (reduction)

The final equation is obtained by summing up the two halfreactions, as follows:

$$\begin{array}{l|l} Cu \rightarrow Cu^{2+} + 2e^{-} & 3 \\ 3e^{-} + N^{5+} \rightarrow N^{2+} & 2 \\ \hline \end{array}$$

$$3Cu + 2N^{5+} \rightarrow 3Cu^{2+} + 2N^{2+}$$

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So, the balanced equation should be:

$$3Cu(s) + 8HNO_3(dil) \rightarrow 3Cu(NO_3)_2(aq) + 2NO(g) + 4H_2O(l)$$

When very dilute nitric acid reacts with zinc, products will be metal nitrate and ammonium nitrate:

$$4Zn(s) + 10HNO_3(\text{very dil.}) \rightarrow 4Zn(NO_3)_2(aq) + NH_4NO_3(aq) + 3H_2O(l)$$

When concentrated nitric acid is used nitrogen dioxide, metal nitrate and water are produced:

$$Ag(s) + 2HNO_3(conc) \rightarrow AgNO_3(aq) + NO_2(g) + H_2O(l)$$

$$Cu(s) + 4HNO_3(conc) \rightarrow Cu(NO_3)_2(aq) + 2NO_2(g) + 2H_2O(l)$$

As you can see, nitric has got special chemical properties those depends on the concentration of acid.

Oxidizing properties of nitric acid

Carbon is oxidized to carbon dioxide on heating, as for sulfur, it is oxidized to sulfuric acid:

$$C(s) + HNO_3(aq) \rightarrow CO_2(g) + 4NO_2(g) + 2H_2O(l)$$

Nitrates

The salts of nitric acid are called nitrates. The nitrates of alkali metals like sodium, potassium, and ammonium have the common name saltpeter. For example, NH_4NO_3 is ammonium saltpeter, and $NaNO_3$ is sodium saltpeter.

All nitrates are solid crystal compounds, which are highly soluble in water. Like nitric acid, the nitrates are also decomposed with the emitting of oxygen on heating.

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Depending on the chemical activity of the metal, which is in the structure of the salt, the decomposition of nitrates occurs differently. The properties of the nitrates vary according to the position of the metal in the reactivity series. This is summarized in the table below.

Metals	Reaction
K Na	$2KNO_3 \xrightarrow{heat} 2KNO_2 + O_2$ Nitrates of these metals are decomposed to nitrite and oxygen by heating.
Li Ca Mg Al Zn Fe Pb Cu	$2Mg(NO_3)_2 \xrightarrow{heat} 2MgO + 4NO_2 + O_2$ Nitrates of these metals are decomposed to the oxide of the metal, nitrogen dioxide and oxygen by heating.
Hg Ag	$2AgNO_3 \xrightarrow{heat} 2Ag + 2NO_2 + O_2$ Nitrates of these metals are decomposed to the metal, nitrogen dioxide and oxygen, because the oxides of these metals are unstable in heat.

All nitrates are well soluble in water

Decomposition reactions of nitrates

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KNO_3 used in food industry (conservation)

Silver nitrate used in medicine

Cannon gunpowder ($NaNO_3$)

Science in context

Gold and platinum are not dissolved by HNO3. However, they can be dissolved in a mixture of concentrated HNO3+HCl in the ratio of 1:3. The mixture is consequently called "Aqua regia" (King water).

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"King water"

Literacy

1. Write reaction of silver with conc. nitric acid.

2. Write decomposition reaction of copper nitrate.

3. Where are ammonium and potassium nitrates used?

4. Find the mass percentage of nitrogen in NH4NO3, AgNO3.

Terminology

- behave - көрсетеді / вести себя;
- depend - байланысты / зависеть;
- indicate - анықтау / определять;
- emit - шығару / выделять.

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9.5 PHOSPHORUS AND ITS COMPOUNDS

Have you ever seen green lights from a cemetery at night?

You will:

- know properties of phosphorus and phosphoric acid;
- compare allotropes of phosphorus;
- know some deposits of phosphorus in Kazakhstan.

Phosphorus

The atomic number of phosphorus is 15. So, electron configuration is 1s22s22p63s23p3 and common oxidation states are –3, +3 and +5.

Phosphorus is a highly reactive nonmetal, so it can not be found in nature in elemental form. Mainly found in a mineral called apatite.

Phosphorus is solid with three allotropes: white, red and black phosphorus. White and red ones are the more important and common forms.

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Dark blue apatite gemstone

White P is highly flammable

White phosphorus

Burning of red phosphorus

Differences between two phosphorus allotropes

White phosphorus	Red phosphorus
whitish-yellow waxy solid	red powder
stored under water	stored dry
poisonous, unstable	not poisonous
illuminates at night	no illumination
garlic smell	no smell

Reactions of phosphorus:

$$2P(s) + 3O2(g) \rightarrow 2P2O3(s)$$

$$2P(s) + 5O2(g) \rightarrow 2P2O5(s)$$

$$P(s) + 3Na(s) \rightarrow Na3P(s)$$

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$$2P(s) + 3Cl_2(g) \rightarrow 2PCl_3(g)$$

$$3P(s) + 5HNO_3(aq) + 2H_2O(l) \rightarrow 3H_3PO_4(aq) + 5NO(g)$$

Phosphoric acid H_3PO_4

Phosphoric acid is a colourless solid. It is one of the most industrially consumed acids in the world. It is mainly used in the production of fertilizers.

It reacts with bases and basic oxides as acid:

$$2H_3PO_4(aq) + 3CaO(s) \rightarrow Ca_3(PO_4)_2(s) + 3H_2O(l)$$

$$H_3PO_4(aq) + 3NaOH(aq) \rightarrow Na_3PO_4(aq) + 3H_2O(l)$$

Deposits of phosphorus in Kazakhstan

As it was mentioned before, phosphorus can found in nature only in forms of minerals. Our country also has some phosphorus deposits. In Zhambyl region, there is Karatau basin where "Zhanatas concentrating mill" works and Shilisai deposit in Aktobe region. On the basis of these deposits, there are factories located in Taraz, Shymkent and Aktobe.

Facts

Phosphoric acid is used as an acidifying agent to give colas their tangy flavor.

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Facts

As a result of its ability to glow in the dark, the element was named “phosphorus”, meaning “light-spreader” in Greek.

Activity

Qualitative analysis of phosphate ion

Materials:

solutions of sodium hydrophosphate Na_2HPO_4, calcium chloride $CaCl_2$, silver nitrate $AgNO_3$, test tubes.

Procedure:

1. Prepare aqueous solutions of Na_2HPO_4, $AgNO_3$ and $CaCl_2$ in different beakers.

2. Add 5 drops of silver nitrate solution to Na_2HPO_4 solution.

3. Add 5 drops of calcium chloride solution to Na_2HPO_4 solution.

Conclusion:

1. Write the reaction occurring between solutions.

2. What is the colour of silver phosphate?

3. The colour of calcium phosphate is ....

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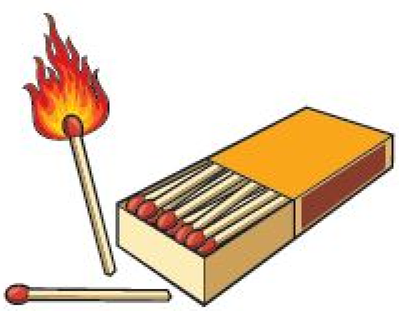
Science in context

Phosphorus is an essential constituent of living organisms. Bones and teeth have a high percentage of calcium phosphate, $Ca3(PO4)2$. Many proteins, especially in seeds, eggs, nerve tissues and brain cells, also contain phosphorus.

Spine of human skeleton

Science in context

Red phosphorus is used on match boxes where the match is struck



Literacy

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1. What are the group and period numbers of phosphorus in the periodic table?

2. How many allotropes of phosphorus are there?

3. Write the formula of apatite mineral.

4. What are the oxidation states of phosphorus in the given compounds respectively: Ca_3P_2, $Ca_3(PO_4)_2$, $Ca_3(PO_3)_2$?

5.How many liters of oxygen at STP is required for complete burning 31 g of phosphorus?

6.What is the empirical formula of phosphorus oxide that contains 43.66% by mass of phosphorus?

Terminology

- light-spreader - жарық шығарғыш / несущий свет;
- apatite - апатит / апатит;
- phosphoric acid - фосфор қышқылы / фосфорная кислота;
- nerve tissues - жүйке ұлпасы / нервные ткани;
- illuminate - жарқырау / освещать;
- tangy - өткір / острый;
- garlic smell - сарымсақ иісті / чесночный запах.

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9.6 FERTILIZERS

How Chile became one of the high-income countries in South America by the 19th century?

You will:

- know the classification of fertilizers;
- know production of phosphorus fertilizers in Kazakhstan;
- understand the effects of nitrogen, phosphorus fertilizers to the environment.

Recent studies have shown that more than 70 elements make up plants. Most of these elements are found in trace amounts, whereas carbon, oxygen, hydrogen, nitrogen, phosphorus, sulfur, magnesium, potassium and calcium are the most abundant and significant ones. Plants can obtain the elements, except nitrogen, phosphorus and potassium (NPK), from air or soil. However, these three elements, NPK, should be applied to plants externally to get a higher yield. To enrich the soil by means of NPK, fertilizers are used.

Tractor fertilizes crops corn in spring

The most important chemicals for plant grows are:

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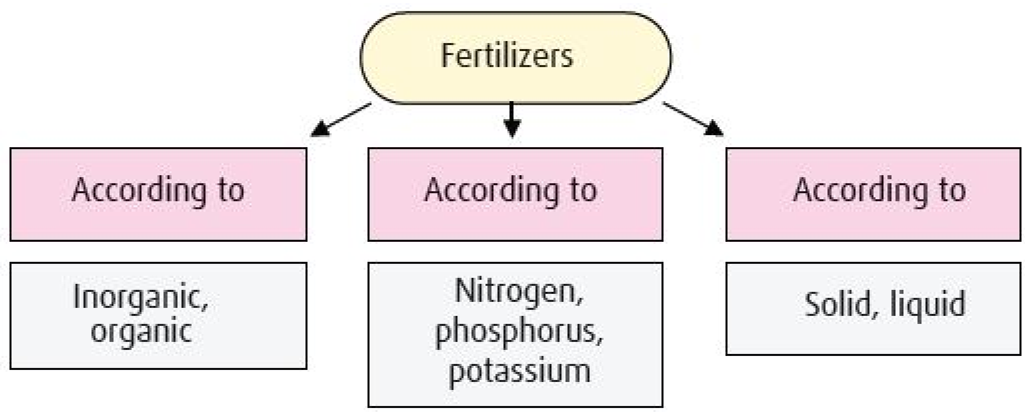
● Carbon, hydrogen and oxygen - available from air and water;

● Nitrogen, phosphorus, potassium - the three macronutrients and the three elements that plants can take from fertilizers;

● Sulfur, calcium, and magnesium - secondary nutrients;

● Boron, cobalt, copper, iron, manganese, molybdenum and zinc - micronutrients.



Nitrogen fertilizers

Nitrogen fertilizer is a compound that stimulates the growth of plants. The nitrogen is required for normal chloroplast formation in plants, which is responsible for the process of photosynthesis. Plants that lack nitrogen will turn yellow and finally perish. Important N fertilizers: (NH4)2SO4, (NH4)2CO3, NH4H2PO4, KNO3, NH4NO3, urea.

Phosphorus fertilizers

Synthetic phosphorus fertilizer is made by chemically processing rock phosphate from the ground. Phosphorus is responsible for photosynthesis, cell division, and the plant's

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ability to use sugars and starches. Many phosphorus fertilizers are produced in Taraz and Shymkent. Chemicals for phosphorus fertilizers come from Karatau, the richest deposit of phosphorus. Important P fertilizers: (NH4)2HPO4, Ca3(PO4)2·CaCO3, Ca(H2PO4)2, etc.

Phosphorus compounds and phosphorus fertilizers have been studied by the academician Bekturov and his students.

Potassium fertilizers

Inorganic salts used as a source of potassium for plants. Potassium chloride, sulfate and carbonate often combined with other compounds containing potassium in a form accessible to plants. Potassium responsible for the quality of products: there is an increase in the sugar content of the whole plant when potassium fertilizers are used. Important K fertilizers: KNO3, KCl, K2SO4·MgSO4.

Karatau mountains

Keep in mind

Natural or chemical substances put on the land to make crops grow better are called fertilizers. Fertilizers make up an

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important branch of agricultural chemistry. Due to the increasing demand for fertilizers, the production of NPK and NPK compounds has increased dramatically.

Sawdust fertilizer in the white plastic bags

Science in context

Abiken Bekturov
(1901 - 1985)

Is the doctor of engineering sciences, professor and academician of AS (Academy of Science) of Kazakh SSR. His scientific works are devoted to the chemical industry of

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phosphorus fertilizers and recycling of phosphoric salts. He established the basic knowledge of preparation of phosphorus fertilizers in Karatau.

Literacy

1. Write the names of the fertilizers that contain phosphorus.

2. Write the names of the fertilizers that contain nitrogen.

3. Prove that use of fertilizers is required for normal plant grows.

4. What fertilizers are more commonly used? Organic or inorganic?

5. Where can we buy fertilizers?

Demonstration

№8. Fertilizers

Use fertilizer samples in your laboratory. Classify the fertilizers : NPK.

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N fertilizers	P fertilizers	K fertilizers

Colourful of fertilizer in wooden box

Terminology

- high-income - үлкен кіріс / высокий доход;
- fertilizer - тыңайтқыш / удобрение;
- thrive - гүлдену / процветать;
- enrich - байыту / обогащать;
- external - сыртқы / внешний;
- recent - жақында, жуырда / недавний;
- recycling - қайта өңдеу / переработка;
- crop - өнім / урожай.

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9.7 SILICON AND ITS COMPOUNDS

How did Silicon Valley get its name?

You will:

- know properties of silicon and its compounds;
- know uses of silicon.

The electron configuration of silicon ends with 3s23p2. So it has -4, +2 and +4 oxidation states. Silicon is metalloid. Silicon is the most important element in the world of minerals.

Silicon is the 2nd most abundant element in the Earth's crust (27.6% by mass). Silicon is a metal-like solid with greyish-blue colour. It is a quite hard and brittle substance. Silicon is not found in elemental form in nature. It is found in compounds such as silica (SiO2) and silicates, which form 95% of the rocks in the earth. Also, it can be found in granite, sand, clay, etc. Silicon is a component of many different compounds that are used for civil engineering, production of concrete, cement, ceramics, pottery. Silicone rubber can used in bathrooms and around windows, pipes and roofs as a waterproof sealant.

Compounds of silicon

Silicon dioxide (SiO2) is a very hard substance. It is used to make laboratory glassware, various lenses, ultraviolet lightpassing glass, fluorescent lamps, and light-sensitive

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electrical measurement instruments. Coloured amorphous SiO_2 is used to make jewellery. It is found in quartz mineral.

Pure silicon


Contact lens


Camera lens


Quartz mineral

Chemical properties of silicon

1. Silicon reacts with nonmetals (carbon, oxygen, sulfur and nitrogen) at high temperatures:

$$Si(s) + C(s) \rightarrow SiC(s)$$

$$Si(s) + O_2(g) \rightarrow SiO_2(s)$$

2. Silicon does not react with acids, except HF:

$$Si(s) + 4HF(g) \rightarrow SiF_4(g) + 2H_2(g)$$

3. Silicon reacts with strong base solutions by forming silicates and releasing hydrogen gas H_2:

$$Si(s) + 2KOH(aq) + H_2O(l) \rightarrow K_2SiO_3(aq) + 2H_2(g)$$

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Chemical properties of silicon compounds:

1. Silicic acid, H_2SiO_3

H_2SiO_3 is a very weak acid and insoluble in water. It is immediately decomposed into SiO_2 and H_2O when heated:

$$H_2SiO_3(s) \rightarrow H_2O(l) + SiO_2(s)$$

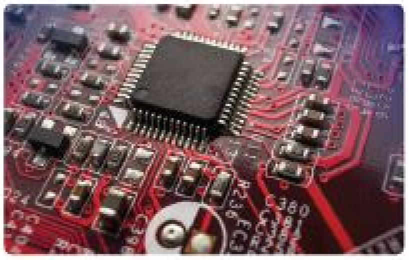
2. Silicon dioxide forms silicates by reacting with metal oxides, hydroxides, carbonates and sulfates at high temperatures.

$$MgO(s) + SiO_2(s) \rightarrow MgSiO_3(s)$$

$$2NaOH(aq) + SiO_2 \rightarrow Na_2SiO_3(aq) + H_2O(l)$$

Science in context

Elemental silicon is used in the preparation of silicone polymers. Because silicon is a semiconductor, it is used to prepare electronic devices such as computer chips and transistors. Pure silicon is used in solar cells.



Electronic circuit

Solar cells

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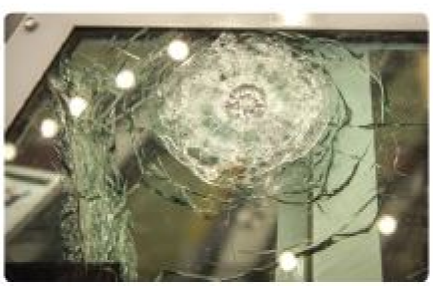
Facts

Silicon carbide (SiC) is an extremely hard substance. It is used in the production of very hard ceramics. Silicon carbide is important abrasive and also used in lasers.

Silicon carbide crystals

Facts

Bulletproof glass is made of two sheets of glass with a sheet of a transparent resin between them, formed under heat and pressure. When subjected to a severe blow, it will crack without shattering.



Bulletproof glass

Literacy

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1. How many electrons and protons are there in silicon atom?

2. What are common oxidation states of silicon?

3. What is the empirical formula of silicon oxide that contains 46.67% by mass of silicon?

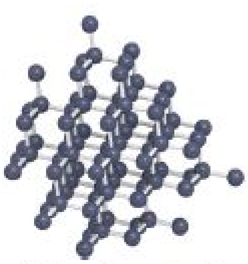
4. Where are silicon compounds used?

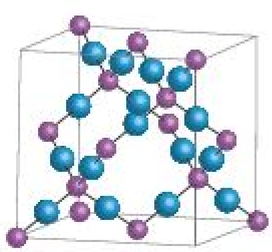
5. When 10 g mixture of silicon and carbon is dissolved in KOH amount of hydrogen produced was 11.2 L at STP. What is the percentage by mass of silicon in the mixture?

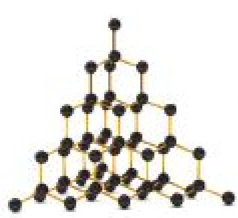
Demonstration

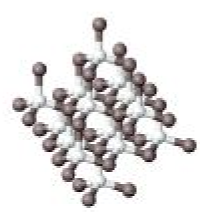
№10. Crystal lattice structures of silicon compounds and diamond

The crystalline lattice structures of silicon, silicon dioxide and silicon carbide are similar to the structure of diamond. As a result, some properties of them are similar to diamond, such as hardness. Construct and compare 3D models of silicon, silicon dioxide, diamond and silicon carbide.


Silicon has atomic crystalline structure


Crystal lattice of silicon dioxide


3D model of a crystal lattice of diamond


Crystal lattice of silicon carbide

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Terminology

- silica - кремнезем;
- semiconductor - жартылай өткізгіш / полупроводник;
- sealant - оқшаулағыш / герметик;
- crystal lattice - кристалдық тор / кристаллическая решетка;
- bulletproof - оқ өтпейтін / пуленепробиваемый;
- transparent - мөлдір / прозрачный;
- solar cell - күн сәулелік батарея / солнечные батарея;
- glassware - шыны ыдыс / стеклянная посуда.

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9.8 SILICATES. SILICATE INDUSTRY�

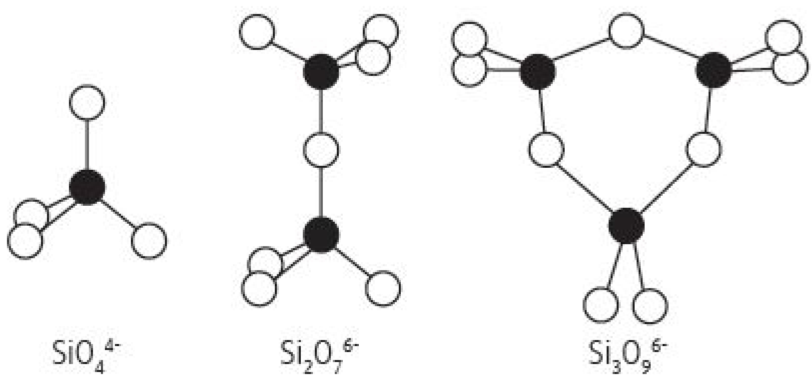
What is cement made of?

You will:

- know qualitative analysis for silicate ion;
- know silicate industry in Kazakhstan.

Silicates

Silicon forms various types of anions with oxygen. Salts containing these anions are called silicates. The main structure of a silicate ion is a regular tetrahedral, as in SiO44- ion. The other silicate anions contain more than one SiO44- tetrahedral ions which are joined together by a bridge of oxygen atoms. Silicates are classifi ed according to bonding variations of these regular tetrahedral:



Schematic representation of the arrangement of atoms in the silicate ions

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Clay

Clays occur naturally as alumina silicate, $H_4Al_2SiO_9$. They are found as a plastic paste or can be converted to a paste by grinding or mixing with water. They can easily be shaped when they are wet. But, if they are dried in a furnace, they have a very hard structure. Clays are used in the manufacture of cement, ceramics, rubber and paint.

Glass

The main compounds of glass are sodium silicate (Na_2SiO_3) and calcium silicate ($CaSiO_3$), which are prepared according to the following reactions at high temperature (1500°C):

$$Na_2CO_3(aq) + SiO_2(s) \rightarrow Na_2SiO_3(aq) + CO_2(g)$$

$$CaCO_3(s) + SiO_2(s) \rightarrow CaSiO_3(s) + CO_2(g)$$

Glass is a supercooled liquid which forms a noncrystalline solid. It is hard, brittle, amorphous and is usually transparent. The formula of ordinary glass is

$$Na_2O \cdot CaO \cdot 6SiO_2$$

Major glass manufacturers are placed in Aktobe, Almaty and Taraz. The glass can have many different colours. It can have a transition or rare earth metal ions added. This table shows some of the typical chemical elements that are used to colour glass:

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Girl sculpts in clay pot


Ceramics (Astana. National Museum)

Typical colours of glasses

The element	Fe^{2+}	Cu^{2+}	Cr^{3+}	Ni^{2+}	Au^{3+}	Mn^{3+}	Co^{2+}	Er^{3+}	Fe-S
Colour of glass	green	blue	pale green	brown	red-violet	purple	blue	pink	orange

Cement

The most commonly used cement in the world is Portland cement. Portland cement is essentially powdered calcium aluminosilicate, which sets to a hard mass when treated with water. It is made by pulverizing a mixture of limestone (CaCO3) and clay (an aluminosilicate). Today, there are many cement manufacturers in Kazakhstan. They are placed in Semey, Karaganda, Almaty, Taraz, Shymkent and Oskemen.


Cement plant


Cement mix

Silicones

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They are organic compounds which have some of the properties of both hydrocarbons and siliconoxygen compounds. Some of them have very good resistance to thermal decomposition and chemicals.

Silicones are used in greases, sealing compounds, enamels, varnishes, resins and synthetic rubber.

Gun with silicon

Science in context

Asbestos, a kind of fi brous silicate mineral, is widely used because of its nonflammability, fl exibility, mechanical strength and inertness to chemical attack.

Asbestos roofs

Facts

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Silicosis is a lung disease caused by breathing in tiny bits of silica, a mineral that is part of sand, rock.

Silicate dust

Literacy

1. Where cement factories located in Kazakhstan?

2. What is the mass percentage of silicon in the Earth's crust?

3. What are chemical formulas of silica and clay?

4. What is the sum of all coefficients in the following reaction?

$$SiC(s) + NaOH(aq) + O_2(g) \rightarrow Na_2SiO_3(aq) + H_2O(l) + Na_2CO_3(aq)$$

5. Which reagents are required for the following transformations?

$$SiO_2 \rightarrow Si \rightarrow Na_2SiO_3 \rightarrow H_2SiO_3 \rightarrow CaSiO_3$$

Terminology

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- silicates - силикаттар / силикаты;
- fibrous - талшықты / волокнистый;
- flexibility - икемділік / гибкость ;
- clay - балшық / глина;
- grinding - өңдеу / шлифовка;
- pulverizing - сепкіш / распылительный;
- grease - жаққыш / смазка.

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Problems: Elements and compounds of 14 and 15 groups

1. What is the oxidation state of nitrogen in each of the following compounds?

$NaNO_2$, KNO_2, N_2O_4, NH_3, NH_2OH

2. Which of the nitrogen oxides is used in medicine as an anestetic?

3. Write the reactions with nitrogen dioxide and water? How does the oxidation state of nitrogen change? Write the oxidizing and reducing agents in this reaction?

4. Write the production reactions of nitric acid in industry.

5. Find mole number of nitric acid which reacts with 10 grams of iron (III) oxide.

6. How many moles of NO_2 are produced by the reaction at high temperature of 1.5 mol of O_2 with sufficient amount of N_2?

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7. How many grams of $Ca(NO3)2$ can be prepared by treatment of 12.0 g CaO with 102 g HNO3? How many grams of excess reactant remains after the reaction?

8. Nitric acid reacts with iron (II) hydroxide to produce iron (II) nitrate and water.

a. Write a balanced chemical equation for the reaction.

b. Determine the mole number of 50 g of nitric acid.

c. How many moles of iron (II) nitrate will produce in a reaction with 50 g of HNO3?

d. What is the mass of produced iron (II) nitrate?

e. How many moles of iron (II) hydroxide is needed to react with this quantity of nitric acid?

f. How many grams of iron (II) hydroxide will be used?

9. Write the electron configurations of the following elements: Si, N.

10. Find the following pairs of elements in the periodic table. Name them. Then compare them in terms of group number and number of valence electrons. Identify each element as a metal, nonmetal or metalloid. List uses of the elements.

- C and Pb

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- Si and P
- Ga and N

11. Name the following silicon compounds:

SiH_4, H_2SiO_3, SiO_2, Mg_2Si, Na_2SiO_3, $CaSiO_3$

12. Calculate the number of molecules in 15.7 mol of silicon dioxide.

13. Silicon reacts with chlorine to produce silicon tetrachloride.

a. Balance the equation: $Si(s) + Cl_2(g) \rightarrow SiCl_4(g)$.

b. If you begin with 3.2 g of silicon and 5.4 g of chlorine, which one is the limiting reactant?

c. How many grams of silicon tetrachloride can be produced from the amount of limiting reactant available?

d. Calculate the mass of excess reactant that remains after the reaction.

14. What is the percent by mass of sodium silicate in a water solution containing 0.497 g Na_2SiO_3 in 58.3 g of the solution?

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15. Write three applications of silicon in industry. Identify some devices, containing silicon found in your home.

16. How many grams of H_2SiF_6 could be obtained by dissolving 50 g of pure sand (silicon dioxide) dissolves in enough amount of dilute HF?

$$SiO_2(s) + 6HF(g) \rightarrow H_2SiF_6(s) + 2H_2O(l)$$

17. Why silicon can have maximum of four bonds and phosphorus has five bonds? Explain.

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CHAPTER 10: MACRO- AND MICROELEMENTS IN HUMAN BODY AND ENVIRONMENT

10.1 THE CHEMICAL COMPOSITION OF THE HUMAN BODY. MACRO AND MICRONUTRIENTS

How many chemical elements does human body contain?

You will:

- name the elements which present in human body and explain their functions;
- study a typical diet of residents in Kazakhstan and make up a balanced diet.

Chemical composition of human body

Six chemical elements make almost 99% of the human body. They are oxygen, carbon, hydrogen, nitrogen, calcium and phosphorus. About 0.85% belong to other five elements:potassium, sulfur, sodium, chlorine and magnesium. The remaining elements present in trace amounts.

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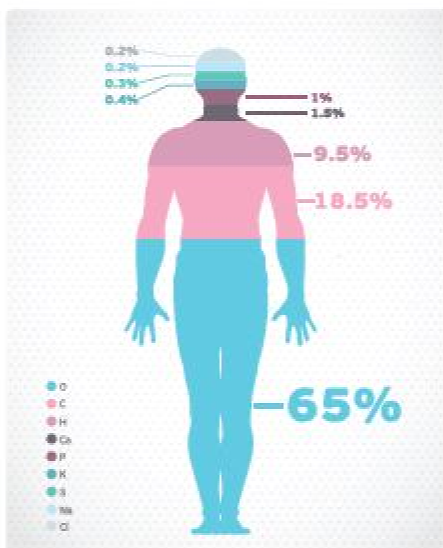
Micronutrients are chemicals needed in small amounts, generally less than 0.005% of body mass. Because of very small amounts, they are usually measured in mg or µg per day. These substances help the body to produce enzymes, hormones and other substances essential for health. Micronutrients include the vitamins and many trace minerals such as Fe, Cu, Zn, I, Se, Mn, Mo, Cr, Co, B.

Macronutrients are those needed in relatively large amounts. They are used to provide energy in the body and build its structure. They include macromolecules like carbohydrates, lipids and proteins as well as some minerals needed in large amounts such as Na, Mg, K, Ca, P, S, and Cl.



Mass percentages of elements in a human body

1. Oxygen (O) - 65%. Oxygen is not only the component of water, but it is also the main block of almost all organic compounds in our body such as carbohydrates, proteins, fats, and others.

2. Carbon (C) - 18%. Carbon is the main element for all living things because there is no any organic compound without

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carbon element. We can say that organic compounds are carbon compounds.

3. Hydrogen (H) - 10%. Hydrogen is also found in water and all organic compounds.

4. Nitrogen (N) - 3%. Nitrogen is found in all proteins and nucleic acids that make up DNA.

5. Calcium (Ca) - 1.5%. Calcium is one of the main building blocks for our bones and teeth.

6. Phosphorus (P) - 1%. Phosphorus is another building block of our bones and teeth. It is also found in ATP molecule, which is the source of energy in a body.

7. Potassium (K) - 0.3%. Potassium plays the main role in carrying of nerve impulses and in keeping blood pressure.

Iron deficiency is one of the most prevalent micronutrient deficiency in the world. Because iron is an essential part of red blood cells. A lack of iron leads to a serious condition known as anemia.

Facts

Iodine is needed for the synthesis of the hormone thyroxine, which regulates the metabolic rate. It is present in most types of seafood and in some vegetables. A lack of iodine causes a swelling of the thyroid gland in the neck known as goiter.

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Facts

The World Health Organization has identified iodine, vitamin A and iron compounds as the most important micronutrients in global health terms.

Sources of vitamin A

Activity

You need to research typical diet of residents of Kazakhstan.

Your aim is to fi nd out what people eat during a day and analyze their menu. Work in groups. You can do it in several

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ways. We recommend using three-day diary method or questionnaire.

I. Three-Day Diary

1. Agree with some students of your school that they will keep a diary of what they eat during three days.

2. Notify them to write honestly, even if they eat not healthy food, so your research will be done on real data.

3. More students involved in writing a diary, more accurate your assessment will be.

4. After students fi nished with diaries, try to make an "average" breakfast, lunch and dinner out of your data.

5. Calculate the amount of energy gained by eating the "average" breakfast, lunch and dinner. Also, calculate the mass of fats gained during the "average" diet. You can use tables with energy, fats data in meals provided by health organizations. Also you can use calorifi c value on the wrapper of any food product and beverages.

6. Analyze whether the "average" diet fulfi ls the amount of macro- and micronutrients needed per a day. Compare your results with data of health organizations.

II. Questionnaire

1. Prepare questions for your interviews. Think about questions that will help you to understand what interviewee eats during his/her day.

2. You can conduct your interviews at food courts, fast food outlets, cafes, etc.

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3. Use steps 2 to 6 from Three-Day Diary.

Note: Do not forget that you will interview people with different age groups. So, try to divide your data into different age groups - teenegers and adults. Compare results to data of health organizations for same age groups.

Questions:

1. Is an average daily diet of students from your school healthy?

2. Does the diet supply body with a recommended value of macro and micronutrients?

3. Can you suggest your healthy daily diet for students of your school/people that you interviewed? Use data tables provided by health organizations.

Literacy

1. What are the main elements found in the human body?

2. Calculate the mass in grams of C, H, O, Ca, Na, S elements in the body of a 50 kg person.

3. What are micronutrients? Give their names.

4. Which foods contain carbohydrates?

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Science in context

"Eat breakfast alone, share lunch with a friend and give your dinner to your enemy." (Chinese proverb)

Terminology

- nutrients - қоректік заттар / питательные вещества;
- essential - қажетті / необходимый, существенный;
- trace - аз / мало;
- swelling - ісік / опухоль;
- prevalent - көп таралған / распространенный;
- diet - тамақтану режимі/ режим питания;
- average - орташа/ усредненный.

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10.2 IMPORTANT NUTRITION IN YOUR FOOD

How does E338 (phosphoric acid) lead to the removal of calcium ions from human body?

You will:

- know the importance of calcium and iron for human body;
- determine calcium in the human bones;
- determine carbon and iron in food.

Importance of calcium

Calcium is one of the most important minerals in the human body. It takes about 1-1.5% of the human body. Calcium helps your body by building strong bones and teeth, clotting blood, sending and receiving nerve signals, muscle contraction, releasing hormones and keeping a normal heartbeat. Dairy products are the best source of calcium.

Importance of iron

Iron is a mineral found in every cell of the body. One of the main roles of iron is to help our red blood cells transport oxygen to all parts of the body. Iron helps in the conversion of blood sugar to energy. The best sources of iron are dried beans, dried fruits, eggs, liver, seafood, greens (all kinds).

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Food sources of various nutrients

Iron rich foods

Sparkling white teeth

Laboratory work

№14. The determination of calcium ions in bones.

Materials:

animal bones, 10 % hydrochloric acid HCl,beaker 1 L, conical flask, sodium carbonate solution.

Procedure:

1. Pour 300 ml of a 10% hydrochloric acid solution into a beaker.

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2. Add some piece of animal bones into the beaker and dissolve it.
3. Filter the solution into a conical flask.
4. Add 5-6 drop of sodium carbonate solution to a filtrate. Record your observations.

Conclusion:

Record your observations. Write all chemical reactions.


Old bone

Laboratory work

№15.1. The determination of carbon in food products.

Materials:

lime water Ca(OH)2, copper (II) oxide, sugar, wood shavings, test tubes, test tube rack, spatula, burner.

Procedure:

1. Place a test tube in the test tube rack and fi ll 1/3 of it with lime water.
2. Place another two test tubes in the test tube rack and number them as 1 and 2.
3. Put a half spatula of copper (II) oxide into each numbered test tube.
4. Then put
• A half spatula of sugar in the test tube 1

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● A half spatula of wood shavings in the test tube 2

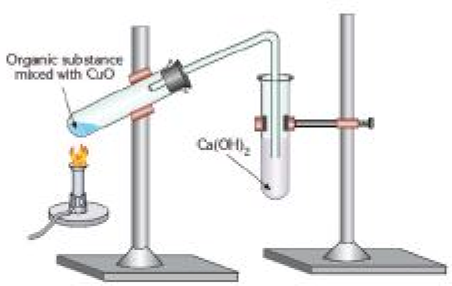
5. Then put another a half spatula of copper (II) oxide on top of the organic material in the each numbered test tube.
6. Heat the test tube 1 with a small hot fl ame for about 3 minutes.
7. Observe the lime water and observe the cooler part of the test tube 1 for any drops of moisture. Record your observations in the table.
8. Stop heating and repeat the procedure for the material in test tube 2 with fresh lime water.

Conclusion:

1. Note your observations in the table.
2. Which other elements can be found in organic compounds? Give examples.
3. Write the reactions that take place in the lime water.

Organic material	Drops of moisture	Lime-water
Sugar	....	....
Wood shavings	....	....

SAFETY: Wear protective glasses.



Carbon is an essential element in organic molecules

Laboratory work

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№15.2. Analysis of iron in foods

Materials:

1M hydrochloric acid HCl, potassium thiocyanate KSCN (or NH_4SCN), crucible, beakers, test tubes, burner, pipette.

Procedure:

1. Prepare salt solutions.
2. Weight about 3 g of corn and place in the crucible.
3. Heat the crucible with a hot burner fl ame until the corn sample will turn to ash (about 5-15 min).
4. Remove the burner and allow the ash to cool, then transfer to a small beaker.
5. Pour about 5 ml of HCl acid and carefully stir. Add 10 ml of distilled water and stir.
6. Add 3-4 drops of KSCN solution.

Conclusion:

1. Record your observations.
2. Write the reaction that took place.

Terminology

- dairy - сүтті өнімдер / молочный;
- clotting - / свертывание;
- wood shavings - ағаш қиқымдары / древесная стружка;
- spatula - шпатель.

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10.3 HEAVY METALS

How do heavy metals denature proteins?

You will:

- learn toxicity of heavy metals using lead and mercury as an example;
- know what the sources of heavy metals are.

Lead toxicity

Lead comes from the Latin word “plumbus”, which means heavy. It is highly toxic and cumulative poison. It can affect every organ system because heavy metals are deposited easily in the body. Even small amounts of lead can cause serious health problems. Children are especially vulnerable to lead poisoning.

Lead poisoning occurs when a lead is ingested. Inhaling dust that contains lead can also cause it.

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"Contains Lead" warning sign


Lead air-gun pellets


Leaded gasoline gives toxic effects

Mercury toxicity

Mercury is a naturally occurring element that is found in air, water, and soil. It has three forms: elemental mercury, inorganic mercury salts, and organic mercury compounds. Any form is poisonous. It has toxic effects on the nervous, digestive and immune systems, skin, lungs, kidneys, and eyes. Mercury has a very low excretion rate.

Mercury is toxic, so is now only used with great care. Mercury easily forms alloys, called amalgams, with other metals such as gold, silver, and tin.

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Shiny mercury metal drops

"Hazardous to environment" symbol

Science in context

Most of the lead produced is used in lead-acid batteries. Also, it is used in solder, paintings, pipes, pottery, roofing materials and some cosmetics.

Old battery leak

Science in context

Mercury is contained in many products, including batteries, measuring, thermometers, barometers, electric switches, lamps, dental fi llings, skin-lightening products and pharmaceuticals.

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Fluorescent light tubes contains mercury

Facts

Mercury is the only metal that is liquid at room temperature.

Broken glass thermometer with mercury

Facts

Despite the fact of being toxic, lead is beneficial element because of highly industry-friendly properties, like excellent malleability and corrosion resistance.

Keep in mind

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Heavy metals are defined as metals with a density of more than 5 g/cm3. Alloy of metal with mercury is called amalgam.

Activity

Effects of some heavy metals on protein denaturation

At almost every meal, we look forward especially to the proteins: ham and eggs for breakfast, hamburgers for lunch, steak or chicken for dinner. We drink milk mostly for the sake of its proteins. Even many our desserts are protein products. Crack an egg, separate white from yolk by letting white fl ow into a cup while retaining yolk in the eggshell. Beat white with a fork.

Shake 5 ml beaten egg white with 5 ml water. Add 5 ml lead (II) nitrate. The $Pb(NO_3)_2$ causes the albumin to coagulate out in white flecks.

Half of broken egg

Activity

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Heavy metal pollution

Discuss followings topics:
1. Heavy metal pollution is a problem not only for areas of intensive industry, automobiles, and roadways.
2. Use of mercury and lead metals should be withdrawn.
3. Coal burning must be replaced with cleaner sources of fuel for energy production.

Literacy

1. Which metals are called heavy metals?
2. Which toxic elements do you know?
3. How to avoid uses of toxic metals?

Terminology

- denature - денатурация / денатурация;
- cumulative - кумулятивті / накапливающийся;
- deposited - жиналу / накапливающийся;
- vulnerable - осал / уязвимые;
- excretion - экскреция / выведение;
- withdrawn - алынып тасталған/ исключать;
- yolk - саруыз / желток.

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Problems: Macro- and microelements in human body and environment

1. What are heavy metals? How they affect human health?

2. Define role of calcium and its compounds like calcium carbonate, calcium phosphate,calcium sulphate in body.

3. Is cow's milk a good source of calcium for the human body?

4. What is the elemental composition of main nutrients such as carbohydrates, fats, and proteins?

5. Why is the mass percentage of oxygen the highest in a human body?

6. Avocado contains mostly .... nutrient.

7. Much of our bodies' dry weight is .... nutrient.

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8. Which nutrient is the main energy source in a body?

9. What is the main function of hemoglobin?

10. Why do we need oxygen for respiration?

11. Deficiency of iron in the blood can lead to ....

12. Dairy products are the main source for .... element.

13. Carbohydrates are also known as ....

14.

a) Look at the wrapper of any chocolate and compare its composition and calorific value for 100 g of product with cucumber.

b) Which of the main nutrients are in a major amount in chocolate and cucumber?

c) It is known that human needs for about 1000 mg of calcium per day. Calculate how many cucumbers with the

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mass of 150 g you need to eat in a day if you do not have another food.

d) Is it enough amount of cucumbers that you need to eat in a previous question for the iron source? A daily dose of iron is about 12 mg.

15. Calculate how many grams of chocolate you need to eat for energy if you do not have any other food. A human needs about 2500 kcal every day (kilocalories).

16. Calculate how many milliliters of milk with two percent fat you need to drink for energy if you do not have any other food.

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CHAPTER 11: INTRODUCTION TO ORGANIC CHEMISTRY

11.1 INTRODUCTION TO ORGANIC CHEMISTRY. CLASSIFICATION OF ORGANIC COMPOUNDS

Why do we call that branch of chemistry as "organic"?

You will:

- learn what organic chemistry is;
- know why carbon can make so many different compounds;
- know the classification of organic compounds.

Introduction

Everybody might know "C" as the symbol of carbon. However, it is not only a symbol but a special key for about 30.000.000 known compounds! Organic chemistry, carbon chemistry, is a huge branch of the chemistry science and actually, it can be said that we live in an Organic Chemistry Age in the 21st century. What does make carbon so unique? Let's consider electron configuration of carbon in ground state:

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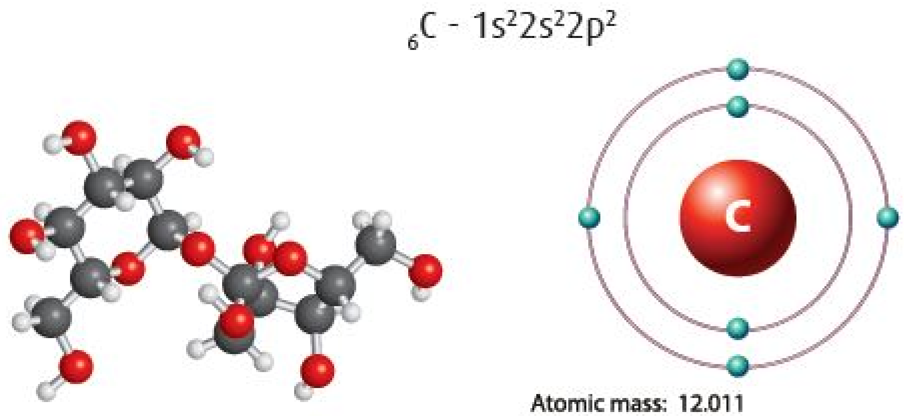
6C - 1s22s22p2



Atomic mass: 12.011
Electron configuration: 2, 4

Sucrose $C_{12}H_{22}O_{11}$ (sugar) molecule

Carbon atom structure

Sometimes organic chemistry is called chemistry of carbon. Why? Carbon atoms can easily bond with other carbon atoms to form long chains or rings. So, carbon itself can make many different compounds. Therefore, we can say that organic chemistry is a branch of chemistry which studies compounds of carbon.

The substances studied in organic chemistry are called organic compounds and they are vital for all living things on this planet. Petroleum, natural gas and coal are the main sources of organic compounds.

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Petroleum


Motor oil


Medical drugs


Soccer ball polymer

These sources are formed by the decay of living organisms over time. Organic chemistry is the chemistry of paints, plastics, drugs, dyes, paper, ink, gasoline and rubbers. Most of the medicines that we use are also organic. Almost all our food and many food additives are organic and all polymers we use in our life like polyethylene, polypropylene, Teflon, polystyrene etc. are organic.


Clothes made up of organic compounds

It can be said that organic chemistry is related to every part of our lives and understanding properties organic compounds have led to a complete change in our lives.

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Organic	Inorganic
1. There are about 30.000.000 known organic compounds.	1. A smaller number of compounds. There are about 500.000 compounds.
2. Compounds include a few elements: C, O, H, N, S, P and the halogens.	2. Compounds may include any of about 100 different elements.
3. Compounds have covalent bonds and may be large molecules with long chains and cycles.	3. Compounds have ionic bonds and small ratios of elements.
4. Generally in liquid or gaseous form.	4. Most of them exist in the solid state. They have high melting and boiling points.
5. Have specific colours and odours.	5. Generally colourless and odourless.

Functional groups

In organic chemistry, functional groups are specifi c groups of atoms that are responsible for the characteristic chemical reactions of the whole molecule.

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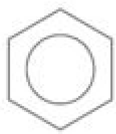
Important families of organic compounds

Family	Structural formula	Name	General formula (functional groups)
Alkane C_2H_6	CH_3-CH_3	ethane	R-H
Alkene C_2H_4	CH_2=CH_2	ethylene	RCH=CH_2
Alkyne C_2H_2	HC≡CH	acetylene	RC≡CH
Arene C_6H_6		benzene	Ar-H
Alcohol C_2H_5OH	CH_3-CH_2-OH	ethyl alcohol	R-OH
Aldehyde CH_3CHO	CH_3-CHO	acetaldehyde	R-CHO
Carboxylic acid CH_3COOH	CH_3-COOH	acetic acid	R-COOH
Amine CH_3NH_2	CH_3-NH_2	methylamine	R-NH_2

Literacy

1. What are the differences between organic and inorganic compounds?

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2. Give five examples of organic and inorganic substances you use at home.

3. What are the most common elements found in organic compounds?

4. An organic compound was found to contain 10% hydrogen and 90% carbon by mass. Find its empirical formula.

5. An organic compound with a molar mass of 88 g/mol contains 55% C, 36% O and 9% H by mass. Find its molecular formula.

Demonstration

№11. Molecular models of compounds

Molecular models

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Element	Symbol	Colour	Bonds to Get Stable State
Hydrogen	H	white	1
Oxygen	O	red	2
Nitrogen	N	blue	3
Carbon	C	black	4

Procedure:

Build the following molecules using the ball-andstick models and predict the formula for the molecule and draw a structure of the molecule.

Name of molecule	Atoms in molecule	Predicted formula	Sketch of Molecule
Methane	4 hydrogen 1 carbon		
Ethane	6 hydrogen 2 carbon		
Ethene	4 hydrogen 2 carbon		
Acetylene	2 hydrogen 2 carbon		
Ethyl alcohol	6 hydrogen 2 carbon 1 oxygen		
Acetic acid	4 hydrogen 2 carbon 2 oxygen		
Aminoacetic acid (glycine)	5 hydrogen 2 carbon 2 oxygen 1 nitrogen		

Terminology

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- vital - өмірлік маңызды / жизненно важно;
- petroleum - мұнай / нефть;
- gasoline - жанармай / бензин;
- polymers - полимерлер / полимеры;
- food additives - тамақ қосындылары / пищевые добавки;
- functional group - функционалды топ / функциональная группа;
- ball and stick models - шар-таяқшалы моделдер / шаро-стержневые модели.

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11.2 HOMOLOGOUS SERIES OF ORGANIC COMPOUNDS. NOMENCLATURE OF ORGANIC COMPOUNDS

Why CH4 is called "methane" but not "monane", while C5H12 is called as "pentane" (mono - 1, penta - 5)?

You will:

- know what a homologous series is;
- give names for organic compounds.

Homologous series

There are first four members of alkanes and alcohols in a table. There is a (-CH2-) difference between members of consecutive alkanes. For example, between C3H6 and C4H10 the atoms increase by 1C and 2H (-CH2-). A series of compounds in which the members are built up in this way is called a homologous series. The alkanes are a homologous series. Compounds that form a homologous series show similar properties.

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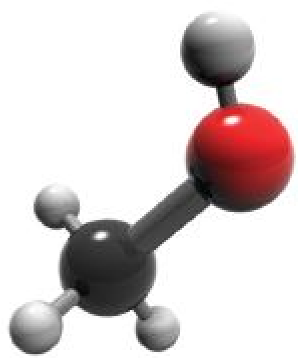
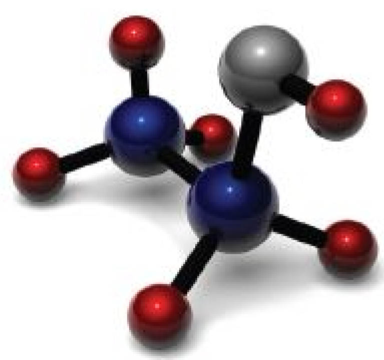
Alkanes, alkyl groups and alcohols naming

Name	Molecular Formula	Name	Molecular Formula	Name	Molecular Formula
Methane	CH_4	Methyl (Me)	CH_3-	Methyl alcohol	CH_3-OH
Ethane	C_2H_6	Ethyl (Et)	C_2H_5-	Ethyl alcohol	C_2H_5-OH
Propane	C_3H_8	Propyl (Pr)	C_3H_7-	Propyl alcohol	C_3H_7-OH
Butane	C_4H_{10}	Butyl (Bu)	C_4H_9-	Butyl alcohol	C_4H_9-OH



Methanol molecule



Ethanol molecule

Keep in mind

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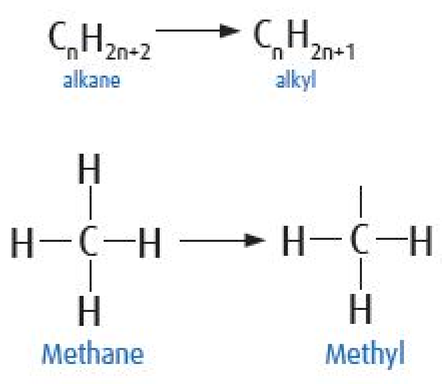
1	mono
2	di
3	tri
4	tetra
5	penta
6	hexa
7	hepta
8	octa

Latin numbers

Nomenclature

IUPAC developed a standard naming of organic compounds. According to the IUPAC system, there is only one name for a compound. If one hydrogen is removed from an alkane, an alkyl group is formed. The general formula for an alkyl group is CnH2n+1. Instead of the –ane suffix in alkanes, "–yl" is used for naming alkyl groups. They can also be shown by "R". R represents "radical".



To name the alkanes according to the IUPAC the following rules can be used.

Rule 1.

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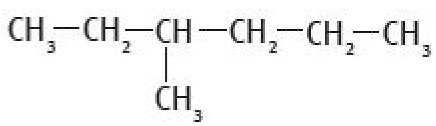
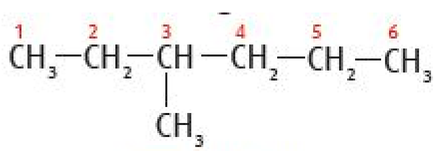
Determine the chain with the longest continuous number of carbon atoms. This gives the starting name (often called the parent name) of the alkane.



There are six carbon atoms in the longest chain in the example. So the parent name of the compound is hexane.

Rule 2.

Number the carbon atoms in the longest chain, starting from the end closest to the branching.

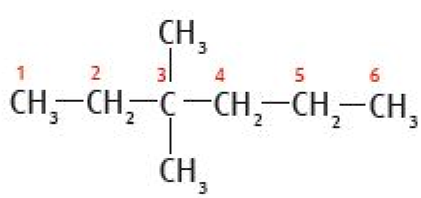


3-methylhexane

Rule 3.

If there is more than one identical a substituent the number of a substituent is indicated by using prefixes –di, –tri, –tetra and so on. Some important substituents other than alkyl groups are the halogens like fluoro (-F), chloro (-Cl), bromo (-Br), iodo (-I) and

hydroxyl (-OH), nitro (-NO2) and amino (-NH2) groups.



3,3-dimethylhexane

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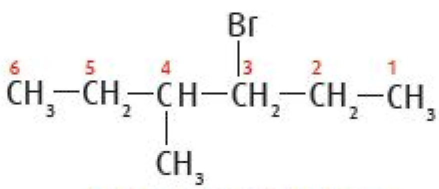
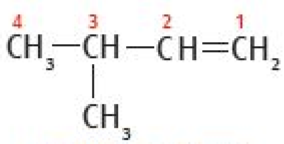
Rule 4.

When two or more different substituents are bonded to the carbon chain, they are ordered alphabetically.



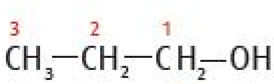
3-bromo-4-methylhexane

In cases, when carbon chain contains the double or triple bond, the carbon atoms are numbered starting from the end nearest to the double bond. A number indicates the location of the double bond before the parent name of the alkene.



3-methyl-1-butene

When the hydroxyl group is attached to the carbon chain you need to change the name of the alkane corresponding to this chain by replacing the final –e and adding the suffix – ol.



propanol-1

Literacy

1. Write four homologues of methyl alcohol (CH3-OH).
2. Write down the IUPAC naming of the following compounds:

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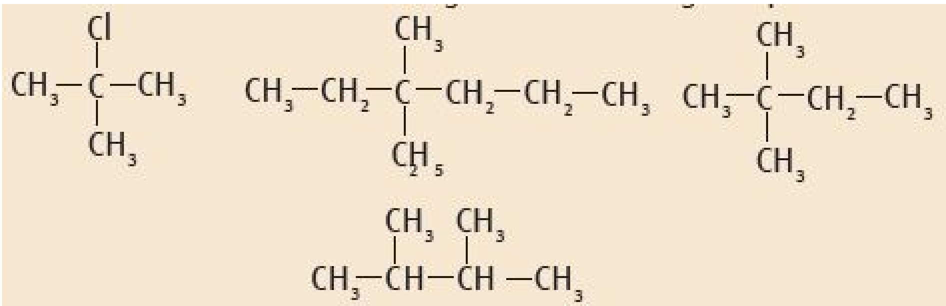
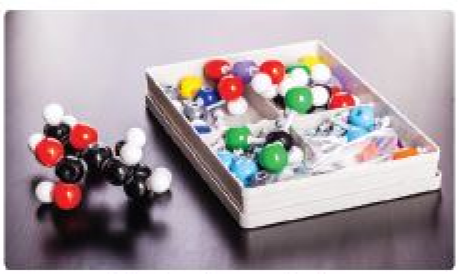


3. Draw the structural formulas of the following compounds:
a- 2,3-dimethylpentane
b- 3,4-dimethyl-4-ethylheptane
c- 2,4-dimethyl-4-ethylheptane

Demonstration

№12. Molecular models of alkanes and alcohol molecules



Molecular models

Use the following information to create your lab report in the classwork section of your notebook. Include the following sections.

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Element	Symbol	Colour	Bonds to Get Stable
Hydrogen	H	white	1
Oxygen	O	red	2
Nitrogen	N	blue	3
Carbon	C	black	4

Procedure:

Build the following molecules using the ball-andstick models and predict the formulas for the molecules and draw their structures.

Name of molecule	Atoms in molecule	Predicted formula	Sketch of Molecule
Methane	4 hydrogen 1 carbon		
Ethane	6 hydrogen 2 carbon		
Propane	8 hydrogen 3 carbon		
Methyl alcohol	4 hydrogen 1 carbon 1 oxygen		
Ethyl alcohol	6 hydrogen 2 carbon 1 oxygen		
Propyl alcohol	8 hydrogen 3 carbon 1 oxygen		

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Terminology

- homologous series - гомологтық қатар / гомологический ряд;
- consecutive - кезекті / последовательный;
- biofuel - биоотын / биотопливо;
- identical substituent - жеке орынбасушы / идентичный заместитель;
- attached - ұсынылған / прилагаемый;
- corresponding - сәйкес келетін / соответствующий.

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11.3 ISOMERISM

Are left- and right-hand gloves superimposable?

You will:

- know what an isomerism is;
- write isomers for alkanes.

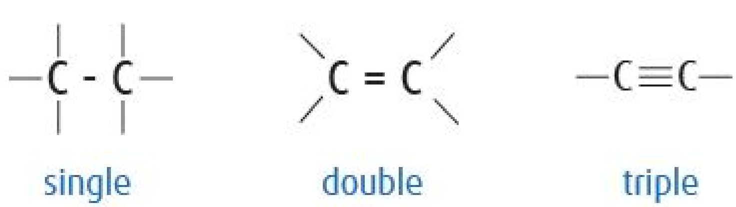
An understanding of how elements are connected in organic compounds can be gained from the structural theory of organic compounds. This theory is a result of the independent studies of Butlerov, Kekule and Couper between 1857-1861. Briefly, the theory explains that:

1. All atoms form a certain number of bonds in organic compounds. The valency concept can explain this. E.g. carbon has a valency of four, (it is tetravalent);

oxygen has a valency of two (divalent): – O –

hydrogen and halogens have a valency of one, and they are monovalent: H–, X–

2. A carbon atom can form single, double or triple bonds with other carbon atoms.



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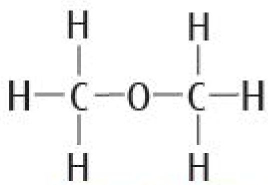
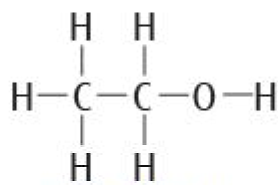
3. Two compounds with the same molecular formula can be different in the connection of their elements. Properties of organic compounds are not only related to the number and type of elements found in them but also with the order of bonding of the elements to each other. These compounds are called as isomers.



dimethyl ether

C_2H_6O

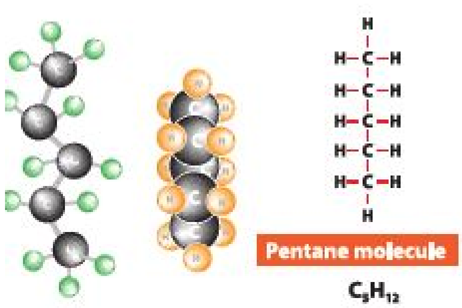


ethyl alcohol

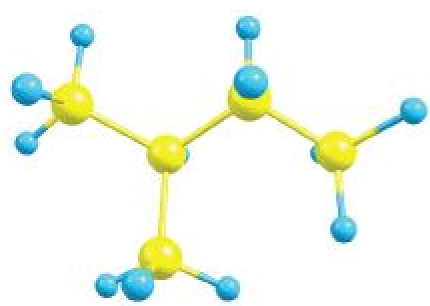
C_2H_6O

Ethyl alcohol in medicine

Diethyl ether solvent



n-pentane structure



Isopentane or methylbutane

Isomerism of alkanes

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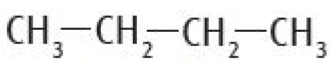
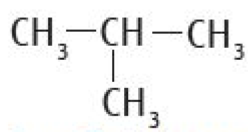
Isomers are different compounds that have the same molecular formula. The atoms are just arranged in a different order. The fi rst three members of the alkanes (methane, ethane, and propane) do not have isomers. However, butane has isomers and they are shown below. The fi rst compound (1) has the longest chain of four carbons and is called n-butane (normal butane) but the second compound (2) has the longest chain of three carbons. But both compounds have the same molecular formula C4H10.


n-butane


2-methylpropane
(isobutane)

The first isomer, n-butane has an unbranched four-carbon chain, but the second isomer isobutane has a methyl group on the second carbon atom. In this case, there are two different possible structures for C4H10. These two compounds have the same molecular weight and number of atoms but different chemical and physical properties. It is called structural isomerism. In general, as the number of "C" atoms increases, the number of isomers increases, too.

Facts

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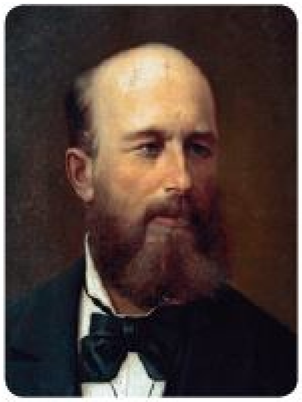

Aleksandr Butlerov(1828 - 1886)

Russian chemist who helped to advance the theory of structure in chemistry. In 1861 Butlerov stated his concept of chemical structure: that the chemical nature of a molecule is defined not only by the number or type of atoms but also by their distribution. He predicted and showed the existence of isomers (molecules composed of the same atoms but in a different way), including the two butanes and three pentanes.

Facts

The number of possible isomers increases with increasing number of carbons in the molecule. For example, for $C30H62$ and $C40H82$, the number of possible isomers are 4 111 846 763 and 62 491 178 805 831 respectively.

Literacy

1. What is isomerism? Give the structural formulas of two compounds that are isomers.

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2. Hexane, C_6H_{14}, has fi ve isomers. Write the structural formulas and the IUPAC names of these isomers.

3. Write isomers of the $C_2H_4O_2$ compound.

4. How many isomers have the compound with the formula $C_6H_4Br_2$?

5. Ethers and alcohols are isomeric. How many alcohol and ether isomers can you fi nd for the molecular formula C_3H_8O?

Terminology

- isomerism - изомерлену / изомеризация;
- isomers - изомерлер / изомеры;
- structural theory - құрылыс теориясы / структурная теория;
- valency concept - валенттілік қағидасы / концепция валентности;
- to foresaw - болжай білу / предвидеть;
- existence - бар болу / существование;
- branched - тармақталған / разветвленный;
- superimposable - қиыстырылған / совмещенный.

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11.4 CHEMICAL CALCULATIONS: DETERMINING MOLECULAR AND EMPIRICAL FORMULAS OF ORGANIC COMPOUNDS

Carbonic acid H2CO3 is an inorganic compound. Is there any organic compound with the same empirical formula?

You will:

- determine empirical and molecular formulas of compounds by using mass percentages;
- determine molecular formulas of gases by using relative density.

Example 1

Analysis of a gas gave: C-85.7% and H-14.3%. If the molecular mass of this gas is 42 g/mol, what are the empirical formula and the molecular formula?

Solution

Step 1
Determine the mass of each element in a 100 g sample:
C = 85.7 g; H = 14.3 g

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Step 2
Find mole numbers of elements:
n(C) = m/M= (85.7 g)/(12 g/mol)= 7.14 mol
n(H) =m/M= (14.3 g)/(1 g/mol)= 14.3 mol

Step 3
Find mole ratio by dividing to the smallest number:
n(C) : n(H) = 7.14 : 14.3 = (7.14/7.14) : (14.3/7.14) = 1 : 2;
The empirical formula: C1H2.

Step 4
Determine the molecular formula:

$$\text{Factor} = \frac{\textit{Molar Mass}}{\textit{Empirical Formula Mass}} = \frac{42\ g/mol}{(12 + 2)\ g/mol} = 3$$

The molecular formula is (C1H2)3 = C3H6 (propene)

Example 2

0.3 grams of an organic compound contains C, H and O atoms. If the masses of C and H are 0.12 g and 0.02 g respectively, what is the empirical formula of this compound?

Solution

Step 1
Find the mass of oxygen in the organic compound. We know that
m(C) + m(H) + m(O) = 0.3 g 0.12 g + 0.02 g + m(O) = 0.3 g
m(O) = 0.16 g

Step 2
Now we fi nd mole numbers of each atom:

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for C: 0.12 g / 12 g/mol = 0.01 mol
for H: 0.02 g / 1 g/mol = 0.02 mol
for O: 0.16 g / 16 g/mol = 0.01 mol

Step 3
The mole ratio of elements in the compound is 0.01 : 0.02 : 0.01 = 1 : 2 : 1.

So the empirical formula is C1H2O1.

Example 3

The relative density of X4H10 according to helium is 14.5. Determine the atomic mass of element X?

Solution

Step 1
Calculate the molecular mass by using relative density:

$$D_{He}(\text{alkane}) = 14.5 = \frac{M_r(X)}{M_r(He)} = \frac{M_r(X)}{4\ g/mol}; \quad Mr(X) = 4 \cdot 14.5 = 58\ g/mol$$

Step 2
Find atomic mass of unknown element :
58 g/mol = Mr(X4H10) = x • 4 + 1 • 10 4x + 10 = 58
4x = 48 x = 12

Chemical formula of compound is C4H10.

Literacy

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1. A compound contains 12% carbon, 16% oxygen and 72% chlorine and weighs 198 g. What is the empirical formula of this compound?
2. An organic compound was found to contain 10% hydrogen and 90% carbon by mass. Find its empirical formula.
3. The empirical formula of an organic compound is CH2O. Find its molecular formula if its molar mass is 180 g/mol.
4. An organic compound with the molar mass of 88 g/mol contains 55% C, 36% O and 9% H by mass. Find its molecular formula.
5. An organic compound contains 1.5 g hydrogen and 9 g carbon by mass. Find its molecular formula if its molar mass is 210 g/mol.
6. The relative density of gas X2 according to methane CH4 is 1.75. Determine the atomic mass of X.
7. Unknown gas X has relative density 1.517 according to air. What will be relative density of gas X according to helium?

Terminology

- empirical formula -эмпирикалық формула / эмпирическая формула;
- relative density - салыстырмалы тығыздық / относительная плотность;
- ratio - қатынас / соотношение;

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Problems: Introduction to Organic Chemistry

1. Using data in the following table, plot a graph of the number of carbon atoms contained in the straight chain alkane (x-axis) against the boiling point of the alkane (y-axis). Draw a curve to join up the points.

Alkane	Number of carbon atoms	Boiling point, ºC
methane	1	-161
ethane	2	-89
propane	3	-42
n-butane	4	-0.5
n-pentane	5	+36
n-hexane	6	+69
n-heptane	7	+98
n-octane	8	?
n-nonane	9	+151
n-decane	10	+174

- Which alkane with the most number of carbon atoms is a gas at room temperature?
- Estimate the boiling point of n-octane.

2. Name the compounds:

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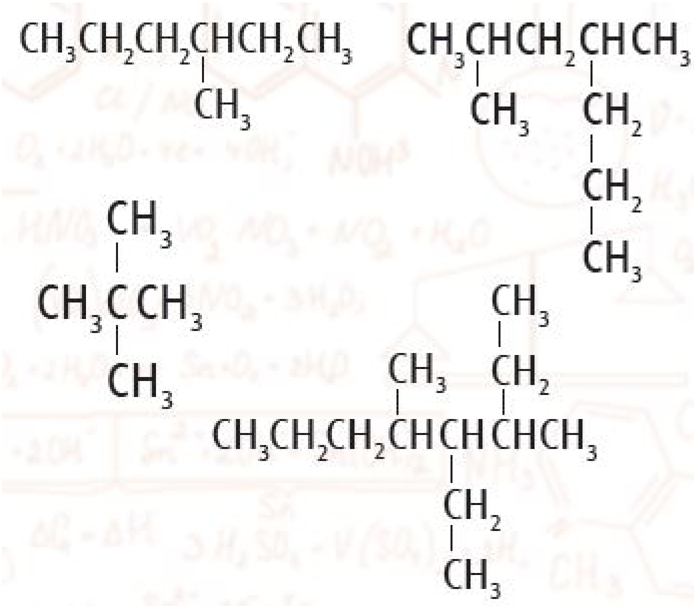

3. Write the structural formulas for the following compounds:

- 3-methylpentane
- 4-ethyl-2-methylheptane
- 2,2,5-trimethyloctane
- 2,3,4-trimethylheptane

4. There are two methyls, one ethyl and one propyl group attached to a carbon atom. What is the IUPAC name of this compound?

5. Draw the three-dimensional structure of ethane (C2H6).

6. Draw the structures of the three isomers of pentane C5H12. It may help to make models of the isomers. If you do not

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have a molecular modelling kit, use straws to represent bonds and plasticine balls of different colours to represent atoms of hydrogen and carbon.

7. The hydrocarbon anthracene has the composition 94.38% C and 5.62% H by mass. What is its empirical formula?

8. Caffeine is a compound with the composition 49.5% C, 5.2% H, 28.8% N and 16.6% O by mass. What is the empirical formula for caffeine?

9. The molecular weight of saccharin is 183 g/mol and the compound is 45.9% carbon, 2.73% hydrogen, 26.23% oxygen, 17.5% sulfur and 7.65% nitrogen by mass. What is the molecular formula of saccharin?

10. One of the most powerful poisons, strychnine, has a weight of 334 g/mol and the composition 75.45% C, 6.59% H, 8.38% N; the remainder is oxygen. Calculate the empirical and molecular formulas of strychnine, arranging the atomic symbols in alphabetical order.

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CHAPTER 12: HYDROCARBONS. FUELS

12.1 ALKANES

The Earth has natural resources like oil and natural gas. Do other planets and the Moon have those natural resources?

You will:

- describe chemical properties of alkanes and write their chemical reactions;
- explain the importance of chlorination reactions for production of solvents;
- explain harmful effects of chloroalkanes.

Alkanes

Alkanes are very common organic compounds. The general formula of the alkanes is C_nH_{2n+2}, where n is an integer number. The first four members (methane, ethane, propane, and butane) of them are gases. Alkanes with 5–17 carbons areliquids, and the rest are solids. Alkanes are named by using suffix “-ane”.

Alkanes are relatively unreactive saturated hydrocarbons. They are also known as paraffin which means "inert". In our

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daily lives, we meet alkanes in almost every place, for example, gasoline, candle wax and natural gas.

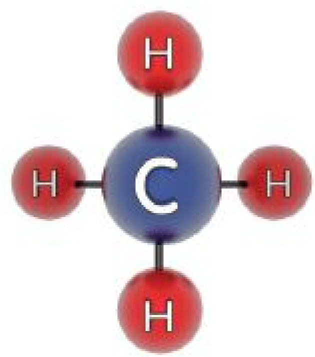
Methane (CH4)

Methane, the first member of the alkanes. It is the main component of natural gas.

Methane is a colourless and odourless gas. It is highly flammable, and in the proper mixture percentages mixed within the air, it is highly explosive. A 10-15% mixture of methane in air may cause an explosion. Explosions in mines are known as "firedamp explosions".


Paraffin is used in candles


Methane is flammable gas



Methane molecule

Chemical properties

1. Alkanes produce CO2 and H2O when they are burnt. This reaction is called combustion reaction:

$$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$$

2. They decompose at high temperatures:

$$2CH_4(g) \rightarrow C_2H_2(g) + 3H_2(g)$$

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3. Alkanes react with chlorine to produce chloroalkanes (at light):

$$CH_4(g) + Cl_2(g) \rightarrow CH_3Cl(g) + HCl(g)$$

$$CH_3Cl(g) + Cl_2(g) \rightarrow CH_2Cl_2(l) + HCl(g)$$

$$CH_2Cl_2(l) + Cl_2(g) \rightarrow CHCl_3(l) + HCl(g)$$

$$CHCl_3(l) + Cl_2(g) \rightarrow CCl_4(l) + HCl(g)$$

Halogenalkanes are formed by replacing the hydrogen atom of a hydrocarbon by a halogen (F, Cl, Br or I) and have the general formula R–X where X = a halogen. Halogenoalkanes are insoluble in water.

Chloroalkanes (CH_3Cl, CH_2Cl_2, CCl_4) were widely used as solvents and refrigerants. CCl_4 is the most important compound of carbon and halogens.

Trichloromethane (or chloroform, $CHCl_3$) is non-flammable and was used as an anesthetic before it was found to cause liver damage. Tetrachloromethane (or carbon tetrachloride, CCl_4) also has anesthetic properties, but it is even more toxic. Some haloalkanes have negative effects on the environment such as ozone depletion. The most widely known family within this group are the chlorofluorocarbons (CFCs). CFCs have damaging effects on the ozone layer.

Aerosol sprays contain CFCs

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Science in context

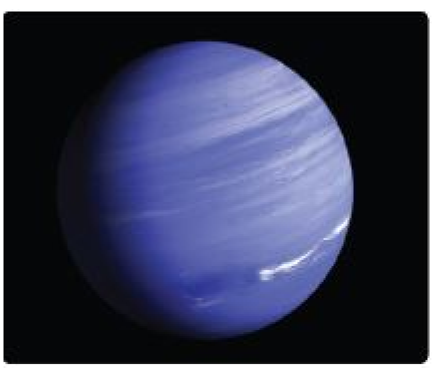
Natural gas is a useful fuel.


Natural gas tank


Natural gas burns in the kitchen

Facts

Neptune's blue colour is largely the result of absorption of red light by methane in the atmosphere.



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Methane is also known as marsh gas and is formed by the decomposition of plants in the absence of oxygen.

Lush green marshes

Science in context

Methane is also used as a feedstock in petrochemical plants to create many different compounds like large lists of plastics.

Demonstration

№13. Fuels

Use coal, oil, natural gas samples in your laboratory. Classify the fuels.

Literacy

1. What is the general formula of alkanes?

2. What is ozone layer?

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3. Write the molecular and structural formula of the alkane that containing 4 carbon atoms.

4. 0.25 mole of an alkane weighs 35.5 g. Find its molecular formula.

5. Complete the equations and name the products:

- CH4(g) + Br2(l)
- Propane + oxygen

6. When 4.8 g of an alkane is burned completely, 13.2 g of carbon dioxide and 10.8 g of water are produced. What is the molecular formula of the alkane?

Terminology

- alkanes - алкандар / алканы;
- saturated - қаныққан / насыщенный;
- paraffi ns - парафиндер / парафины;
- firedamp explosion - жарылғыштың жарылуы / взрыв взрывчатого вещества;
- refrigerants - салқындатқыштар / хладагенты;
- feedstock - бастапқы материал / исходный материал;
- marsh gas - батпақ газы / болотный газ.

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12.2 ALKENES

Why do plastic bags pose a threat to marine life?

How to determine unsaturated hydrocarbons?

You will:

- understand why organic compounds can be unsaturated;
- study chemical reactions of alkenes;
- explain structures of polymers and mechanism of the polymerization reaction;
- explain and study how plastics affect the environment.

Alkenes are unsaturated hydrocarbons whose structure contains a double bond. A double bond is formed because the carbon atoms don't bond to enough hydrogen atoms to complete their octet. For this reason, they are described as unsaturated.

The general formula is CnH2n and the first member of this homologous series is C2H4. The systematic IUPAC name of this compound is ethene, though it is commonly known as is ethylene.

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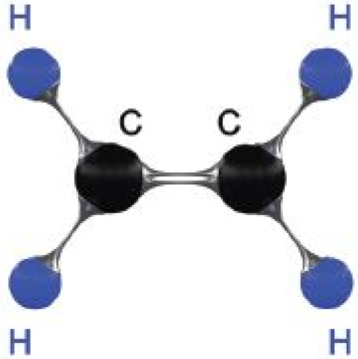


Ethylene molecule


Olefins plant

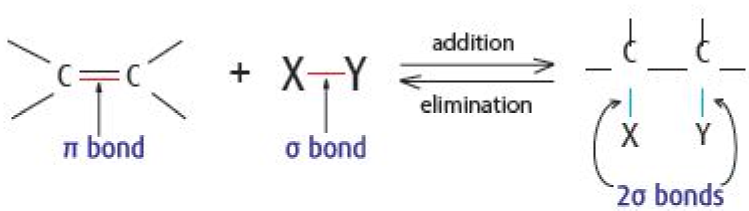
The first four members of alkenes

Name	Molecular Formula	Structural Formula
Ethene (Ethylene)	C_2H_4	$CH_2=CH_2$
Propene (Propylene)	C_3H_6	$CH_2=CH-CH_3$
1-Butene	C_4H_8	$CH_2=CH-CH_2-CH_3$
1-Pentene	C_5H_{10}	$CH_2=CH(CH_2)_2CH_3$

Chemical properties

Addition reactions

Addition reactions are characteristic of unsaturated compounds. In addition reactions, an unsaturated bond (−C=C−) is completely or partially saturated by addition of a molecule across the multiple bonds.



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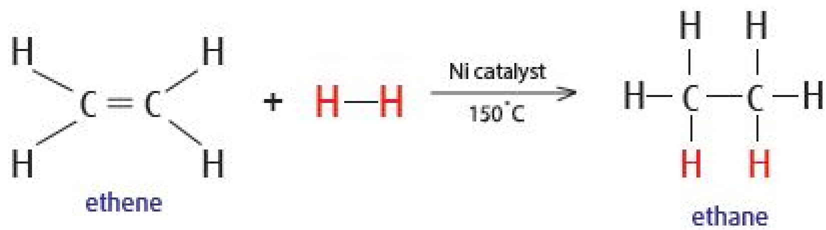
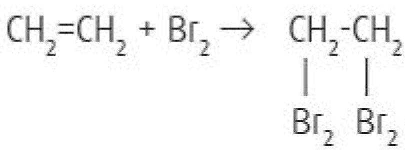
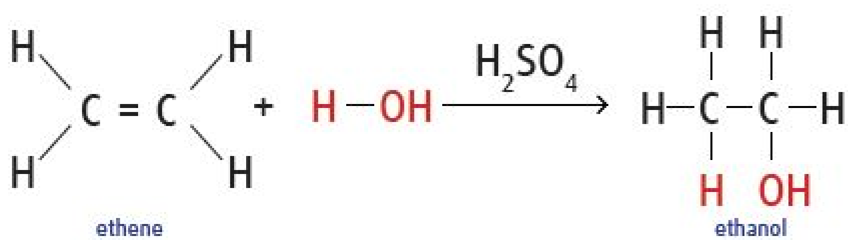
1. Ni, Pt or Pd metals are used as catalysts in addition reactions of hydrogen to alkenes. Addition of H2 to alkenes, which are unsaturated hydrocarbons, produces alkanes.



2. Addition of Br2 to alkenes is a useful reaction which shows us if a hydrocarbon is saturated or unsaturated.



3. Hydration is the addition of water to an alkene:



Oxidation of ethylene

Alkenes undergo oxidation reactions in which the carbons in the double bond are oxidized. This reaction can be used to confi rm whether or not a compound is an alkene. When an alkene is treated with cold, alkaline KMnO4 solution, the violet colour of KMnO4 solution disappears and turns brown.

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To distinguish between alkanes and alkenes, $KMnO_4$, an oxidizing agent in a basic solution is used.

Polymerization

A polymer is a long, repeating chain of atoms, formed through the linkage of many identical molecules called monomers. The reaction by which polymers are formed is called polymerization.

$$\underset{\text{ethylene (monomer)}}{n\ CH_2{=}CH_2} \xrightarrow{\text{heat cat.}} \underset{\text{polyethylene (monomer)}}{(-CH_2-CH_2-)_n}$$

HDPE (high-density polyethylene) and LDPE(low-density polyethylene) are common types of polyethylene prepared under different reaction conditions and having different physical properties. HDPE is opaque and rigid and used in milk containers and water jugs. LDPE is less opaque and more flexible and used in plastic bags and electrical insulation.

HDPE pipes

Plastic recycling symbols

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Science in context

Alkenes are used in artificial ripening of fruits.

Facts

Alkenes are also known as olefins because they react with chlorine to form an oil-like liquid.

Literacy

1. Write general formulas of alkenes.

2. 3 mole of an alkene weighs 84 g. Find its molecular formula.

3. Write the equations for the reactions between propene with hydrogen and bromine.

4. Find the molecular formula of the alkene that contains 85.7% carbon by mass.

5. What is polymer widely used in packaging?

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Science in context

80% of organic chemistry is related to polymer chemistry. One of the simplest polymers is polyethylene which is made from many ethylene molecules. Trash bags, sandwich wraps, teflon, automobile tires, varnishes, and paints are all examples of polymers that we use in our daily life.

Activity

Work in groups. You will need to make a research about polyethylene. Summarize your ideas in the presentation. Talk about utilization methods for polyethylene.

Demonstration

№14. Chemical properties of ethylene.

Materials:

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ethyl alcohol, Al2O3, dry sand, potassium permanganate solution, test tubes, burner.

Procedure:

1. Take a test tube and fill it with standard sand up to about 3 cm height.

2. Pour ethanol on the sand so that it is completely wet in ethanol.

3. Place 3 spatulas of aluminium oxide in the middle of the test tube.

4. Ignite the burner and heat the front of the test tube then heat the aluminium oxide to a red-glow.

5. After about 30-second slip the tip of the delivery tube to the mouth of the inverted test tube in the water in the crystallizing dish.

6. When the inverted test tube is full of evolved gas. Slip the tip of the delivery tube to the mouth of the second inverted test tube.

7. Close the test tubes with rubber stopper under water, then place them in the test tube rack.

8. Remove the tip of the delivery tube from the water andextinguish the burner.

9. Take one of the test tubes containing collected gas and put a few drops of potassium permanganate solution in the test tube.

10. Shake the test tube vigorously

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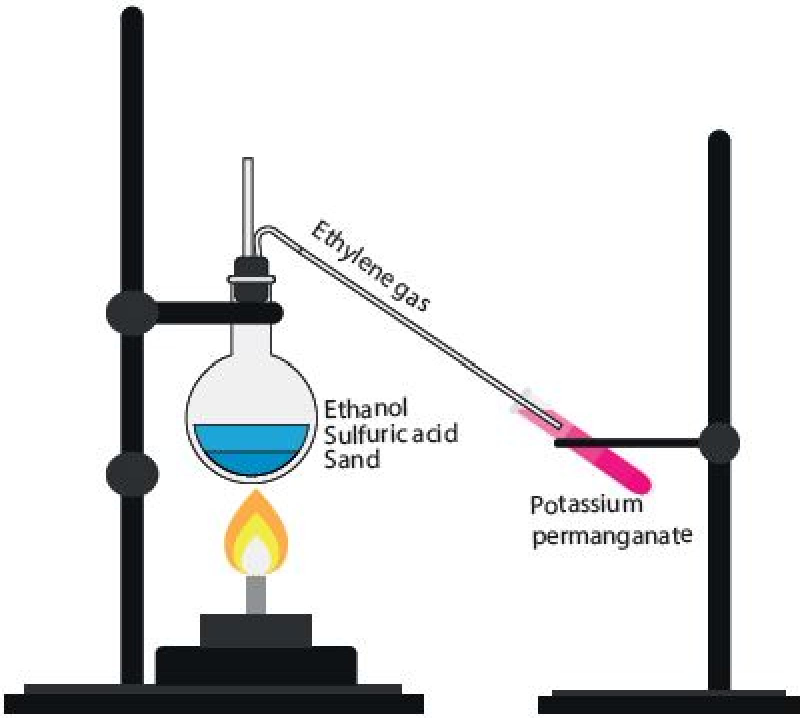
11. Ignite the burner. Hold the second test tube containing collected gas upside down so that the mouth of the test tube at the flame of the burner, then remove the stopper.



Terminology

- alkenes - алкендер / алкены;
- unsaturated - қанықпаған / ненасыщенный;
- oxidation - тотығу / окисление;
- disappears - жоғалады / исчезает;
- monomer - мономер / мономер;
- polymerization - полимерлену / полимеризация;
- olefins - олефиндер / олефины;
- to pose a threat - қауіп төндіру / представлять угрозу.

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12.3 ALKYNES

Why are cylinders with different gases painted in different colours? For example, cylinders with acetylene are painted in maroon colour.

You will:

- study chemical properties of alkynes;
- study properties and preparation method of acetylene.

Unsaturated hydrocarbons that contain carbon-carbon triple bond "−C≡C−" are called alkynes. The general formula of alkynes is CnH2n−2 where n is an integer number starting from 2. At room temperature, the fi rst three members of the series (ethyne, propyne, and butyne) are gases, the others are liquids.

Acetylene

Acetylene (ethyne) is the fi rst member of the alkyne series and one of the major chemicals used in industry. Pure acetylene is a colourless gas that has a slight odour. It is

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soluble in water and highly soluble in acetone. In industry, it is mixed with PH_3 and H_2S which cause it to smell very bad. It boils at –83°C and can be liquefi ed at 1°C. When it is liquefi ed, it becomes extremely explosive, so it is dissolved in acetone.

Acetylene and gas steel storage tanks for welding

Preparation of Acetylene

The preparation of acetylene from calcium carbide is the most important preparation method. When quicklime and coke react with each other at high temperature, calcium carbide is formed. The reaction of calcium carbide with water produces acetylene:

$$CaO + 3C \rightarrow CaC_2 + CO$$

$$CaC_2 + 2H_2O \rightarrow CH\equiv CH + Ca(OH)_2$$

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Preparation of acetylene from calcium carbide


Liquefied acetylene is highly explosive

Chemical properties

Alkynes are unsaturated compounds like alkenes and therefore their chemical properties are similar to those of alkenes.

1. Combustion reaction

Alkynes produce CO2 and H2O when they are burnt in oxygen. Acetylene gas explodes at about 15 atm pressure. Because of this, it is stored under low pressure (less than 10 atm). Acetylene burns with a bright fl ame:

$$2C_2H_2(g) + 5O_2(g) \rightarrow 4CO_2(g) + 2H_2O(l)$$


Explosion of acetylene gas

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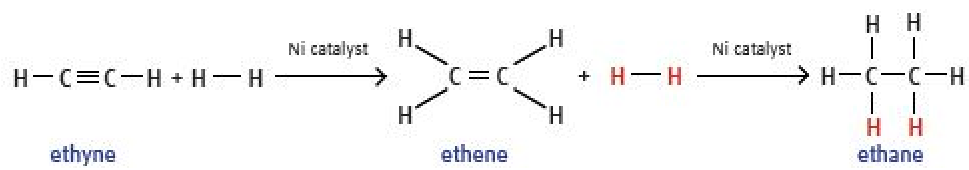
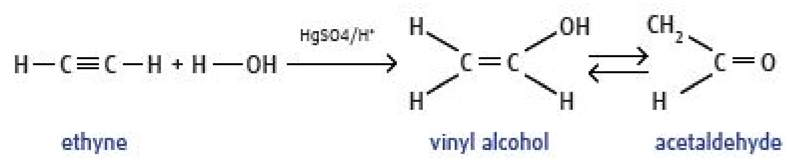
2. Addition of hydrogen.

Two hydrogen molecules are added to one triple bond (−C≡C−) using a nickel, platinum or palladium catalyst:



3. A mixture of mercury (II) sulfate, HgSO4, and sulfuric acid enables water to add to alkynes.



4. Qualitative reactions

Potassium permanganate (KMnO4) and bromine (Br2) water are used to test for alkynes. Acetylene turns them to colourless:

$$CH{\equiv}CH + Br_2 \rightarrow Br{-}CH{=}CH{-}Br + Br_2 \rightarrow Br_2{-}HC{-}CH{-}Br_2$$

Keep in mind

Acetylene is the simplest member of unsaturated hydrocarbons called alkynes or acetylenes. Most important of all starting materials for organic synthesis.

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Demonstration

№15. Fuel types

Use fuel samples in your laboratory. Classify the fuel types

Facts

In the atmosphere of Jupiter, acetylene molecules have been detected.

Science in context

Acetylene is used for welding with O2. At 3300°C two metals can be welded to each other.

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Literacy

1. Why is acetylene used for welding of metals?
2. Write reactions of acetylene with chlorine gas.
3. When 0.2 moles of an alkyne is burnt, 8.96 L of CO_2 gas is produced at STP. What is the molecular formula of this alkyne?
4. A 30 L of a mixture of C_2H_2 and C_2H_4 is saturated with 50 L of H_2. What is the mole percentage of acetylene in the mixture?
5. When 5 grams of impure CaC_2 is added to water, 1.12 L of acetylene is produced at STP. What is the percentage purity of the CaC_2 sample?

Terminology

- alkynes - алкиндер / алкины;
- acetylene - ацетилен / ацетилен;
- ripening - пісу / созревание;
- maroon - қою қызыл / темно-бордовый;
- welding - дәнекерлеу / сварка.

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12.4 AROMATIC HYDROCARBONS

What does asphalt smell like? What compounds cause "new car smell"?

You will:

- describe properties and uses of benzene;
- know preparation method of benzene.

Benzene and compounds having similar chemical properties to benzene are called aromatic compounds. The name "aromatic" is used because of the characteristic and pleasant odours of these compounds. Aromatic hydrocarbons are also known as arenes.

Although aromatic hydrocarbons are unsaturated, they have very different chemical properties to alkenes and alkynes. For example, benzene doesn't undergo an addition reaction with bromine despite having a double bond.

The structure of benzene

Benzene is the oldest known organic compound, firstly discovered by Michael Faraday in 1825. Later, Eilhardt Mitscherlich heated benzoic acid with limestone and

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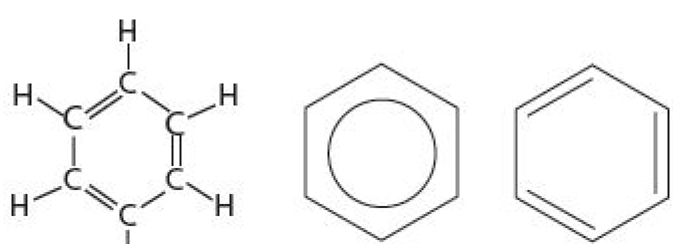
synthesized benzene. He also found that benzene had the molecular formula C6H6:

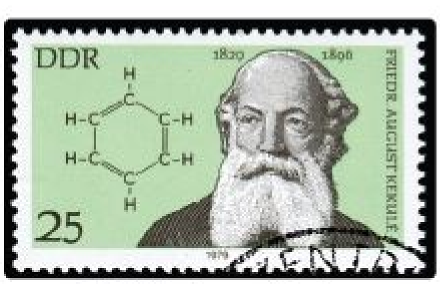
C6H5COOH(s) + CaO(s) → C6H6(l) + CaCO3(s)

The structure of benzene was proposed by the German chemist August Kekulé only in 1865. According to the structure, Kekulé proposed, the benzene molecule had a regular hexagonal shape. The six carbon atoms are located at the corners and each bonded to two neighbors with one single and one double bond. The single and double bonds swap with each other around the ring. One hydrogen atom is bonded to each carbon atom.

However, Kekulé's description is not enough to understand the structure of benzene. If the structure proposed by Kekulé was exact, the bond lengths of the C = C and C – C bonds would be different. But researchers show that the benzene ring is a hexagon with equal internal angles of 120°. Accordingly, there has to be another explanation of the benzene ring.



The structures of benzene



Friedrich August Kekule
(1829-1896),
German organic chemist

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Benzene is a colourless, poisonous liquid with a specific odour. It dissolves in organic solvents such as ether, alcohol. Benzene is a good solvent for nonpolar substances, it is used to dissolve fats, resins, rubber, iodine, and sulfur. Its carbon content is high, therefore, when burned, it gives a sooty flame.

Benzene burns with a sooty flame

Benzene is toxic substance

Preparation of benzene

Coal tar is the main natural source of benzene and other aromatic hydrocarbons. Coal tar is the main natural source of benzene and other aromatic hydrocarbons. Acetylene is trimerized under high pressures and temperatures:

$$\underset{\text{acetylene}}{3C_2H_2} \xrightarrow[\text{pressure}]{500\text{-}600\ C} \underset{\text{benzene}}{C_6H_6}$$

Uses of benzene and its derivatives

Two benzene rings are fused together to form naphthalene (C10H8). It has a sharp, aromatic odour and is used to protect clothes from moths and to dispel the bad odours in bathrooms.

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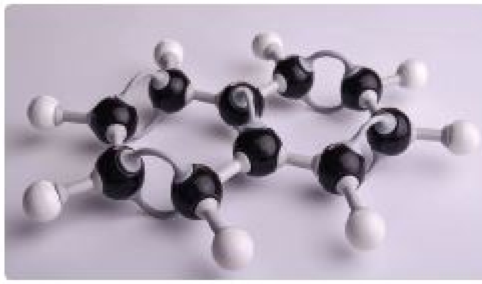

Naphthalene structure

□□□□□□□□□□
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Anthracene (C14H10) is formed by fusing three benzene rings together. It is a colourless, crystalline compound used in the production of paints.

Facts

Research has shown benzene to be a carcinogen (cancer-causing). Longterm exposure may affect bone marrow and blood production. Short-term exposure to high levels of benzene can cause drowsiness, dizziness, unconsciousness, and death.

Keep in mind

Benzene is a colourless, fl ammable liquid with a sweet odour. It evaporates quickly when exposed to air. Benzene is formed from natural processes, such as volcanoes and forest fi res, but most exposure to benzene results from human activities. Benzene is also a natural part of crude oil, gasoline, and cigarette smoke.

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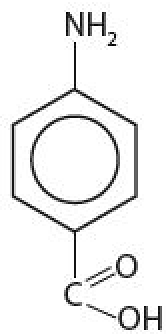
Facts

All commercially available sunscreens contain a benzene ring. A sunscreen absorbs ultraviolet radiation and thus shields the skin for a time from its harmful effects. Two sunscreens that have been used for this purpose are p-aminobenzoic acid.



Science in context

Benzene is used in the manufacture of plastics, detergents, pesticides, and other chemicals.


Polystyrene plastics


Farmer spraying pesticide

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Literacy

1. How many double bonds in benzene molecule?
2. What is benzene? Who discovered its stable structure?
3. Where is used benzene derivatives?
4. What volume of oxygen is needed to burn 56 liters of benzene at STP?
5. Find the mass of benzene that is obtained from the acetylene that takes up a volume of 13.44 L at STP. The yield of the reaction is 80%.

Terminology

- aromatic hydrocarbons - ароматты көмірсутектер / ароматические углеводороды;
- benzene - бензол / бензол;
- arenes - арендер / арены;
- sunscreen - күннен қорғайтын крем / солнцезащитный крем.

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12.5 HYDROCARBON FUELS. OIL INDUSTRY

Which research octane number (RON) is the best for gasoline: 92, 95, 98 or 102?

You will:

- know that carbon-containing compounds used as fuels;
- investigate the alternative types of fuels;
- name the depositions of coal, oil and natural gas in Kazakhstan;
- name the crude oil fraction products and their uses.

At all stages of the historical development humanity has used energy. Ancient people used wood fuel as a source of energy for cooking and heating housing. Until the middle of XIX century, 90% of energy was obtained from wood. With the development of society and technological progress fuel wood is replaced by fossil fuels as a coal, oil, and gas.

An industry which is engaged in the production of gas, oil, and coal is named as fossil fuel industry. Fuel industry is one of the main sectors of power engineering. High level of economic development shows that the more energy is produced in the country. The national economy of Kazakhstan is provided mainly by its own source of energy. Coal widely used as a cheap source of energy. The energy released during combustion of hydrocarbons, used in the form of heat, or converted to other forms of energy

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(electrical, mechanical). But natural sources of hydrocarbons should not be considered as an inexhaustible wealth. According to preliminary calculations, if their production and consumption will continue intensively, the natural gas reserves will suffi ce for about 50, and oil reserves at 40-50 years. It's important to economize on the use of natural sources of fuel and attract alternative energy: the energy of atoms, water, wind, solar, etc.


Wind turbines


Nuclear power station

Fuel industry and environment

With the development of the fuel industry problems appeared related to production and use of natural resources. One problem is growing demand for fuel. At the same time harmful gases and solid residues (ash and soot), which are formed during the combustion of the fuel consumed by motor vehicles, heating power stations, and waste of various industries are emitted into the atmosphere. Sulfur and nitrogen-containing compounds that make up these emissions are converted into the corresponding oxides and also pollute the environment.

Natural resources of hydrocarbons

The primary source of hydrocarbons here on Earth is through fossil fuels - coal, oil, and natural gas. These are extracted from the ground in quantities of millions of tons per day and are the primary energy source for today's civilization. 85% of

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all electricity worldwide is generated by the burning of hydrocarbons, and hydrocarbon fuel is used to propel practically every mobile machine: cars, trucks, trains, planes, and ships.

Natural Gas

Kazakhstan is important to world energy markets because it has signifi cant oil and natural gas reserves. Most of Kazakhstannatural gas reserves are located in the west of Kazakhstan, with roughly 25 percent of proven reserves situated in Karachaganak fi eld. There are other fi elds like Zhanazhol, Kyzyloyskoe, Zhetibay, Kalamkas etc.

In fact, natural gas is really a mixture of gases that formed from the fossil remains of ancient plants and animals buried deep in the earth. The main ingredient in natural gas is methane.

Karachaganak

Oil industry

Kazakhstan has the largest oil (petroleum) and gas reserves in the Caspian Sea basin and is producing 1.5 million barrels of oil a day today. Kazakhstan contains signifi cant quantities of gas and oil in particular. Kazakhstan sits near the northeast portion of the Caspian Sea and claims most of the Sea's biggest known oil fi elds. Oil has been produced in Atyrau, Mangystau, Aktobe and Kyzylorda regions.

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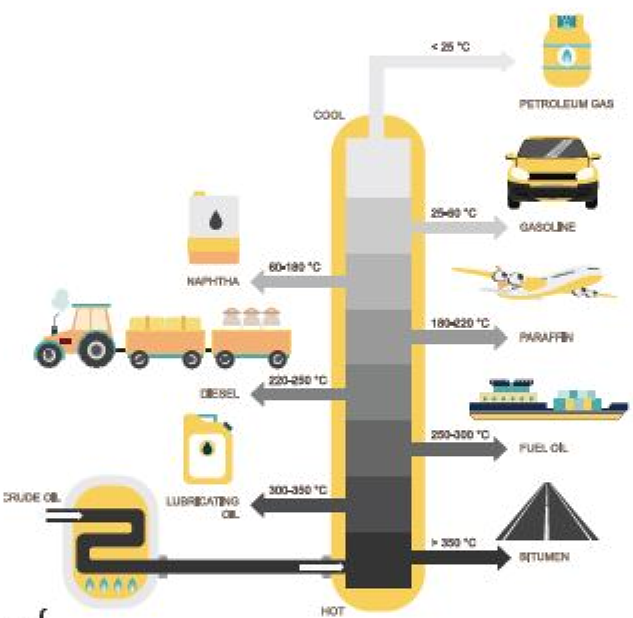
Crude oil is a mixture of alkanes and aromatic hydrocarbons which have carbon atom numbers ranging from 1 to 40. In different regions of the world, the composition of oil is different.

Refining

Crude oil in its natural form can only be used as a fuel, and not in any other areas. Because it consists of many different substances with different densities, petroleum can be separated into its components by fractional distillation.



Refining of petroleum

Coal

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Coal is the natural source of hydrocarbons which formed in the earth's crust as a result of decomposition of plant residues.

In our country, there are Ekibastuz, Karagandy, Turgay, Nizhneiliysky coal basins and many smaller deposits. At present in Kazakhstan coal is used as the primary source of fuel. There are two reasons for it: first, our country has large reserves of coal and the second, it is possible to obtain low-cost open-pit.

Coal loading

Facts

Kazakhstan on the proven reserves of petroleum are today at the 9th place in the world (2011).

Facts

Kazakhstan on the proven reserves of coal are today at the 8th place in the world.

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Demonstration

№16. Oil and oil products

Use petroleum products samples in your laboratory. Classify the petroleum products

Literacy

1. Where in Kazakhstan do produce oil?
2. What is oil?
3. What are products from oil refi ning process?
4. What are the advantages of natural gas?
5. Where is coal found in Kazakhstan? Which fossil fuel is more important? Oil, natural gas or coal?

Terminology

- inexhaustible - таусылмайтын / неисчерпаемый;
- gasoline - бензин / бензин;
- Research Octane Number (RON) - зерттеу әдісімен октан санының өлшенуі (А) / Автомобильное измерение октанового числа по Исследовательскому методу (АИ);
- residues - қалдықтар / остатки;
- corresponding - сәйкес келетін / соответствующий;
- proven reserves - зерттелген қорлар / разведанные запасы;
- refining - өңдеу / переработка
- coal basins - көмір кен орындары / угольные бассейны.

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Problems: Hydrocarbons. Fuels

Alkanes

1. Calculate the molar mass of the alkane that has 10 hydrogen atoms.

2. How many single bonds are there in propane and pentane molecules?

3. 0.34 mol of an alkane weighs 19.72 g. Find its molecular formula.

4. An alkane contains 83.33% carbon by mass. Find the molecular formula of this compound.

5. When 35.2 g of an unknown alkane is burned in an excess amount of oxygen 53.76

L of carbon dioxide is formed. What is the molecular formula of alkane?

Alkenes

1. Which following compound reacts with bromine solution? ethane, ethylene, methane.

2. 8.4 g of an alkene occupies 4.48 L at STP conditions. What is the formula of alkane?

3. What amount of hydrogen in liters should be used to saturate 19.6 g of ethylene at STP?

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4. 20 g mixture of methane and butene can react with 6.72 L of hydrogen gas at STP. What is the mass of methane in the mixture?

5. What's the difference between polyethylene PE and polypropylene PP used in furniture?

Alkynes

1. Write equations for the following reactions:

- acetylene + $Cl_2(g)$(excess) →
- 2-butyne + $H_2(g)$ (excess) →
- 2-butyne + $HCl(g)$ (excess) →

2. Draw the structural formulas of C_2H_2, C_3H_4, C_4H_6.

3. How would you carry out the following transformations?

$CaC_2 \rightarrow C_2H_2 \rightarrow C_2H_4 \rightarrow CO_2$

4. 10% of the molecular weight of an alkyne is hydrogen. What is the molecular formula of the alkyne?

5. A 2.7 g sample of alkyne can be saturated with 2.24 L of hydrogen at STP. What is the molecular formula and name of the alkyne?

Aromatic hydrocarbons

1. Write the combustion reactions for the following compounds:

- Benzene

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- Toluene
- Naphthalene
- Anthracene

2. Draw the structural formulae and give the names of all the possible isomers of the aromatic C8H10 compounds.

3. Find the volume of hydrogen (at STP) necessary to saturate 226.2 grams of benzene.

4. Find the mass of benzene that is obtained from the acetylene that takes up a volume of 17.248 L at STP.

5. Which compounds are aromatic?

Hydrocarbon fuels. Oil and gas

1. Ray's bus is, like most buses, powered by a petrol engine. These buses contribute to environmental pollution. Some cities have trolleybuses: they are powered by an electric engine. The voltage needed for such an electric engine is provided by overhead lines (like electric trains). The electricity is supplied by a power station using fossil fuels. Supporters for the use of trolley buses in a city say that these buses don't contribute to environmental pollution. Are these supporters right? Explain your answer (PISA question)

2. What are fossil fuels? What kinds of fossil fuels are used in Kazakhstan today?

3. When 0.5 g of benzene (C6H6) is burnt in a bomb calorimeter, the temperature of the calorimeter rises from

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25°C to 55°C. If the molar heat of combustion of benzene is 263.6 J/g, find the heat capacity of the calorimeter?

4. When 26.27 kg of diesel is burnt in a bomb calorimeter, the temperature of the calorimeter rises from 30°C to 550°C. If the heat of combustion of diesel is 42.7 MJ/kg, find the heat capacity of the calorimeter?

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CHAPTER 13: OXYGEN AND NITROGEN CONTAINING ORGANIC COMPOUNDS

13.1 ALCOHOLS

Why do we use ethyl alcohol as a disinfectant before injections? Why are not other chemicals?

You will:

- know classification and properties of alcohols;
- know preparation methods of methyl and ethyl alcohols;
- understand infl uences of methanol, ethanol on the human body;
- know physical properties and uses of glycol and glycerine.

Alcohols are compounds whose molecules have a hydroxyl group (-OH) bonded to a saturated carbon atom. Alcohols can be described as alkyl derivatives of water where one hydrogen in the water molecule has been replaced by an alkyl (R-) group.

R - H	H - OH	R - OH
alkane	water	alcohol

The carbon atom having the -OH group can be bonded to another carbon atom by a single bond. The carbon chain of

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the alcohol can be saturated or unsaturated. In this lesson, we will learn only saturated alcohols. The general molecular formula of saturated alcohols is CnH2n+1OH or CnH2n+2O. Alcohols can be classifi ed as monohydric and polyhydric according to the number of -OH groups in the structure.

Methyl Alcohol (Methanol)

Methyl alcohol is colourless, fl ammable and has a characteristic odour. Its taste is similar to ethanol but it is very toxic. Ingestion of even small quantities of methyl alcohol can cause blindness, large quantities cause death.

As methyl alcohol has a low freezing point (–97°C), it has been used as antifreeze in radiators. Methanol can be converted into formaldehyde which is the initial material for industrial products such as plastics, paints, and solvents.

Methyl alcohol is very toxic substance

In some countries, methyl alcohol is used as fuel

Ethyl Alcohol (Ethanol)

Physical Properties

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Pure ethyl alcohol is colourless toxic liquid and has a characteristic smell. It is miscible with water in all proportions.

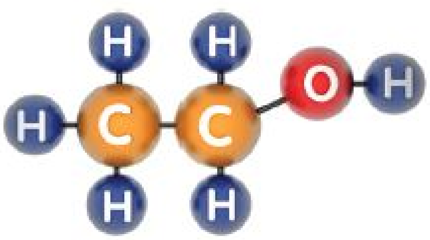
Ethanol is an important organic solvent. It is used in the preparation of tincture of iodine, brilliant green, paints, perfumes and cosmetics. Ethyl alcohol is the starting substance for most organic compounds.

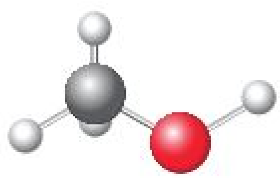
A solution of 70–85% of ethyl alcohol is commonly used as a disinfectant. It kills organisms by denaturing their proteins and dissolving their liquids. It is effective against most bacteria, fungi and many viruses.

Ethanol taken into the body via alcoholic drinks causes harmful effects.


Ethanol in medicine


Purell hand sanitizer (ethanol)


Ethanol structure


Methanol structure

Preparation of ethyl alcohol

1. By Fermentation

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Most ethanol is prepared by the fermentation of plants containing sugar. In the fermentation process, glucose and fructose in a presence of yeast are converted into alcohol and carbon dioxide.

$$\underset{\text{glucose}}{C_6H_{12}O_6} \xrightarrow{\text{fermentation}} \underset{\text{ethyl alcohol}}{2C_2H_5OH} + 2CO_2$$

2. By hydration from ethene

Ethyl alcohol for industrial purposes is produced by hydrating ethene using a catalyst. This process costs less than fermentation.

$$\underset{\text{ethylene}}{C_2H_4} + H_2O \xrightarrow[\text{pressure}]{300°C} \underset{\text{ethyl alcohol}}{C_2H_5OH}$$

Chemical properties of ethyl alcohol

1. Combustion reaction

Burning of ethyl alcohol reaction given as follow:

$$C2H5OH(l) + 3O2(g) \rightarrow 2CO2(g) + 3H2O(g) + 1374\ kJ$$

Ethanol can burn very well, therefore, it can be used in internal combustion engines and in the laboratory for burners.

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Burning of methanol and ethanol
(Borax test)

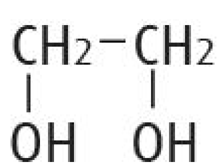
2. Dehydration

When monohydric alcohol is heated in the presence of an acid catalyst at high temperature, water and alkene are produced.

Ethylene glycol

Ethylene glycol C2H4(OH)2, is a colourless, odourless, syrupy liquid. It is completely miscible with water. Since it has a low freezing point it is used as antifreeze in automobiles. A high boiling point (197°C) and heat of vaporization also make it useful for this purpose. It is also used in hydraulic brake fl uid in cars and as a paint, oil, ink and resin solvent.

Pouring antifreeze to the 0ºC



Etylene glycol structure

Glycerine (propane triol)

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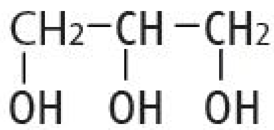
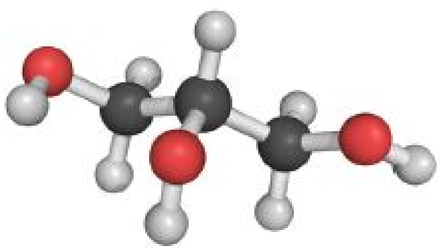
Glycerine C3H5(OH)3 is the simplest trihydric alcohol, also known as glycerol. The IUPAC name of glycerine is 1, 2, 3–propanetriol. Glycerine is used as a moisturizing substance in tobacco, shaving and toilet soaps, cosmetics and lotions, and in the manufacture of plastics, cellophane, water colours, printing-press ink, ointment, antifreeze and dynamite.



Propane triol structure



Glycerine molecular structure

Glycerine as medical

Toilet soaps

Yellow thin polythene plastic bag

Keep in mind

Nowadays hundreds of alcohols are known. However, when the word alcohol is used, many people connect it only with

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ethyl alcohol.

Activity

Look at the picture below and tell where ethyl alcohol is used.

Activity

Name the following alcohols according to the IUPAC rules:

a) CH3-OH

b) CH3-CH2-OH

c) CH3-CH2-CH2-CH2-OH.

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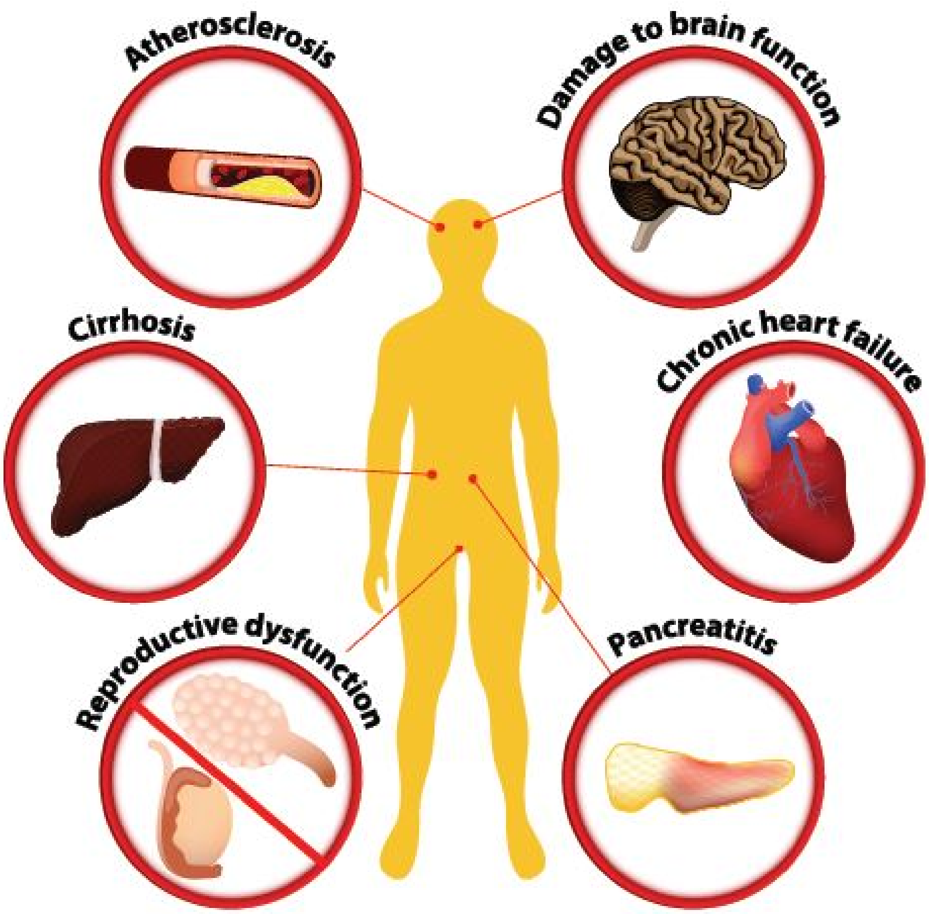
Activity

Work in groups and make a small presentation based on a picture below:



Harmful effects of alcohol on the human body

Literacy

1. Which chemical elements are present in alcohol?

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2. What are some physical and chemical properties of methyl alcohol?
3. What are some harmful effects of alcohol?
4. How many liters of CO_2 gas is produced by the combustion of 0.5 moles of ethyl alcohol with suffi cient amount of oxygen gas?
5. When 4 kg sample of glucose is fermented, 1.84 kg of ethanol is obtained. What was the mass of pure glucose in the sample?
6. Write dehydration reaction for ethyl alcohol.

Terminology

- alcohols - спирттер / спирты;
- injection - ине салу / инъекция;
- ingestion - жұту / проглатывание;
- blindness - соқырлық / слепота;
- antifreeze - антифриз;
- miscible - араласатын / смешивающийся;
- tincture - дайындалған тұнба / настойка;
- perfumes - әтірлер / духи;
- fermentation - ашу / ферментация.

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13.2 CARBOXYLIC ACIDS

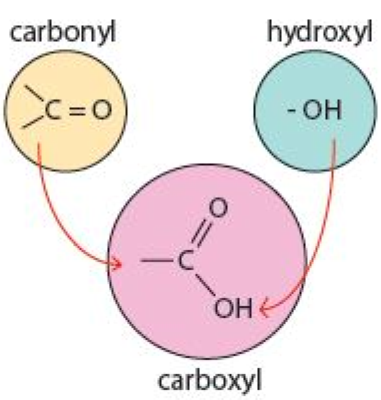
Why vinegar is healthy for washing fruits and vegetables?

You will:

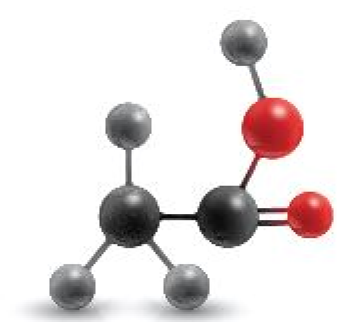
- know the composition of carboxylic acids;
- know chemical properties of acetic acid and its uses.

Composition of carboxylic acids

The group that is formed by the combination of a carbonyl and hydroxyl - OH group is called the carboxyl group -COOH. Compounds that contain the carboxyl group are called carboxylic acids. Most organic acids found in fruits and vegetables are carboxylic acids. Carboxylic acids can be represented by R-COOH. The R- group can be aliphatic or aromatic.



Carboxyl group is a combination of carbonyl and hydroxyl groups



Ball and stick illustration of acetic acid molecule

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Acetic acid and its properties

Acetic acid CH_3COOH is an important carboxylic acid. It has the characteristic sharp odour and taste of vinegar. Vinegar is 4-8% aqueous solution of acetic acid. Actually, the name acetic acid comes from “acetum” meaning vinegar in Latin. Another name for CH_3COOH is an ethanoic acid. Pure acetic acid is a colourless, crystalline compound that melts at 16.7°C and it boils at 118°C. Acetic acid shows all the general properties of carboxylic acids. It reacts with metals to produce hydrogen gas and acetate salts. CH_3COOH also can be neutralized by the reaction of it with bases and basic salts.


Apple vinegar and fresh apple

Chemical properties of acetic acid

1. Reaction with active metals

The reaction of acetic acid with active metals produces hydrogen gas and salt.

$$2CH_3COOH(aq) + Mg(s) \rightarrow (CH_3COO)_2Mg(aq) + H_2(g)$$

The salts of acetic acid are called *acetates* (CH_3COO^-).

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2. Reaction with basic oxides

As an inorganic acid acetic acid reacts with basic oxides to form salt (potassium acetate) and water:

2CH3COOH(aq) + K2O(s) → 2CH3COOK(aq) + H2O(l)

3. Reaction with bases

It reacts with bases to produce salt (sodium acetate) and water:

2CH3COOH(aq) + NaOH(aq) → CH3COONa(aq) + H2O(l)

4. Reaction with carbonates

Ethanoic acid reacts with carbonates to produce salt, carbon dioxide, and water:

2CH3COOH(aq) + CaCO3(s) → (CH3COO)2Ca(aq) + CO2(g)+ H2O(l)

Acetic acid reacts with egg shell ($CaCO_3$) to produce CO_2

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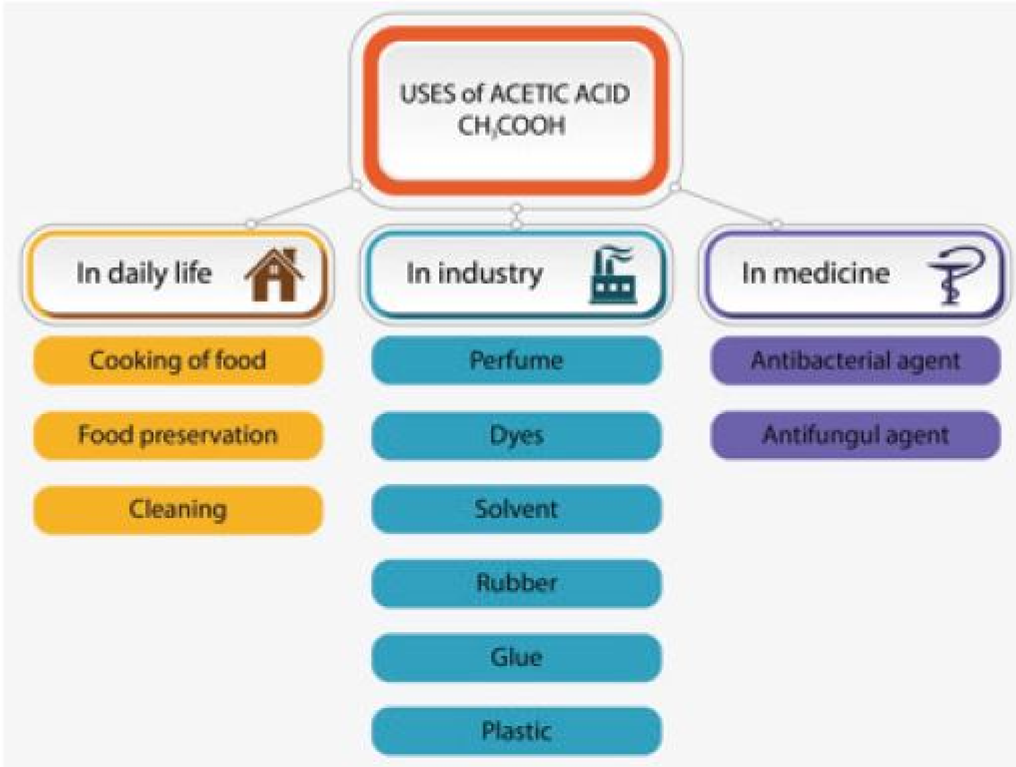

Laboratory work

№16. Properties of acetic acid

Materials:

1 M acetic acid solution, 1 M sodium carbonate solution, 1 M sodium hydroxide solution, Mg ribbons, beakers, test tube, pipettes.

Procedure:

1. Pour 30 ml of acetic solution into the beaker.

2. Add a few drops of methyl orange (or litmus) indicator to a solution of CH3COOH.

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3. Using a pipette add drop by drop solution of sodium carbonate to acetic acid solution. Observe changes.

4. Repeat the experiment by adding of sodium hydroxide solution.

5. Pour 2-4 ml of acetic acid solution into the beaker.

6. Add a small piece of magnesium ribbon to the solution of acetic acid. Observe changes. Try to confi rm the identity of the gas given off.

Safety: Wear eye protection.

Observation & questions:

1. Write chemical equations for the reactions conducted in a lab work.

a) ....

b)..

c) ....

2. Explain colour changes, gas formations, metal dissolution.

Literacy

1. Look at the picture of ball and stick illustration of acetic acid above. Explain and show atoms of carbon, hydrogen and oxygen.

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2. Find mass percentages of all elements in butyric acid C_3H_7COOH.

3. How many milliliters of water and 70% solution of acetic acid are needed to get 1400 ml of 4% vinegar? Assume that the density of all solutions is equal to 1 g/ml.

4. What is the mass of calcium acetate produced from reaction of 8 g Ca with excess amount of acetic acid?

Terminology

- acetic acid - сірке қышқылы / уксусная кислота;
- vinegar - сірке суы / уксус;
- preservation - консервілеу / консервирование;
- antifungal - зеңге қарсы / противогрибковый;
- to prevent - алдын алу / предотвратить;
- fainting - талу / обморок;
- consciousness - ес / сознание;
- pipette - тамшуыр / пипетка.

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13.3 ESTERS AND FATS

As you know bears hibernate during the winter. How bears can survive whole winter without food?

You will:

- explain features of esters and fats;
- learn functions of fats.

Esters

Esters are derivatives of carboxylic acids formed by replacing the hydroxyl (the -OH) group by an alkoxy (the -OR) group. They can be defined as alkyl salts of carboxylic acids and are represented by the general formula RCOOR'.

Esters are among the most widespread of all naturally occurring compounds. Many simple esters are pleasant-smelling liquids

that are responsible for the fragrant odours of fruits and flowers. They are obtained from natural sources such as plants, flowers, and fruits and are what give them their pleasant smells. So, for example, the smells of mint and thyme are due to esters in their structures.

Natural fruit aromas are mixtures of certain organic compounds and esters. Synthetic aromas prepared in laboratories are simple mixtures of these same esters and organic compounds. They are used in perfumes, foods, and drinks to give taste and pleasant smells. Ethyl acetate, for example, is a colourless liquid with an apple flavor; it is

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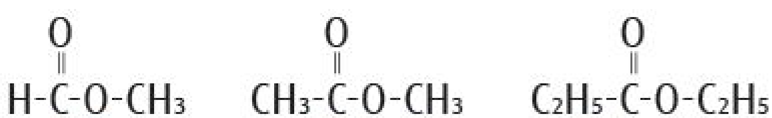
known as apple ester and is used in perfumery as a fruit essence. Propyl acetate has the smell of pears, isopentyl acetate that of bananas and ethyl butyrate smells of pineapples. All are colourless liquids. Higher molar mass esters are odourless.

Nomenclature of esters

The nomenclature of esters is similar to the nomenclature of the carboxylic acid salts. The alkyl group bonded to the oxygen atom is named first, then the –ic acid ending of the corresponding carboxylic acid is changed to –oate.



methyl formate   methyl acetate   ethyl propionate

Some members of esters

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Name	Structure	Odour
Isobutyl formate	$HCOOCH_2CH(CH_3)_2$	 Raspberry
Ethyl acetate	$CH_3COOC_2H_5$	 Apple
Propyl acetate	$CH_3COOC_3H_7$	 Pear
Ethyl butyrate	$C_3H_7COOC_2H_5$	 Pineapple
Isopentyl acetate	$CH_3COOC_5H_{11}$	 Banana
Pentyl butyrate	$C_3H_7COOC_5H_9$	 Apricot

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Sunflower oil in bottle

Isoamyl acetate gives pears their pleasant smell

The smell of pineapple is due to butyl butanoate in its structure

The reaction between an acid and a base is called neutralization and the products are salt and water. The parallel reaction between a carboxylic acid and an alcohol is called esterifi cation and the products are an ester and water.

$$\underset{\text{carboxylic acid}}{R-\overset{\overset{O}{\|}}{C}-OH} + \underset{\text{alcohol}}{HO-R'} \xrightleftharpoons{H^+} \underset{\text{ester}}{R-\overset{\overset{O}{\|}}{C}-OR'} + \underset{\text{water}}{H_2O}$$

Fats

Fats are esters of fatty acids and glycerine. They are also known as triglycerides. Fatty acids are long, straight-chained carboxylic acids and glycerine is a trialcohol. Fats are formed

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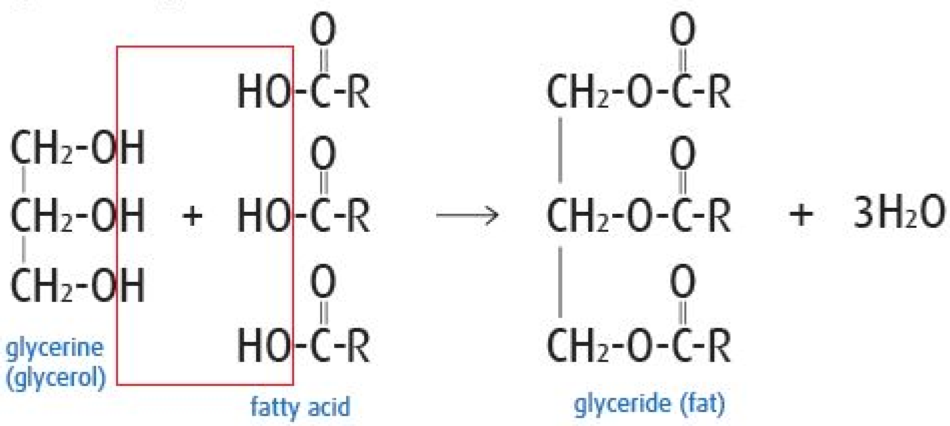
by replacing the hydrogen atoms in the hydroxyl groups of glycerine with acyl groups of fatty acids.



Healthy fats

Corn, a Important source of oil

If the connecting fatty acids to glycerine are, all the same, the glyceride known as simple, if the acids are different, it is known as a complex.

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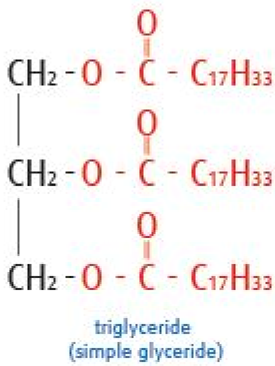

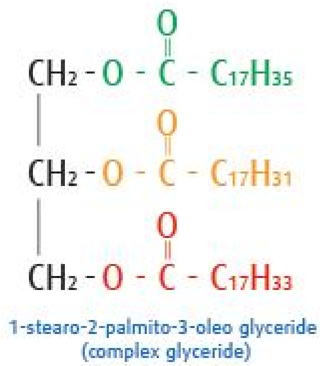

Classification of fats

Vegetable fats:

These are largely stored in the seeds of vegetables. Olive, corn, cotton, sunflower, soybean, sesame, peanut, hazelnut, dates, almonds and coconuts are the main sources of vegetable oils.

Animal fats:

Sheep, cow, and fish are the main source of animal fats. Suet and fish oil are the most common animal fats. They may be either solid or liquid, the same as vegetable fats. If the fatty acids that form the fats and oils are unsaturated, the fats tend to be liquids. Liquid oils are unsaturated, numbers of double bonds in the fatty acids decreases the freezing point of the fat or oil.

Literacy

1. Write the molecular formula of the esters produced by the acids and alcohols given below:

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- ethyl alcohol and acetic acid
- ethyl alcohol and formic acid
- methyl alcohol and acetic acid

2. How to prepare an ester in the lab using alcohols and carboxylic acids?
3. Why are oil and water immiscible?
4. What are the natural sources of oils?
5. What are the factors affecting the physical states of fats?
6. What are the differences between wax, fat, butter and olive oil?

Facts

Fats play an important role in nutrition. Occurring naturally in foods; fats and oils are a concentrated form of energy for the body. As well as storing energy in the body, fats are used to insulate body tissues and help transport fat-soluble vitamins throughout the blood.

Terminology

- esters - күрделі эфирлер / сложные эфиры;
- fats - майлар / жиры;
- to hybernate - аңдардың қысқы ұйқыға кетуі / впадать в зимнюю спячку;
- widespread - кең таралған / широко распространен;
- pleasant smell - жағымды иіс / приятный запах;
- fragrant - ароматты / ароматный;
- raspberry - таңқурай / малина;
- esterifi cation - эфирлену / этерификация;
- fatty acids - май қышқылдары / жирные кислоты.

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13.4 AMINOACIDS. PROTEINS

Why do diabetics use insulin?

You will:

- explain formation of peptide bonds;
- investigate denaturation reaction of proteins;
- explain biological role and functions of proteins.

Aminoacids

Amino acids contain both amino (–NH2) and carboxyl (–COOH) groups in their structure. Aminoacids are the basic building blocks of proteins, which are the basis of living organisms. There are over 700 naturally occurring amino acids. The amino group in amino acids obtained from the proteins of plants and animals is in the position with respect to the carboxyl group.

Because of the existence of both (the –NH2) and (the –COOH) groups, aminoacids display amphoteric properties (i.e., have both acidic and basic properties). The first member of aminoacid is glycine (aminoethanoic acid).

Peptide formation and proteins

Proteins are the largest and most complicated molecules that exist in the cells of living organisms. Proteins are polymers that are formed by many hundreds or even thousands of amino acid units. These units are bonded together by a peptide linkage.

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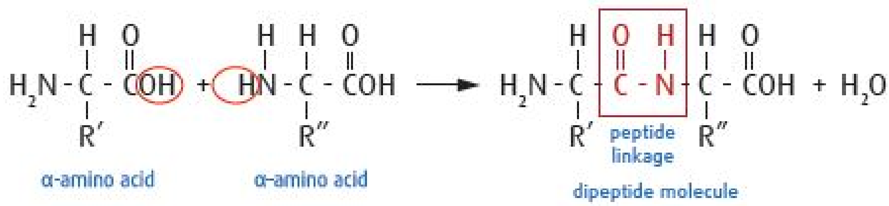
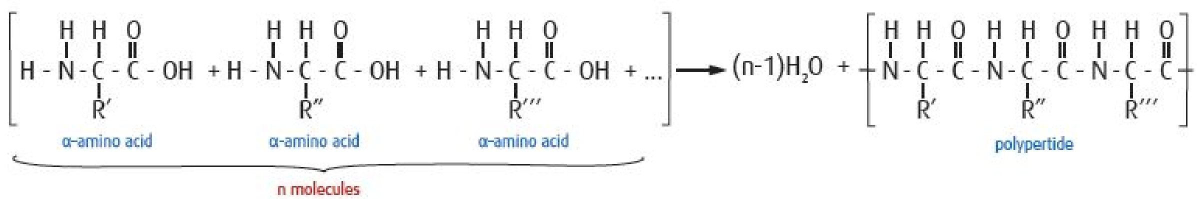
Peptides are amides formed by the reaction of amino groups with the carboxyl groups of amino acids. According to the number of amino acid units they are made up from, they are known as dipeptides, tripeptides or polypeptides.



If the number of amino acids forming peptide bonds is "n", (n–1) molecules of water are produced in the peptide formation.



If the number of amino acids forming polypeptide bonds is more than 12.000, the polypeptides are called proteins. Although proteins contain only 20 kinds of amino acids, they can be arranged in many different sequences. Consequently, a small number of amino acids may form many different types of proteins.Proteins are used for repairing degenerated tissue in living organisms.

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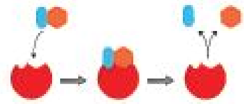
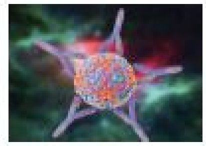
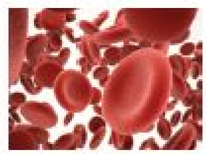
Functions of proteins

Classification	Function	
Enzymatic proteins	Selective acceleration of chemical reactions	
Defensive proteins	Protection against disease	
Storage proteins	Storage of aminoacids	
Transport proteins	Transport of substances	
Hormonal proteins	Coordination of an organism's activities	
Receptor proteins	Response of cell to chemical stimuli	
Contractile and motor proteins	Movement	
Structural proteins	Support	

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Foods high in proteins

Keep in mind

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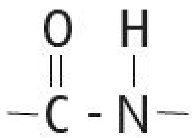
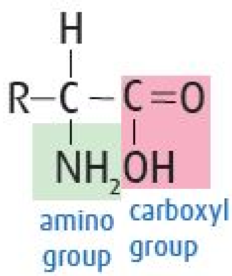
Amino acids are linked by peptide bonds. These bonds are formed by a dehydration synthesis reaction between the carboxyl group of the first amino acid and the amino group of the second amino acid.

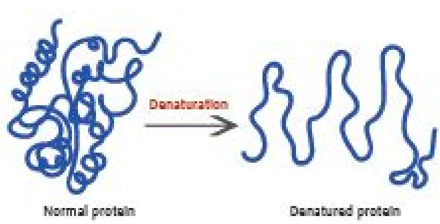


An amino acid molecule contains both the amino and carboxyl group.



Facts

High temperatures or various chemical treatments will denature a protein, causing it to lose its shape and hence its ability to function.



Laboratory work

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№22. Denaturation of protein

Materials:

burner, ring stand, stirring rod, 4 raw eggs, 4 test tubes, 95% ethanol, 1% Pb(NO3)2 solution, lemon juice, sodium chloride NaCl

Procedure:

1. Place 100 mL of water in a 250 mL beaker, place on a ring stand and heat to boiling.

2. Label 4 test tubes #1-4.

3. Separate 2 eggs, placing the egg white in a test tube until half fi lled.

4. Place test tube #1 in the boiling water and allow to “cook” till egg turns white.

5. Add lemon juice to test tube #2 and stir.

6. Add 95% ethanol to test tube #3 and stir.

7. Add 1% Pb(NO3)2 solution to test tube #4.

8. Record observations on the table below.

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Data table:

Test tube	Added	Observation
1	Heat	
2	Lemon juice	
3	95% ethanol	
4	1% $Pb(NO_3)_2$ solution	

Conclusion and questions:

1. What common result occurred in all experimental tubes? Why?

2. Why are heat and alcohol used to disinfect medical equipment?

Literacy

1. Explain why amino acids are generally amphoteric compounds.
2. Explain how peptide bonds are formed.
3. What is the difference between an amino acid and a protein?
4. What is the molecular weight of the dipeptide obtained from an amino acid of which 0.1 mole has a mass of 75 grams?
5. How many water molecules are formed when 100 amino acid molecules are bonded together by peptide bonds?
6. What is the importance of proteins in daily life?

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Terminology

- amino acid - аминқышқылы / аминокислота;
- protein - нәруыз / белок;
- peptide - пептид;
- cell - жасуша / клетка;
- denaturation - денатурация;
- storage - сақтау орны / место хранения;
- enzyme - фермент;
- receptor - рецептор;
- helix - спираль.

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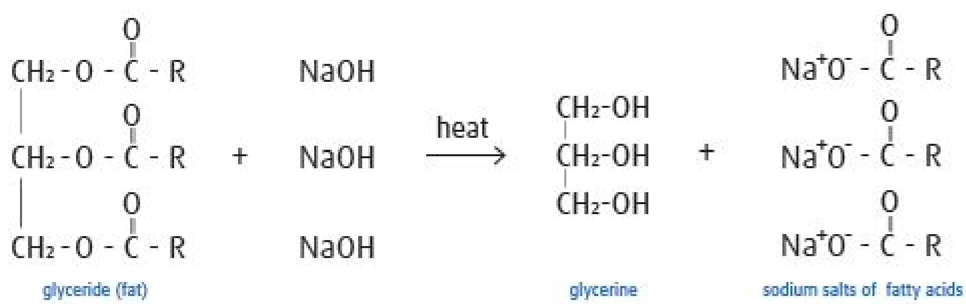
13.5 SOAP AND SYNTHETIC DETERGENTS

Why frequent use of soap can lead to negative effects?

You will:

- know preparation of soap and its uses;
- explain the effects of synthetic detergents on the environment.

Hydrolysis of glycerides (fats) in a basic medium produces glycerol (glycerine) and a mixture of salts of long-chained carboxylic acids (fatty acids).



Fats, when heated with a solution of NaOH or KOH are hydrolyzed. After the hydrolysis, glycerine and long chained carboxylic acids salts are left, this mixture is soap and the process is called saponification. Soaps are basic salts which are formed by weak fatty acids and strong bases. For this reason, soap solutions show basic properties. Saponification is the reverse process of esterification. When NaOH is used in

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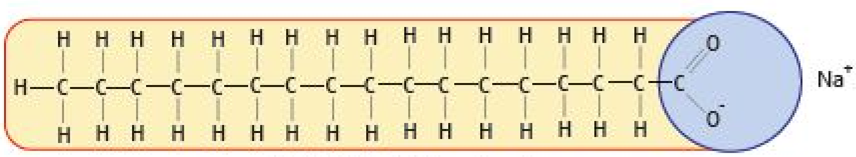
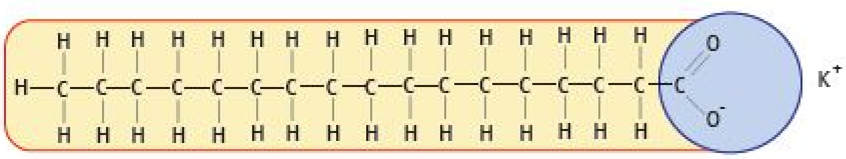
the saponification process, a solid soap is produced but when KOH is used, a molten soft soap is produced.

Handmade soaps



$C_{17}H_{35}COONa$ Sodium stearate



$C_{17}H_{35}COOK$ Potassium stearate

Water soluble stains on the surface of clothes can easily be cleaned using water. If our hands get covered in salt, for example, it is enough to wash them with plenty of water. However, water isn't so effective at getting rid of oily stains. Most dirt particles (on the surface of clothes, on the skin etc.) become surrounded by a layer of oil or fat. Water molecules alone are unable to get rid of this type of dirt because they

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cannot penetrate the oily layer. Soap must be used to disperse this type of dirt.

Soap has been used by humankind for some 2,000 years. Historical records describe its manufacture in the first century and document a soap factory in Pompeii. Prior to this time, clothes were cleaned by rubbing them on rocks in the water, or by forming soapy lathers from the roots, bark, and leaves of certain plants. These plants produced natural materials called saponins, which act in much the same way as modern-day soaps. Soaps, however, have their disadvantages, foremost among the fact that they form water-insoluble salts when used in water containing Ca^{2+}, Mg^{2+}, or Fe^{3+} ions (hard water):

$$C_{17}H_{35}COONa + Ca^{2+} \rightarrow [C_{17}H_{35}COO]_2Ca + 2Na^+$$

This water-insoluble calcium, magnesium, and iron salts of fatty acids create problems, including rings around the bathtub, films that spoil the luster of hair, and grayness and roughness that build upon textiles after repeated washings.

Synthetic detergents

Detergents are artifi cial soaps. Their structure is similar to soaps; any molecule having nonpolar and polar sections similar to those in soap molecules may disperse oily stains on clothes, hence detergents too have a hydrophobic and hydrophilic end. Detergents in which the hydrophilic group is an anion are called anionic detergents. The most common of these are the alkyl benzene sulfanates (ABS) and alkyl sulfates.

Synthetic detergents are more active cleaners than soaps. They don’t form precipitates with Ca^{2+} and Mg^{2+} ions in

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hard water and are therefore more effective cleaners in hard water than soaps.


Liquid detergent


Washing powder

Keep in mind

Soaps are salts of carboxylic acids that have many carbon atoms in a long hydrocarbon chain.

Facts

Detergents are not decomposed into simpler substances by microorganisms, therefore when detergents get into rivers, lakes and ground water, they become an environmental problem.

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Activity

You can visit local water sources and observe if the river / lake / tank / pond are unpolluted / slightly polluted / moderately polluted or severely polluted by looking at water or by checking pH of water. Document the name of the river and the nearby urban or industrial site from where the pollution is generated. Inform about this to Pollution Control Board's offi ce set up by Government to measure pollution levels. Ensure that appropriate action is taken. You can write to the press also. Do not dump waste into a household or industrial drain which can enter directly into any water body, like, river, pond, stream or lake. Use compost instead of chemical fertilizers in gardens. Avoid using pesticides like DDT, malathion etc.

Literacy

1. Explain how to make soaps.
2. What colour does soap solution change to when adding indicator? Why does soap have a pH above 7?
3. Why is detergent more effective in hard water than soaps?
4. What is the advantages of soap over detergents?

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5. Which brand of soap and detergents do you use in daily life?

Terminology

- soap - сабын / мыло;
- detergent - жуғыш заттар / моющее средство;
- saponifi cation - сабындану / омыление;
- hydrophobic -гидрофобты (“судан қорқатын”) / гидрофобный;
- hydrophilic - гидрофилді (“суды жақсы көретін”) / гидрофильный.

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13.6 CARBOHYDRATES

Honey is generally composed of carbohydrates. Why does honey not spoil for centuries?

You will:

- know classification of carbohydrates;
- know biological role of carbohydrates and their functions.

Glucose

Glucose $C_6H_{12}O_6$ is a well-known monosaccharide. It is the energy source of living organisms, stored in liver and muscles, found in grape and honey. Glucose is white crystalline, soluble in water, and the sweet substance.

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Glucose, one of the most important members of monosaccharides, is found in grapes

Honey is an important source of glucose

Refined sugar

Sucrose (sugar)

Sucrose C12H22O11 is formed by linking of one molecule of glucose to a fructose molecule. It occurs widely in plants and is particularly abundant in sugar cane and sugar beet from which it is extracted and refined for use as table sugar.

Sugar candies

Sugar is produced from sugar beets

Starch

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Starch $(C_6H_{10}O_5)_n$ is the most important polysaccharide and is formed by combining glucose molecules with a glycosidic linkage. Corn, potatoes, rice and the roots of plants and seeds are the main sources of starch. Starch is an essential nutritional resource.


Potato starch


Starch is an essential food for humans. Bread is composed of 50–75% starch


Round bundles of dry grass in the field

Cellulose

Cellulose $(C_6H_{10}O_5)_n$ is the most abundant organic substance innature. The walls of plant cells are made of cellulose. The main cellulose sources in nature are wood, grass, hay, cotton, linen, and hemp.


Cellulose is the main component of wood and its derivatives. 60-70% of wood is cellulose.


Cotton balls on the plant

Literacy

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1. What products are formed when glucose is completely burnt?
2. Which materials in your house contain carbohydrates? Research.
3. What is the primary product of the photosynthesis process?
4. What are the most important polysaccharides in nature?
5. A sugar contains 42.1% C, 6.433% H and 51.462% O by mass. What is the molecular formula of this compound?
6. Write the names and formulae of all isomers of the sugar with the general formula C6H12O6.

Terminology

- carbohydrate - көмірсу / углевод;
- monosaccharide - моносахарид / моносахарид;
- glucose - глюкоза / глюкоза;
- sucrose - сахароза / сахароза;
- sugar beets - қант қызылшасы / сахарная свекла;
- starch - крахмал / крахмал;
- cellulose - целлюлоза / целлюлоза.

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Problems: Oxygen and nitrogen containing organic compounds

ALCOHOLS

1. Draw structures for the following compounds:

- 2-pentanol
- 3-methyl-2-butanol
- 2-chloroethanol
- isopropyl alcohol
- 2,2-dimethyl pentanol

2. Write down the possible isomers of the alcohols that have the molecular formula, C5H11OH.

3. Which alcohol and how many grams are produced by the hydration of 9.6 g of 2-butene?

4. How many liters of hydrogen gas at STP react with carbon monoxide to obtain 1.6 g of methyl alcohol?

5. When a 12 g sample of alcohol is reacted with metallic sodium, 2.24 L of hydrogen at STP are liberated. What is the molecular weight of the alcohol?

CARBOXYLIC ACIDS. ESTERS

1. Write equations for the reactions of formic acid with the following reagents:

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• NaOH, CH_3OH, Na

2. A compound X has all of the properties below.

- It is a liquid at 25°C.
- It mixes completely with water.
- It reacts with aqueous sodium hydroxide.

What could X be?

A. acetic acid   B. ethyl alcohol   C. ethane   D. ethyl acetate

3. Which compound is a product of the hydrolysis of $CH_3COOC_3H_7$ by boiling aqueous sodium hydroxide?

A. CH_3OH B. C_3H_7OH C. C_3H_7COOH D. $C_3H_7COO^-Na^+$

4. Fats and grease that build up on pans used in cooking are esters. Pans which are dirty from fats or grease may be cleaned by

heating them with a reagent that will react with the ester group. What may be used to clean such pans by this reaction?

1 vinegar - aqueous ethanoic acid, CH_3COOH

2 alcohol - ethanol, C_2H_5OH

3 baking powder - sodium hydrogencarbonate, $NaHCO_3$

A. 1,2,3   B. 1,2   C. 2,3   D. 3 only

5. The ester $CH_3CH_2CH_2COOCH_3$ is responsible for the aroma of apples. When this ester is hydrolysed by acid in the stomach, what is the empirical formula of the organic acid produced?

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A. $C_4H_8O_2$ B. C_2H_4O C. $C_2H_4O_2$ D. $C_3H_7O_2$

CARBOHYDRATES

1. Starch is a

A. simple sugar B. monosaccharide C. cellulose D. polymer

2. Glucose ia a (an)

A. polysaccharide B. amino acid C. part of cellulose D. 5-carbon sugar

3. Which of the following might be called "animal starch?"

A. glucose B. plant starch C. glycogen D. cellulose

4. Carbohydrates are produced in the green leaves of plants by the process of

A. photosynthesis B. metabolism C. hydrolysis D.respiration

5. Which one of the following does not contain cellulose?

A. cell wall of plant cell B. wood C. cotton D. stone

LIPIDS. AMINOACIDS

1. How do saturated and unsaturated fatty acids differ in molecular structure?

2. Explain why amino acids are generally amphoteric compounds.

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ANSWERS

Chapter 1

1) a) F

b) F

c) T

d) T

e) T

2) a) weak

b) nonelectrolyte

c) weak

d) strong

e) nonelectrolyte

f) strong

g) strong

3) conductivity of electricity

5) 25%

8) Ca2+ + CO32- → CaCO3(white)

9) 3Ag+ + PO43- →Ag-3PO4(yellow)

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$Ag^+ + Cl^- \rightarrow AgCl$ (white)

10) $2HCl + Pb^{2+} \rightarrow PbCl_2 + 2H^+$

$2H^+ + 2Cl^- + Pb^{2+} \rightarrow PbCl_2 + 2H^+$

$Pb^{2+} + 2Cl^- \rightarrow PbCl_2$

11) a) Ba^{2+}, NO_3^-, K^+, PO_4^{3-}

b) $3Ba(NO_3)_2 + 2K_3PO_4 \rightarrow Ba_3(PO_4)_2(s) + 6KNO_3$

c) $3Ba^{2+} + 2PO_4^{3-} \rightarrow Ba_3(PO_4)_2(s)$

12) a) basic,

b) acidic,

c) acidic,

d) acidic,

e) neutral,

f) basic

13) $n(Al_2(SO_4)_3) = 0.00125$ mol

$n(Al^{3+}) = 0.0025$ mol

$n(SO_4^{2-}) = 0.00375$ mol

14) solubility in water

15) add $AgNO_3$ solution

16) 1) gives p-pt,

2) no reaction,

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3) gives p-pt,

4) no reaction,

5) gives p-pt,

6) no reaction

Chapter 2

1) a) 2.2 mol H_2,

b) Fe

c) 0.1 mol HCl

2) a) 0.64 mol KCl,

b) KOH,

c) 0.24 mol $CuCl_2$

3) $CH_4 + 2O_2 \rightarrow CO_2 + H_2O$

a) CH_4,

b) 0.8 mol CO_2,

c) 1.6 mol H_2O,

d) 12.8 g O_2

4) $2Ca + O_2 \rightarrow 2CaO$

m(CaO)=33.6 g,

m(Ca)=8 g (excess)

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5) $2Li + S \rightarrow Li_2S$, $m(Li_2S)=32.2$ g

6) a) $Pb(NO_3)_2 + H_2SO_4 \rightarrow PbSO_4(s) + 2HNO_3$

7) a) $AgNO_3 + HCl \rightarrow AgCl(s) + HNO_3$

10) Adding Ba^{2+} salts

12) E

Chapter 3

1) a) 2-, b) 2, c) 2, d) 1

2) II, V, I, IV, III

3) II, III

4) II

5) B

6) C

Chapter 4

6) a) irrev.,

b) rev.,

c) irrev.,

d) irrev.,

e) rever.,

f) rever.

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8) a) yes, b) no, c) yes

9) to right, to left, to left, to right

10) to right, to left, to left

12) to left, to right

Chapter 5

1) Ca - reduc.agent - oxidized

O_2 - oxid.agent - reduced

3) +3, +7, +2, +7, +6

4) C - oxidized, HNO_3 - reduced

7) -2, +6, +2

8) 25

9) N_2O

10) D, E

11) A

12) E

13) a) $2FeCl_3 + 2KI \rightarrow 2FeCl_2 + I_2 + 2KCl$

b) $Cu_2S + 2O_2 \rightarrow 2CuO + SO_2$

c) $2KMnO_4 + 10FeSO_4 + 8H_2SO_4 \rightarrow 5Fe_2(SO_4)_3 + 2MnSO_4 + K_2SO_4 + 8H_2O$

d) $4FeS + 7O_2 \rightarrow 2Fe_2O_3 + 4SO_2$

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Chapter 6

9) $Fe_2O_3 + 2Al \rightarrow Al_2O_3 + 2Fe$

12) 120 g

13) 75%

14) 1.12 L

15) 6.72 L H_2

16) 63.75%

Chapter 7

11) a) Na, Li, K, b) Cs, c) Fr

12) a) Be, b) Ra, c) Be, d) Mg,

e) Mg, f) Ca

14) 37.33 L H_2

15) 2.43 g H_2

Chapter 8

1) $KBrO_3$

2) 33.9 g FeF_3

3) 21.3 g Cl_2

4) 15.68 L H_2

5) 8.96 L F_2

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6) 1.2 g HF

7) 79.875 g Cl2

8) 87.46% H2SO4

9) 750 g MgSO4, 94.8%

10) 246 g P4S7

11) 92.9% H3PO4

14) NaCl + H2SO4 → HCl + NaHSO4

Cl2 + 2NaI → 2NaCl + I2

Chapter 9

3) 2NO2 + H2O → HNO2 + HNO3

5) n(HNO3)=0.375 mol

6) n(NO2)= 3 mol

7) m(Ca(NO3)2)=35 g, 75 g HNO3 excess

8) b) 0.794 ml HNO3 ,

c) 0.397 mol Fe(NO3)2,

d) 71.43 g Fe(NO3)2

e) 0.397 mol Fe(OH)2,

f) 35.73 g Fe(OH)2

12) N(SiO2)=9.45x1024 molecules

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13) b) Cl_2 gas,

c) 6.465 g $SiCl_4$

d) 2.135 g Si (excess)

14) $w(Na_2SiO_3)=0.85\%$

16) 120 g H_2SiF_6

Chapter 11

2) 3-methylhexane

2,4-dimethylheptane

2,2-dimethylpropane

4,6-dimethyl,5-ethyl-octane

4) 3,3-dimethylhexane

7) $C_{14}H_{10}$

8) $C_4H_5N_2O$

9) $C_7H_5NO_3S$

10) $C_{21}H_{22}N_2O_2$ ($C_{10}H_{11}NO$)

Chapter 12

Alkanes

1) 58

2) 10, 16

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3) C_4H_{10}

4) C_5H_{12}

5) C_3H_8

Alkenes

1) ethylene

2) C_3H_6

3) 15.68 L H_2

4) 3.2 g CH_4

Alkynes

1) product - $C_2H_2Cl_2$

product - C_4H_{10}

product - $C_4H_8Cl_2$

3) $CaC_2 + 2H_2O \rightarrow Ca(OH)_2 + C_2H_2$

$C_2H_2 + H_2 \rightarrow C_2H_4$

$C_2H_4 + 3O_2 \rightarrow CO_2 + 2H_2O$

4) C_3H_4

5) C_4H_6

Aromatic hydrocarbons

1) $2C_6H_6 + 15O_2 \rightarrow 12CO_2 + 6H_2O$

$C_7H_8 + 9O_2 \rightarrow 7CO_2 + 4H_2O$

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$C_{10}H_8 + 12O_2 \rightarrow 10CO_2 + 4H_2O$

$2C_{14}H_{10} + 33O_2 \rightarrow 28CO_2 + 10H_2O$

3) 194.88 L H_2

4) 20 g C_6H_6

Hydrocarbon fuels. Oil and gas

3) c=1.74 (J/(g*K))

c=2.05 (J/(g*K))

Chapter 13

Alcohols

3) 12.7 g butanol

4) 2.24 L H_2

5) Mr=60 g/mol

Carboxylic acids

2) A

3) D

4) D

5) A

Carbohydrates

1) D

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2) C

3) C

4) A

5) D

Lipids. Aminoacids

4) 89 water molecules

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GLOSSARY

A

Acid rain – rain that contains a high concentration of pollutants, chiefly sulfur dioxide and nitrogen oxide, released into the atmosphere by

the burning of fossil fuels such as coal or oil.

Acids – any of a class of chemical compounds whose aqueous solutions turn blue litmus paper red, react with and dissolve certain metals to form salts and react with bases to form salts.

Activation energy – the energy, in excess of the ground state, which must be added to an atomic or molecular system to allow a particular process to take place.

Alkali metals - elements of group 1 in the Periodic table.

Alkaline earth metals – the heaviest members of group 2 in the Periodic table: lithium, sodium, potassium, rubidium, cesium, and francium.

Alkalis – any of various bases, the hydroxides of the alkali metals and of ammonium that neutralize acids to form salts and turn red litmus paper blue.

Ammonium – the univalent ion, NH4+, or group, which plays the part of the metal in the salt formed when ammonia reacts with an acid.

Anion – an ion that is negatively charged.

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Antacid – any substance that counteracts or neutralizes acidity.

Apatite – a common mineral, calcium fluorophosphate, Ca5FP3O12, occurring in individual crystals and masses and varying in colour, formerly used in the manufacture of phosphate fertilizers.

B

Bases – compounds that react with a protonic acid to give water (and salt).

Biofuel – a gaseous, liquid, or solid substance of biological origin that is used as a fuel.

C

Carbohydrate – any of a class of organic compounds that are polyhydroxy aldehydes or polyhydroxy ketones, or change to such substances on simple chemical transformations, as hydrolysis, oxidation, or reduction, and that form the supporting tissues of plants and are essential food for animals and people.

Cast iron – an alloy of iron, carbon, and other elements, cast as a soft and strong, or as a hard and brittle, iron, depending on the mixture and methods of molding.

Catalyst – a substance that alters the velocity of a chemical reaction and may be recovered essentially unaltered in form and amount at the end of the reaction.

Cation – a positively charged atom or group of atom.

Cement – any of various calcined mixtures of clay and limestone, usually mixed with water and sand, gravel, etc., to

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form concrete that is used as a building material.

Chemical equilibrium – a condition in which a chemical reaction is occurring at equal rates in its forward and reverse directions so that the concentrations of the reacting substances do not change with time. Also known as equilibrium.

Chlorophyll – the green colouring matter of leaves and plants, essential to the production of carbohydrates by photosynthesis, and occurring in a bluish-black form, C55H72MgN4O5 (chlorophyll a) and a dark-green form, C55H70MgN4O6 (chlorophyll b).

Collision – the meeting of particles or of bodies in which each exerts a force upon the other, causing the exchange of energy or momentum.

Concentration – in solutions, the mass, volume, or number of moles of solute present in pro portion to the amount of solvent or total solution.

Condensation – transformation from a gas to a liquid.

Corrosion – oxidation of a metal in the presence of air and moisture.

Crystal lattice – the regular array of points about which the atoms, ions, or molecules are composing a crystal are centered.

D

Dehydration – removal of water from anysubstance.

Denaturation – to treat (a protein or the like) by chemical or physical means to alter its original state.

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Detergents – an organic compound or compounds composed of molecules containing both hydrophilic (polar) and hydrophobic (nonpolar) portions.

Dissociation – separation of a molecule into two or more fragments (atoms, ions, radicals) by collision with a second body or by the absorption of electromagnetic radiation.

Dissolution – dissolving of a material.

Double displacement reaction – a chemical reaction between compounds in which the elements in the reactants recombine to form two different compounds.

E

Electrolyte – a chemical compound, which when molten or dissolved in certain solvents, usually water, will conduct an electric current.

Electronegativity – about an atom or group of atoms that has a relatively great tendency to attract electrons to itself.

Empirical formula – a chemical formula that indicates the composition of a compound regarding the relative numbers and kinds of atoms in the simplest ratio.

Enzymes – any of various proteins, as pepsin, originating from living cells and capable of producing certain chemical changes in organic substances by catalytic action, like indigestion.

Esterification – a chemical reaction whereby esters are formed.

Explosion – a chemical reaction or change of state which is effected in an exceedingly short space of time with the

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generation of high temperature and a large quantity of gas.

Explosive – an explosive agent or substance, as dynamite.

F

Fats – any of several white or yellowish greasy substances, forming the chief part of adipose tissue of animals and also occurring in plants, that when pure are colourless, odourless, and tasteless and are either solid or liquid esters of glycerol with fatty acids.

Fermentation – a change brought about by a ferment, as yeast enzymes, which convert grape sugar into ethyl alcohol.

Fertilizer – a natural or chemical substance that is spread on the land or given to plants.

Flame test – a test for detecting the presence of certain metals in compounds by the colouration they give to a flame. Sodium, for example, turns a flame yellow.

Flotation – a process for separating the different minerals in a mass of powdered ore based on their tendency to sink in, or float on, a given liquid.

Functional groups – an atom or group of atoms, acting as a unit, that has replaced a hydrogen atom in a hydrocarbon molecule and whose presence imparts characteristic properties to this molecule; frequently represented as R-. Also known as functionality.

G

Gunpowder – an explosive mixture, as of potassium nitrate, sulfur, and charcoal, used in shells and cartridges, in fireworks, for blasting, etc.

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Gypsum – a very common mineral, hydrated calcium sulfate, $CaSO_4 \cdot 2H_2O$, occurring in crystals and masses, soft enough to be scratched by the fingernail: used to make plaster of Paris, as an ornamental material, as a fertilizer, etc.

H

Haber process – a process for synthesizing ammonia from gaseous nitrogen and hydrogen under high pressure and temperature in the presence of a catalyst.

Halogen – any of the elements of the halogen family, consisting of fluorine, chlorine, bromine, iodine, and astatine.

Heavy metal – any metal with a specific gravity of 5.0 or greater, especially one that is toxic to organisms, like lead, mercury, copper, and cadmium.

Homeostasis – the tendency of a system, especially the physiological system of higher animals, to maintain internal stability, owing to the coordinated response of its parts to any situation or stimulus that would tend to disturb its normal condition or function.

Hydrolysis – in aqueous solutions of electrolytes, the reactions of cations with water to produce a weak base or of anions to produce a weak acid.

Hydronium ion – H_3O^+ an oxonium ion consisting of a proton combined with a molecule of water; found in pure water and all aqueous solutions.

Hydrophilic - having an affinity for, attracting, adsorbing, or absorbing water.

Hydrophobic - lacking an affinity for, repelling, or failing to adsorb or absorb water.

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I

Inhibitor – a substance that decreases the rate of or stops completely a chemical reaction.

Isomer – one of two or more chemical substances having the same elementary percentage composition and molecular weight but differing in structure, and therefore in properties; there are many ways in which such structural differences occur.

K

King water – a fuming, highly corrosive, volatile liquid with a suffocating odour made by mixing 1 part concentrated nitric acid and three parts concentrated hydrochloric acid; reacts with all metals, including silver and gold.

L

Le Chatelier's principle – a law that states that if a system in physical or chemical equilibrium is subjected to a change in temperature, pressure or concentration, then the system will automatically alter itself so as to reduce the effects of the change. It can be shown that this law must be true if energy is neither created nor destroyed.

Limestone – a sedimentary rock consisting predominantly of calcium carbonate.

Limiting reagent – in a chemical reaction, the reagent that controls the quantity of product which can be formed.

M

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Manufacture – the making of goods or wares by manual labor or by machinery, especially on a large scale.

Medium – an intervening substance, as air, through which a force acts or an effect is produced.

Metal – any of a class of elementary substances, as gold, silver, or copper, all of which are crystalline when solid and many of which are characterized by opacity, ductility, conductivity, and a unique luster when freshly fractured.

Metal alloy – a substance composed of two or more metals, or of a metal or metals with a nonmetal, intimately mixed, as by fusion or electrodeposition.

Metallic bond – the type of chemical bond that is present in all metals, and may be thought of as resulting from a sea of valence electrons which are free to move throughout the metal lattice.

Metallurgy – the technique or science of working or heating metals to give them certain desired shapes or properties.

Mineral – any of a class of substances occurring in nature, usually comprising inorganic substances.

N

Natural gas – a combustible mixture of gaseous hydrocarbons that accumulates in porous sedimentary rocks, especially those yielding petroleum, consisting usually of over 80 % methane together with minor amounts of ethane, propane, butane, nitrogen, and, sometimes, helium: used as a fuel and to make carbon black, acetylene, and synthesis gas.

Neutralization – the process of making a solution neutral by adding a base to an acid solution.

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Nitrogen cycle – the natural circulation of nitrogen by living organisms.

Nutrients – any substances that plants or animals need to live and grow.

O

Olefin – CnH2n, a family of unsaturated, chemically active hydrocarbons with one carboncarbon double bond; includes ethylene and propylene.

Ores (deposits) – rock or soil from which metal can be obtained.

Organic chemistry – the study of the structure, preparation, properties, and reactions of carbon compounds.

Oxidation – a chemical reaction in which a compound loses electrons that is in which the positive valence is increased.

Oxidation state – the number of electrons to be added (or subtracted) from an atom in a combined state to convert it to elemental form; also known as oxidation number.

Oxidizing agent (oxidizer) – a compound that gives up oxygen easily, removes hydrogen from another compound, or attracts negative electrons; also known as an oxidant.

P

Paraffin – one of the higher members of the alkane series, solid at ordinary temperatures, having a boiling point above 300°C, which largely constitutes the commercial form of this substance.

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Peptide bond – a bond in which the carboxyl group of one amino acid is condensed with the amino group of another to form a –CO-NH linkage. Also known as peptide linkage.

Petroleum – an oily, thick, flammable, usually dark-coloured liquid.

pH scale – the symbol for the logarithm of the reciprocal of hydrogen ion concentration in gram atoms per liter.

Photosynthesis – the complex process by which carbon dioxide, water, and certain inorganic salts are converted into carbohydrates by green plants, algae, and certain bacteria, using energy from the sun and chlorophyll.

Polymer – a substance made of giant molecules formed by the union of simple molecules (monomers); for example polymerization of ethylene forms a polyethylene chain or condensation of phenol and formaldehyde (with a production of water) forms phenolformaldehyde resins.

Polymerization – the bonding of two or more monomers to produce a polymer.

Potash – K2CO3, white, water-soluble, deliquescent powder, melting at 891°C; insoluble in alcohol; used in brewing, ceramics, explosives, fertilizers, and as a chemical intermediate.

Precipitate – a substance precipitated from a solution.

Pressure – the exertion of force upon a surface by an object, fluid, etc., in contact with it.

Protein – the plant or animal tissue rich in such molecules, considered as a food source supplying essential amino acids to the body.

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Purification – to make pure; free from anything that debases, pollutes, adulterates, or contaminates.

Q

Qualitative analysis – the analysis of a gas, liquid, or solid sample or a mixture to identify the elements, radicals, or compounds composing the sample.

R

Rate of reaction – a measurement based on the mass of reactant consumed in a chemical reaction during a given period.

Reactant – a substance that reacts with another one to produce a new set of substances (products).

Recrystallization – repeated crystallization of material from fresh solvent to obtain an increasingly pure product.

Redox system – a chemical system in which reduction and oxidation (redox) reactions occur.

Reducing agent (reducer) – 1. a material that adds hydrogen to an element or compound; 2. a material that adds an electron to an element or compound, that is, decreases the positiveness of its valence.

Reduction – 1. reaction of hydrogen with another substance; 2. chemical reaction in which an element gains an electron (has a decrease in positive valence).

Refrigerant – a liquid capable of vaporizing at a low temperature, like ammonia, used in mechanical refrigeration.

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Reversible chemical reaction – a chemical reaction that can be made to proceed in either direction by suitable variations in the temperature, volume, pressure, or quantities of reactants or products.

S

Saltpeter – KNO3, flammable, water-soluble, white crystals with saline taste; melts at 3370C; used in pyrotechnics, explosives, and matches, as a fertilizer, and as an analytical reagent. Also known as niter.

Salt – the reaction product when a metal displaces the hydrogen of an acid.

Saponification – the process of converting chemicals into soap; involves the alkaline hydrolysis of a fat or oil or the neutralization of a fatty acid.

Semiconductor – a substance, as silicon or germanium, with electrical conductivity intermediate between that of an insulator and a conductor: a basic component of various kinds of electronic circuit element (semiconductor device) used in communications, control, and detection technology and computers.

Soap – a substance used for washing and cleansing purposes, usually made by treating a fat with an alkali, as sodium or potassium hydroxide, and consisting chiefly of the sodium or potassium salts of the acids contained in the fat.

Solubility – the ability of a substance to form a solution with another substance.

Solution – any liquid mixture of two or more substances that is homogeneous.

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Solvent – any liquid that dissolves another solute and forms a homogeneous solution.

Spoiling – to damage severely or harm (something), especially concerning its excellence, value, usefulness, etc. can occur when certain materials such as tung oil are stored in bulk, resulting from the generation of heat, which cannot be readily dissipated; often heat is generated by microbial action.

Stainless steel – alloy steel containing 12 % or more chromium, to be resistant to rust and attack from various chemicals.

T

Temperature – a measure of the warmth or coldness of an object or substance with reference to some standard value. The temperature of two systems is the same when the systems are in thermal equilibrium.

U

Universal Indicator – a chemical solution made from a mixture of substances that produce many different colour changes according to different pH levels.

V

Vinegar – a sour liquid consisting of dilute and impure acetic acid, obtained by acetous fermentation from wine, cider, beer, ale, or the like: used as a condiment, preservative, etc.

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CHEMISTRY

Grade 9

Authors:

Kanat Baikenov
Temirlan Khassen
Nurbolat Zhumagulov
Dauren Kaliyev
Olzhas Yussupov
Abylay Samatov
Abdurrahman Sel
Ali Tor

Edited by:

Aidyn Tussyubzhanov

Designed by:

Yelnar Beimish

Cover design:

Darkhan Berdibayev

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