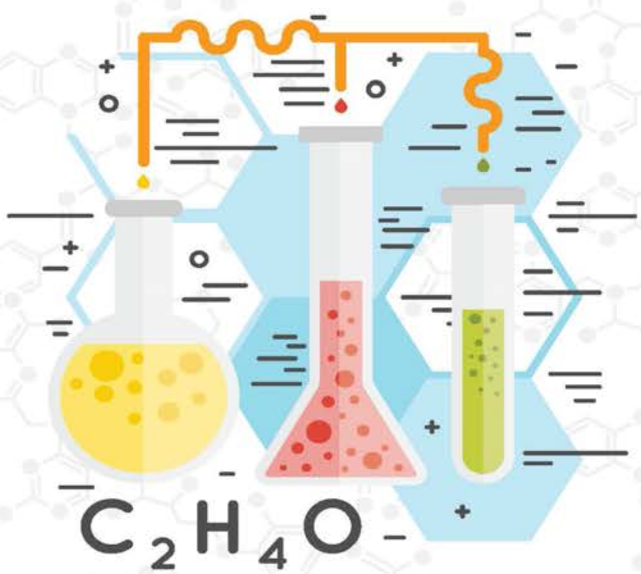
CHEMISTRY

TEXTBOOK



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АСТАНА
КІТАП

Dauren Kaliyev
Almas Ordabayev
Nurbolat Zhumagulov
Abylay Samatov
Ali Tor

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

CHEMISTRY

Grade 8

1ST EDITION

АСТАНА
КІТАП

Astana 2017

UDC 373.167.1(075.3)
LBC 24 я 72
C 51

D. Kaliyev
C 51 **CHEMISTRY, Grade 8:** Textbook / Dauren Kaliyev, Almas Ordabayev, Nurbolat Zhumagulov, Abylay Samatov, Ali Tor
– Almaty: Астана-кітап, 2017. - 128 p.
ISBN 978-601-7415-66-2

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ISBN 978-601-7415-66-2

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.

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

via telegram app: @astanakitap

Best regards,

team of authors, “Астана-кітап”

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CHAPTER 1: ELECTRONS IN ATOMS

1.1 ELECTRON ARRANGEMENT

How do electrons affect the properties of the atom?

You will:

- define the number of electrons in each level;
- write electron arrangement of the first 20 elements in Periodic Table.

The lightest basic particle of an atom is the electron. It has a mass of approximately 1/2000 amu (amu = atomic mass unit is equal to $1.66*10^{-27}$ kg). For a neutral atom, numbers of protons and electrons are always equal. For example, hydrogen is the first element in the Periodic Table, so it has one proton and one electron.

Electrons are negatively charged particles. They rotate on fixed energy levels (shells) around the nucleus. The first shell is the nearest to nucleus and denoted as "K" shell. The second shell is known as "L", the third is "M" and so on in an alphabetical order.

The total number of energy levels in an atom matches with the number of the period of its element in the periodic table.

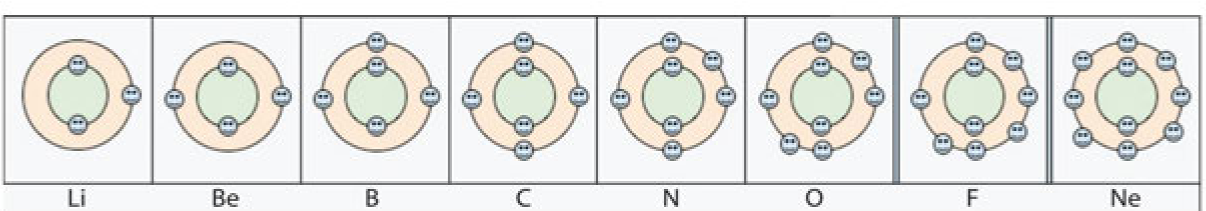
Each shell has a certain number of electrons. Number of electrons is defined by the equation $N=2n^2$. Here, n is the shell number. The first energy level (K) can include a maximum of 2 electrons, the second energy level (L) have 8 electrons, and so on.

Here are below a maximum number of electrons on "K", "L", "M", "N" shells.

First shell (K)	for n = 1	$2 \times n^2 = 2 \times 1^2 = 2$ e
Second shell (L)	for n = 2	$2 \times n^2 = 2 \times 2^2 = 8$ e
Third shell (M)	for n = 3	$2 \times n^2 = 2 \times 3^2 = 18$ e
Fourth shell (N)	for n = 4	$2 \times n^2 = 2 \times 4^2 = 32$ e

When the first attempts were made to construct a Periodic Table, nobody knew about the structure of the atom. However, now we can connect position of the element with electron configuration and its properties.

Electrons in the outermost shell of the atom are called valence electrons. Elements in the same group have the same number of valence electrons and have similar properties. It means that a number of valence electrons determine properties of an element. For example, alkali metals that are located in a 1st group, have 1 valence electron. All alkali metals have similar properties. They have relatively low density, easily oxidize in the air, violently react with water.



Electron distribution of elements in 2nd period of alkali metals

Atomic Number (Protons)	Symbol	Name	State at room conditions	Electron in the shells
1	H	Hydrogen	gas	1)
2	He	Helium	gas	2)
3	Li	Lithium	solid	2) 1)
4	Be	Beryllium	solid	2) 2)
5	B	Boron	solid	2) 3)
6	C	Carbon	solid	2) 4)
7	N	Nitrogen	gas	2) 5)
8	O	Oxygen	gas	2) 6)
9	F	Fluorine	gas	2) 7)
10	Ne	Neon	gas	2) 8)

Keep in mind:

The distance between nucleus and shells increases with increasing the number of shells.

Literacy

1. Write electron arrangements of elements: Na, Mg, Al, Si, P, S, Cl, Ar, K, Ca.
2. Which ones of the elements above have similar chemical properties?
3. Why is helium placed in a group 18 with neon but has different electron configuration? (Use the Periodic table on page 116)

Lab work

Introduction:

Before constructing the model, you will need to know how many protons, neutrons and electrons has the atom. Let's take carbon atom as an example. Using information from the periodic table of the elements, we can say that carbon atom has 6 protons, 6 neutrons and 6 electrons.

Materials:

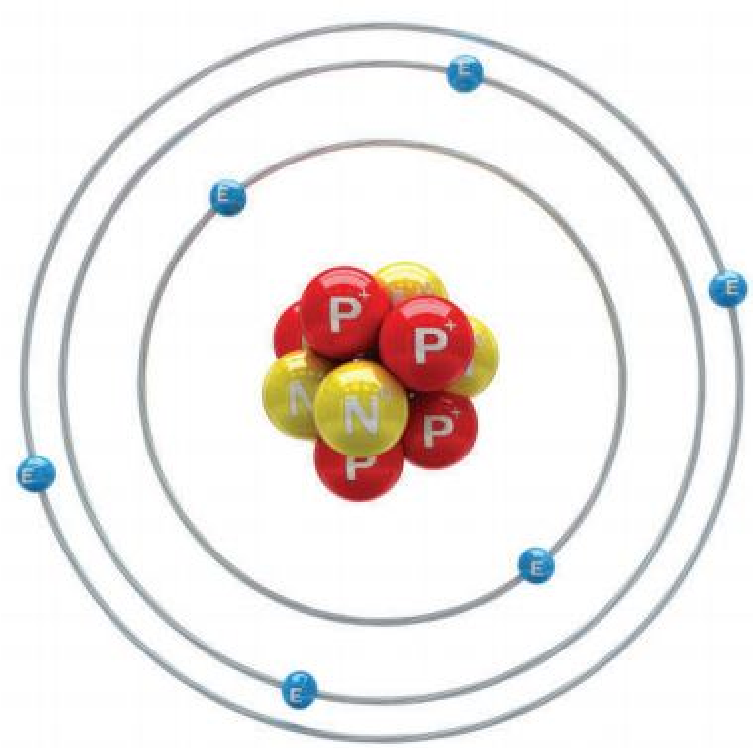
Coloured or painted ping-pong balls (or rubber balls), wires.

Procedure:

The nucleus of the atom consists of protons and neutrons. Electrons are surrounding the nucleus on certain shells. Build an atom model with proton, neutron and electron particles using balls and wires. Use your own idea and imagination.

Observation & questions:

- Which particles are charged negatively?
- Charge of the proton is .... and charge of the neutron is ....
- What is the total number of charged particles in a carbon atom?



Structure of the carbon atom

Terminology

- light - жеңіл / легкий;
- amu (atomic mass unit) - а.м.б. (массаның атомдық бірлігі) / а.е.м. (атомная единица массы);
- approximately - жуық / приблизительно;
- to occupy - көлем алу / занимать;
- outermost - сыртқы / внешний;
- valence electrons - валенттік электрондар / валентные электроны;
- electron distribution - электрондардың орналасуы / распределение электронов;

- electron arrangement -электрондардың орналасуы / распределение электронов.

1.2 FORMATION OF IONS. WRITING CHEMICAL FORMULA FOR COMPOUNDS

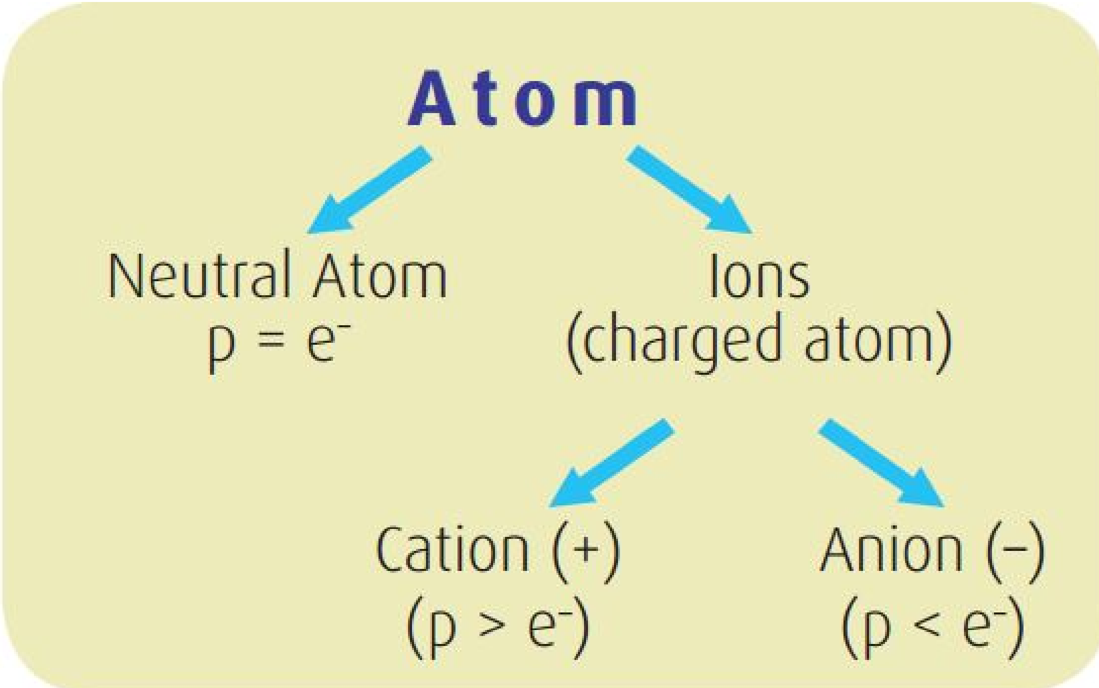
Why do elements "want" to be like Noble gases?

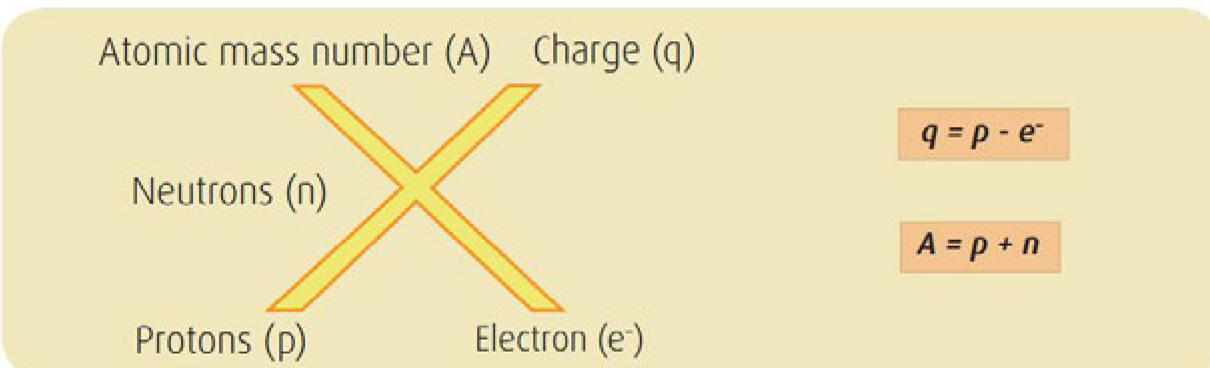
You will:

- understand how some atoms complete their electron shells;
- write chemical formula for compounds.

Every atom "wants" to be stable. Stability of any atom is related to the electron arrangement. Atoms with completed electron shells are known as the most stable ones. So, to become stable atoms need to lose or gain electrons. For example, if sodium atoms ($_{11}Na$) lose one electron, they will gain the electron configuration of neon ($_{10}Ne$). If chlorine atoms ($_{17}Cl$) gain one electron, they will have the stable electron configuration of argon ($_{18}Ar$).

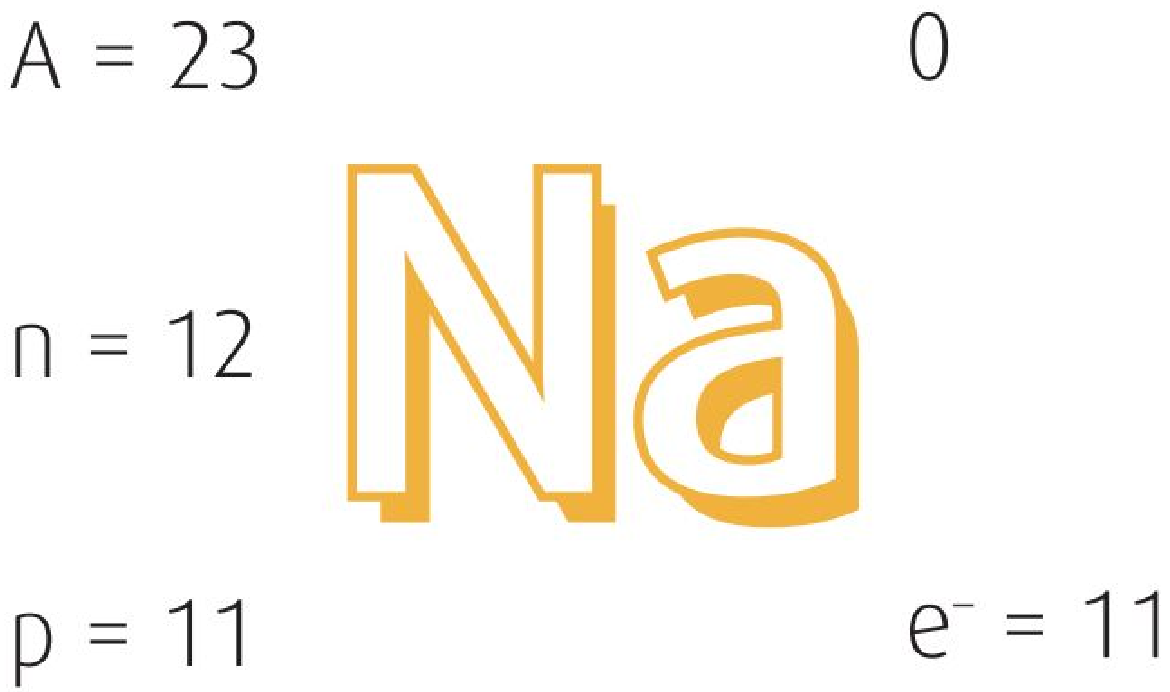
Atoms are neutral particles. Their number of protons and electrons are equal. Therefore, the charge of a neutral atom is zero. But there are also charged particles. Charged atoms are simply called ions. There are two types of ions: cations and anions. If the number of protons is greater than the number of electrons in an atom, it is a cation. As for anion, the number of protons is smaller than the number of electrons.





The X representation shows an atom's number of electrons, number of protons, number of neutrons, charge and atomic mass number.

Here, X represents any symbol of an element such as Al, K, Mg, etc... For example, neutral sodium atom (Na) has 11 protons, 11 electrons, 12 neutrons and an atomic mass number of 23.



Example 1

What are the number of neutrons and the charge of a bromine ion?

Solution

If $A = p + n$ $\quad$ $n = A - p$ and $n = 80 - 35 = 45$

If $q = p - e$-and then $q = 35 - 36 = -1$

Writing formulas of ionic compounds

The sum of the oxidation numbers (charges) of all elements in a compound is equal to zero.

Example 2

Find sum of ions' charges in a CaCI2.

Solution

Ca has +2 charge and we know that Cl has -1 charge.

So +2 x 1(Ca atom) + (-1) x 2(2Cl atoms) = +2 + (-2) = 0

Answer is 0.

In order to write the formula of the compound, formed by X^{+n} and Y^{m-}, the charges should be crossed, as shown in the example. Here, crossing means writing a number of the charge of an ion as a subscript on the other one.

Example 3

Show how formulas are written for the compounds: NaCl and KNO3.

Solution

a. Na^{+1} Cl^{-1}

Na_1Cl_1 or $NaCl$

b. K^{+1} NO_3^{-1}

$K_1(NO_3)_1$ or KNO_3

Exercise

Write formulas for the compounds formed between following pairs of ions:

a. Na^{+1} and O^{-2}

d. K^{+1} and PO_4^{-3}

b. Ca^{+2} and S^{-2}

e. Mg^{+2} and SO_4^{-2}

c. Al^{+3} and F^{-1}

f. Fe^{+3} and NO_3^{-1}

Literacy

Fill in the blanks.

- Atom is the basic building block of ....
- The subatomic particles are .... , ... and ....
- .... and .... are found in the nucleus.
- Electrons turn around the ....
- The mass of the atom is the sum of the .... and ....
- The numbers of electrons and protons are .... in the neutral atom. • The numbers of electrons and protons are .... in the ionic atom.
- The charge of the proton is .... but the charge of the electronis....................
- The charge of the neutron is ....
- The mass of .... or .... are 1 a.m.u. but a mass of the electron is about ....
- The charges of cation and anion are crossed to write the .... of a compound.
- The formula of Atomic Mass(A)=..

Terminology

- stable - тұрақты / стабильный;
- particle - бөлшек / частица;
- electron shells - электрон қауыздары / электронные оболочки;
- to gain electrons - электрон алу / получать электроны;
- to lose electrons - электрон жоғалту / терять электроны.

Problems: Electrons in Atoms

1. What kind of charge does a neutron have?

2. What kind of charge does an electron have?

3. How many electrons are there in the following elements?

   a. O
   b. Fe
   c. He
   d. Ar

4. How many valence electrons does each atom have?

   a. Sodium
   b. Fluorine
   c. Chlorine
   d. Chromium

5. Fill the gap: Elements in the same group have the same number of................................electrons.

6. If an atom has 13 protons in the nucleus, how many electrons will surround the nucleus?

7. If an atom has 11 protons in the nucleus, how many valence electrons will it have in outer shell?

8. How many protons are there in the nucleus with an atomic number 21?

9. What is the mass number of an atom with 26 protons, 30 neutrons and 26 electrons?

10. How many neutrons are there in the nucleus of an atom with an atomic number of 20? (Use the Periodic table)

11. An ion of nitrogen has a charge of -3. How many protons and electrons do the ion have?

12. The mineral halite is made of chlorine and sodium. Use the Periodic table of the elements to determine what charge each of these elements will take to form a compound.

13. The element oxygen will always take charge of -2 in naturally occurring rocks and minerals. The chemical formula for the compound, which makes up the mineral ruby, is Al2O3. What is the charge of aluminium in this compound?

CHAPTER 2: CHEMICAL REACTIONS

2.1 WRITING CHEMICAL EQUATIONS

Can you write any reaction that occurs in nature?

You will:

- understand the meaning of symbols;
- know how to use Periodic Table;
- calculate molecular masses of different compounds.

Atomic and molecular masses

Now you know that atom has 3 subatomic particles: proton (p), neutron (n) and electron (e-). It also has mass which is called relative atomic mass (Ar). As you remember Ar is the addition of p and n.

$$Ar = p + n$$

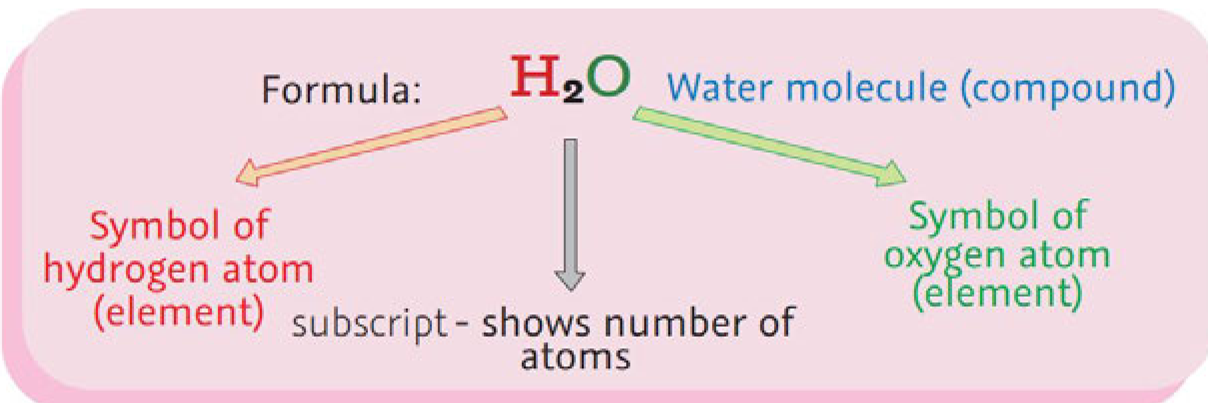
Elements contain only one type of the atom. We use symbols to show elements. For example, gold – Au, hydrogen – H, oxygen - O and iron – Fe. All elements are placed in the Periodic Table.

Nowadays, scientists discovered 118 elements. 92 of them are natural elements. They are building blocks of everything.

Elements in the Periodic Table are arranged by the number of protons or atomic number. Look at the example on the left. The atomic number of the carbon is 6. Its atomic mass is 12. Ar(6C) = 12.

Atomic mass of oxygen is 16. We write it like Ar(8O) = 16.

The combination of two or more elements is called compound. All compounds are shown by formulas. Here some examples of compounds: H2O (water), CO2 (carbon dioxide), CaO (calcium oxide), CaCO3 (calcium carbonate), H2SO4 (sulfuric acid).



Mass of compounds is called relative molecular mass or just molecular mass (Mr). To calculate molecular mass of compound uses atomic masses of elements in that compound. For any compound, which has chemical formula X Y molecular mass is

$$M_r(X_nY_m) = A_r(X) \cdot n + A_r(Y) \cdot m$$

As an example, we will take water. Water has 2 atoms of H and 1 atom of O.

$$Ar(H) = 1, Ar(O) = 16.$$

Molecular mass of water is equal to

$$Mr(H_2O) = Ar(H) \bullet 2 + Ar(O) \bullet 1 = 1 \bullet 2 + 16 \bullet 1 = 18$$

Keep in mind

Some substances have two or more same atoms: O_2 - oxygen molecule has two atoms of oxygen; C_{60} - fullerene molecule composed of sixty atoms of carbon.

Facts

The number of known chemical compounds is about 29.000.000.

Writing chemical reactions

As we know, a chemical reaction is the formation of a new substance. In these changes, complicated substances can break down into simpler substances, simple substances can combine into complex ones or can exchange parts. Let's see some examples.

Hydrogen + Oxygen --> Water

$$H_2 + O_2 \rightarrow H_2O$$

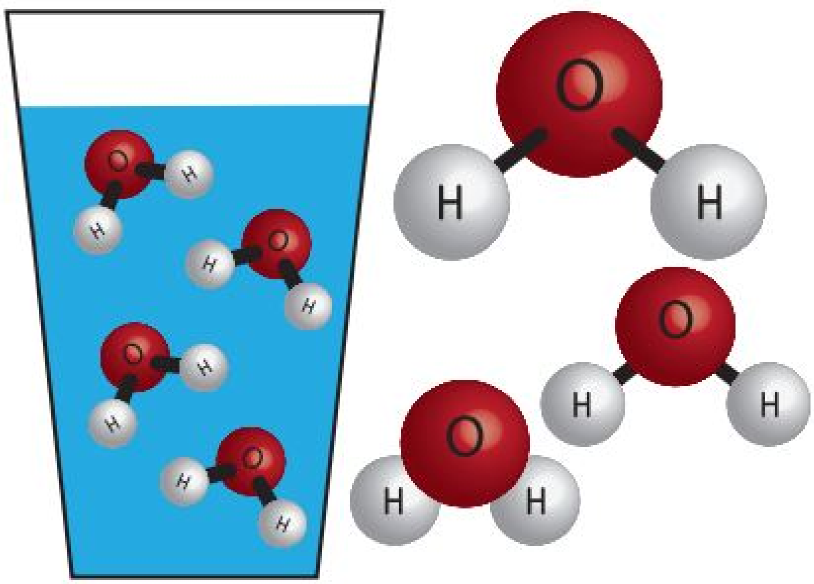
Iron + Sulfur --> Iron (II) sulfide

$$Fe + S \rightarrow FeS$$

Carbon dioxide + Water --> Glucose + Oxygen

CO_2 + H_2O --> $C_6H_{12}O_6$ + O_2

Photosynthesis reaction is essential for life on the Earth



Water molecules

Literacy

1. Find atomic masses A r of following elements. Use the Periodic Table.

   a. Na
   b. Br
   c. Pb

2. Calculate molecular masses M r of following compounds. Use the Periodic Table to find A of elements.

   a. Al_2O_3 (Aluminium oxide)
   b. $KMnO_4$ (Potassium permanganate)
   c. CH_3COOH (Acetic acid from vinegar)
   d. $C_6H_{12}O_6$ (Glucose)

3. Complete following reactions. Write chemical formula of missing compounds:

   a. Al (aluminium) + ________ (oxygen molecule) --> Al_2O_3 (aluminium oxide)
   b. ________ (water) + SO_3 (sulfur trioxide) > H_2SO_4 (sulfuric acid)
   c. CaO (calcium oxide) + _____(carbon dioxide) > $CaCO_3$ (calcium carbonate)

Terminology

- relative – салыстырмалы / относительная
- atomic mass– атомдық масса / атомная масса
- compound – қосылыс / соединение
- carbon dioxide – көмірқышқыл газы / углекислый газ;
- sulfuric acid – күкірт қышқылы / серная кислота;
- substance – зат / вещество;

- vinegar – сірке суы / уксус;
- acetic acid – сірке қышқылы / уксусная кислота.

Activity

Discussion about elements.

- Which elements are more important in our life? Why?
- Which elements do you think are less important? Why?

2.2 BALANCING CHEMICAL EQUATIONS

Is it possible for us to produce something from nothing?

You will:

- understand what is a coefficient;
- balance chemical equations.

Usually, we work with equations in math class. In math equations, the two sides of an equation are equal. It is the same for chemical equations. The number of atoms on the reactants (left) and products (right) sides should be the same.

In a chemical reaction, the masses and number of atoms in reactants and products are equal

To have an equal number of atoms in reactants and products, we should balance equations. "Balancing the equation" is putting natural numbers called coefficients in front of the symbols and formulas, and thereby getting equal numbers of the same atoms on the left and the right sides of the equation.

How can we balance a chemical equation?

a. Write the Skeleton Equation

In the skeleton equation, we just write the symbols or formulas of the reactants and products. For example, we want to write a balanced chemical equation for the reaction between methane CH_4 and oxygen gas O_2. The products of the reaction are carbon dioxide CO_2 and water H_2O. To begin, write the correct formulas for both reactants and products. Place the reactants CH4 and O2 on the left side of the arrow, separated by a plus sign. Then, write the products CO2 and H2O on the right side.

$$\underbrace{CH_{4(g)} + O_{2\,(g)}}_{\text{Reactants}} \rightarrow \underbrace{CO_{2\,(g)} + H_2O_{\,(g)}}_{\text{Products}}$$

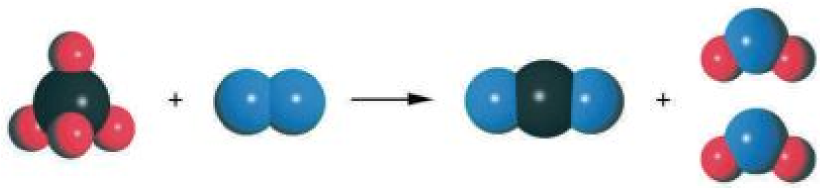
b. Check the Number of Atoms

Count the number of atoms of each element on each side of the equation.

$CH_4 + O_2$	$\rightarrow$	$CO_2 + H_2O$
1 C atom		1 C atom
4 H atoms		2 H atoms
2 O atoms		3 O atoms

c. Balance the number of atoms by coefficients

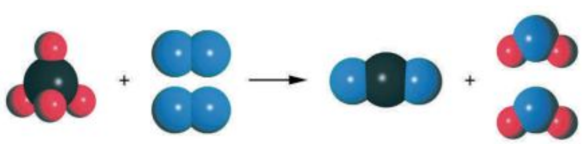
The number of carbon atoms on the two sides of the equation are equal. But numbers of hydrogen and oxygen atoms are not equal. We need to use coefficients to balance H and O. The number of H atoms in the reactants is twice the number of H atoms in the products. Therefore, we give coefficient “2” in front of the water molecule. It means that we need to double the number of water molecules on the product side. As a result, we equalized the number of hydrogen on left and right sides of reaction.



$CH_4 + O_2 \rightarrow CO_2 + 2H_2O$

1 C atom	1 C atom
4 H atoms	4 H atoms
2 O atoms	4 O atoms

Now there are 2 oxygen atoms on the left side and 4 oxygen atoms on the right. To balance the equation, write “2” in front of the oxygen in the reactants. Finally, check the number of atoms on both sides. Make sure that everything is balanced.



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

1 C atom	1 C atom
4 H atoms	4 H atoms
4 O atoms	4 O atoms

Word equation	Methane + Oxygen → Carbon dioxide + Water
Skeleton equation	$CH_4 + O_2 \rightarrow CO_2 + H_2O$
Balanced equation	$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$

In a chemical reaction, the masses and number of atoms in reactants and products are equal.

Burning of natural and associated gases

Keep in mind:

To balance an equation, we usually start with the most complex compound.

Never change the formulas when you are balancing an equation!

Literacy

Write an equation of chemical reaction in words and in symbols for next processes:

1. Decomposition of water;
2. Rusting of iron;
3. Burning of sulfur.

Lab work №2. Ratio of reactants

Introduction:

In this experiment we will heat a mixture of iron and sulfur to produce a new compound.

Materials:

Iron powder, sulfur powder, test tube, burner, test tube holder, scale.

Procedure:

1. Measure mass of a test tube with 5 g of iron Fe and 3 g of sulfur S.
2. Switch on the burner.
3. Mix iron and sulfur powders in a test tube.
4. Heat the test tube with mixture on a medium flame
5. Cool test tube.
6. Measure the mass of test tube with the new compound.

Observation & questions:

1. Write down the equation for the reaction and balance it.
2. What is the chemical formula for iron sulfide?
3. What is the colour of new substance?
4. Did the mass of test tube with product change?


Sulfur

Terminology

- thereby - яғни / таким образом;
- reactant – реагент / реагент;
- to suppose – тұжырымдау / предполагать;
- to measure - өлшеу / измерять;
- products - өнімдер / продукты;
- observation - бақылау / наблюдение;
- heating - қыздыру / нагревание;
- to balance - теңестіру / сбалансировать;
- powder - ұнтақ / порошок;
- equation - теңдеу / уравнение.

2.3 TYPES OF CHEMICAL REACTIONS

What are the chemical reactions around us?

You will:

- know the types of chemical reactions and differences between them;
- understand some reactions in daily life.

As we know, chemical reactions are changes in which new substances are formed. Most chemical reactions can be classifi ed as follows (4 main types): combination, decomposition, single displacement and double displacement reactions.

1. Combination (synthesis)

Combination reactions occur where two or more substances react to form just one product. For example, sulfur is an element found in fossil fuels. When we burn these fuels, sulfur S also reacts with oxygen O2 to produce sulfur dioxide SO2:

$$S + O_2 \rightarrow SO_2$$

Then, sulfur dioxide SO2 combines with oxygen O2 in the air to give sulfur trioxide SO3:

$$2SO_2 + O_2 \rightarrow 2SO_3$$

Finally, sulfuric acid H_2SO_4 is formed by the combination of sulfur trioxide SO_3 and water H_2O. This acid may cause acid rain:

$$SO_3 + H_2O \rightarrow H_2SO_4$$

In these reactions, simpler substances combine to make a more complex one. Such reactions are called combination or synthesis reactions.

We can show combination reaction in this way:

$$\boxed{A + B \longrightarrow AB}$$

2. Decomposition reaction

When an electric current is passed through water, water molecules break down into their constituent elements, hydrogen and oxygen:

$$2H_2O \rightarrow 2H_2 + O_2$$

In this reaction, a complex substance breaks down into simpler substances. Such reaction is called decomposition reaction.

We can show decomposition reaction in this way:

$$\boxed{AB \longrightarrow A + B}$$

3. Single displacement reaction

Reducing pure metals from oxides is an example of single displacement reaction. As a reducer, we can use substances such as carbon monoxide CO and hydrogen H_2. For example, when magnetite, Fe_3O_4, is heated with hydrogen, pure iron Fe is obtained:

$$Fe_3O_4 + 4H_2 \rightarrow 3Fe + 4H_2O$$

In the reaction above, hydrogen gas H_2 displaces iron Fe from Fe_3O_4. Reactions in which one element displaces another one are called as single displacement reactions.

We can show single displacement reaction in this way:

$$\boxed{A + BC \longrightarrow B + AC}$$

4. Double displacement reaction

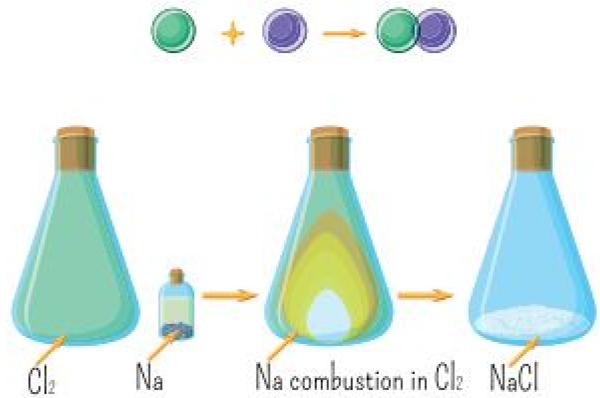
In a double displacement reaction, two parts of different compounds displace to form two new compounds. In such reactions, two reactants give two products.

We can show double displacement reaction in this way:

$$\boxed{AB + CD \longrightarrow AD + CB}$$

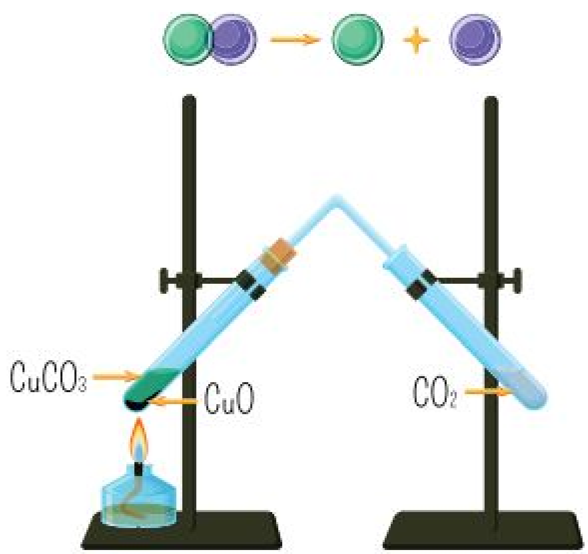
For example, when potassium chloride solution KCl mixes with silver nitrate $AgNO_3$ solution, the potassium and silver exchange their atoms. As a result, two new compounds are formed: silver chloride $AgCl$ and potassium nitrate KNO_3:

$$KCl + AgNO_3 \rightarrow KNO_3 + AgCl$$



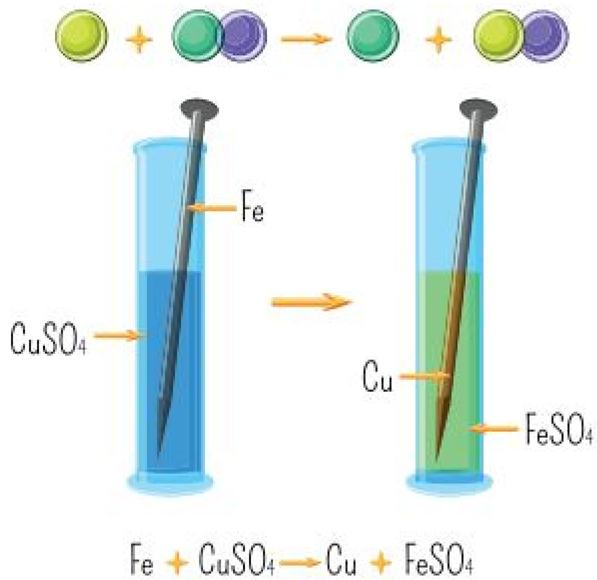
$2Na + Cl_2 \rightarrow 2NaCl$

Combination reaction

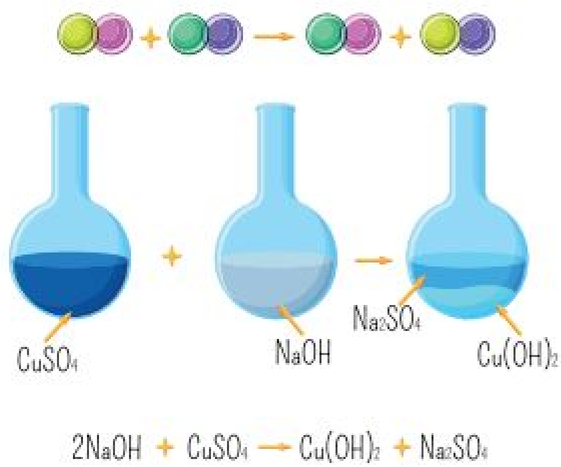


$CuCO_3 \rightarrow CuO + CO_2$

Decomposition reaction



Single displacement reaction



Double displacement reaction

Literacy

Classify the following reactions:

a. Fe(s) + 2HCl(aq) --> FeCl2(aq) + H2(g)
b. Pb(NO3)2(aq) + Na2SO4(aq) --> 2NaNO3(aq) +

$PbSO_4(aq)$
c. $2K(s) + Cl_2(g) \rightarrow 2KCl(s)$
d. $MgI_2(aq) + Br(l) \rightarrow MgBr_2(aq) + I_2(l)$

Facts

Almost all biological processes such as respiration and photosynthesis are chemical reactions.

Terminology

- to occur – болу, орын алу / происходить, иметь место;
- electric current – электр тогы / электрический ток;
- combination reaction – қосылу реакция соединения;
- to cause – себеп болу / являться причиной;
- decomposition reaction – ыдырау, айырылу реакциясы / реакция разложения
- singe displacement reaction – орынбасу реакциясы / реакция замещения
- double displacement reaction - алмасу реакциясы / реакция обмена
- fossil fuel - қазба отыны / ископаемое топливо;
- solution – ерітінді / раствор;;
- respiration – тыныс алу / дыхание;
- combustion – жану / горение;
- constituent - құраушы /; составляющий.

Facts

There is a tree in Africa named as Sclerocarya birrea but commonly known as Marula. Fruits of that tree are edible by men and animals. But once fruits fell down of a tree, they go into alcoholic fermentation. Alcoholic fermentation is a chemical change when glucose decomposes into carbon dioxide gas and poisonous ethyl alcohol. Usually, animals such monkeys, elephants, some birds eat fallen fruits and get drunk! When animals get drunk they often fall or even cannot stand.

2.4 CHEMICAL FORMULA AND CALCULATIONS

Which one contains a higher percentage of sodium metal: table salt or washing soda?

You will:

- find mass percentage of elements in compounds;
- find formulas of compounds.

Calculating mass percentage of elements

To find a mass percentage of an element (w) we need to calculate the relative molecular mass of compound Mr. Let's see in an example of SO2 (sulfur dioxide). We can calculate (w) in two ways:

a. Proportions

The SO2 molecule has 1 atom of sulfur and 2 atoms of oxygen.

$$Ar(S) = 32,$$

$$Ar(O) = 16.$$

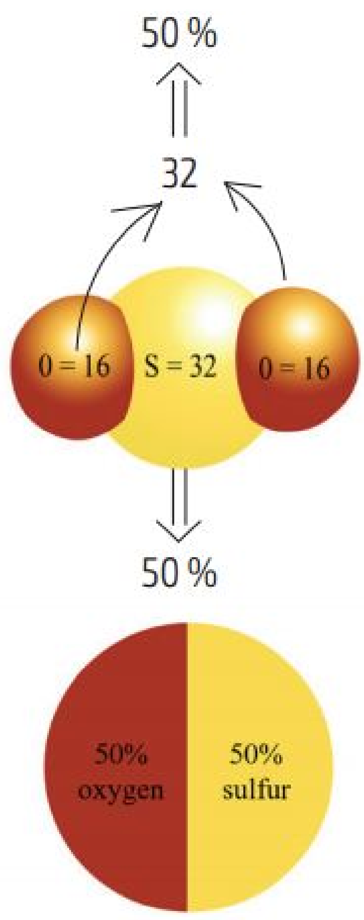
$$Mr(SO2) = Ar(S) + Ar(O) * 2 = 32 + 16 * 2 = 64$$

We can calculate the mass percentage of elements using proportion. Take, that Mr(SO2) is 100%:

$$M_r(SO_2) - 64 \qquad \text{is} \qquad 100\%$$
$$A_r(S) - 32 \qquad \text{is} \qquad \omega(S)$$

$$\omega(S) = \frac{A_r(S) \cdot 100\%}{M_r(SO_2)} = \frac{32 \cdot 100\%}{64} = 50\%$$

The other 50% is the mass percentage of oxygen because there are only two types of atoms (S and O).



Mass percentage of elements in sulfur dioxide (SO_2)

b. Formula

Let's take the chemical formula of XnYm . Molecular mass is Mr(XnYm), and atomic masses of elements are A r(X) and Ar(Y). We can use following formula to calculate the mass percentage of element X:

$$\omega(X) = \frac{A_r(X) \cdot n}{M_r(X_nY_m)} \cdot 100\%$$

Facts

Sulfur dioxide is one of the gases that cause acid rain.

Example 1

Calculate mass percentage of iron (Fe) in iron (III) oxide (Fe2O3).

Solution:

Iron (III) oxide (Fe2O3) has 2 atoms of Fe and 3 atoms of O. Find atomic masses Fe and O in the Periodic Table.

Ar(Fe)=56 and Ar(O) = 16.

Mr(Fe2O3) = Ar(Fe) • 2 + Ar(O) • 3 = 56 • 2 + 16 • 3 =112 + 48 = 160

Use equation to find mass percentage of iron:

$$\omega(Fe) = \frac{A_r(Fe) \cdot 2}{M_r(Fe_2O_3)} \cdot 100 = \frac{56 \cdot 2}{160} \cdot 100 = 70\%$$

$$\omega(O) = 100\% - 70\% = 30\%$$

Finding formula of a compound using mass percentages of elements

To find a chemical formula by given mass percentages of elements .(X) and .(Y) in a compound Xn Y m we need to find a ratio between "n" and "m" (n : m). It is equal to

$$n : m = \frac{\omega(X)}{A_r(X)} : \frac{\omega(Y)}{A_r(Y)}$$

In this operation, we need to turn "n" and "m" numbers to natural numbers. Let's look at the example:

Example 2

Find chemical formula of a compound Crn Om with given ω(Cr) = 68.4% and ω(O)=31.6%.

Solution.

Step 1: Find atomic masses of elements in the compound using the Periodic Table. They are Ar(Cr) = 52 and Ar(O) = 16. Now, to find ratio between "n" and "m" use equation:

$$n:m = \frac{\omega(Cr)}{A_r(Cr)} : \frac{\omega(O)}{A_r(O)} = \frac{68.4}{52} : \frac{31.6}{16} = 1.315 : 1.975$$

Step 2: Divide this two numbers by the smallest number of them. The smallest number is 1.315. Then turn them into natural numbers.

$$n:m = \frac{1.315}{1.315} : \frac{1.975}{1.315} = 1 : 1.5 = 2 : 3$$

Formula of unknown compound is Cr2O3.

Science in context

Approximate mass percentage of "Nauryz kozhe": 42% of milk (dairy products), 25% of water, 17% of meat, 8% of onion, 4% of rice and 4% of millet.

Nauryz kozhe

Literacy

1. Calculate the mass percentage of oxygen ω(O) in following compounds. Use the Periodic Table to find atomic masses of elements. Al2O3, K2Cr2O7, CaCO3, Mg(OH)2.
2. Find chemical formula of the following compounds with given mass percentages: ZnxOy,

   ω(Zn) = 80.2% and ω(O) = 19.8%;
   MnxCly, ω(Mn) = 27.9%
   Use the Periodic Table to find atomic masses Ar of elements.

Terminology

- quantitative – сандық / количественный;
- mass percentage – массалық үлес / массовая доля;
- equation – теңдеу / уравнение;
- ratio – қатынас / отношение;
- dairy – сүтті / молочный;
- millet – тары / пшено;
- approximate - шамамен, жуық / примерный.

Problems: Chemical reactions

1. Calculate the molar masses of following compounds: CaO, Na_2S, SiO_2 , KI, OF_2 , $NaHCO_3$, Li_2SO_4 , H_2CO_3, CH_3COOH.

2. How many atoms of each element are represented in each of the following expressions?

   A) $5H_2O$
   B) $3Al(OH)_3$
   C) $CaCO_3$
   D) $15NH_4OH$
   E) $10C_2H_5OH$

3. What is a word equation? Write the word equation for the following reactions:

   A) $2Na(s) + Cl_2(g)$ --> $2NaCl(s)$
   B) $C(s) + O_2(g)$ --> $CO_2(g)$

4. Write the word equations and equations with symbols and formulas for the following reactions:

   A) The metal calcium reacts with fluorine gas and forms solid calcium fluoride, CaF_2.
   B) Carbon dioxide gas reacts with water to give an aqueous solution of carbonic acid, H_2CO_3.

5. Balance the following chemical equations:

   A) $Fe + O_2$ --> Fe_2O_3
   B) $Fe + HCl$ > $FeCl_2 + H_2$
   C) Ag_2O --> $Ag + O_2$
   D) $Fe_2O_3 + Al$ --> $Al_2O_3 + Fe$

E) Ca(OH)2 + HNO3 --> Ca(NO3)2 + H2O
F) KBr + Cl2 --> KCl + Br2
G) MgO + H3PO4 --> Mg3(PO4)2 + H2O

6. What is the difference between combination and decomposition reaction? Give two examples of each.

7. Complete these word equations and write corresponding symbol equations:

A) Iron (II) oxide + Carbon -->
B) Zinc chloride + Magnesium -->
C) Copper (II) oxide + Hydrogen -->

8. What is the percentage by mass of oxygen in Fe3O4?

9. What is the percentage by mass of oxygen in CaSO4*2H2O?

10. Oxide of manganese contains 63.22% of manganese and 36.78% of oxygen by mass. According to the given information determine the empirical formula of the oxide?

11. Which one is double displacement reaction?

A) H2 + Cl2 --> 2HCl
B) 4P + 5O2 --> 2P2O5
C) Pb(NO3)2 + Fe --> Fe(NO3)2 + Pb
D) Al2O3 + 6HCl --> 2AlCl3 + 3H2O
E) CaSO3 --> CaO + SO2

12. Which one is the combination reaction?

A) 2NaHCO3 --> Na2CO3 + CO2 + H2O
B) 2Ca + O2 --> 2CaO
C) 2NaBr + Cl2 --> 2NaCl + Br2

D) $KOH + HI \dashrightarrow KI + H_2O$
E) $2HgO \dashrightarrow Hg + O_2$

13. Which of the following reactions is decomposition reaction?

A) $C + O_2 \dashrightarrow CO_2$
B) $MgCO_3 \dashrightarrow MgO + CO_2$
C) $H_2O(l) \rightarrow H_2O(g)$
D) $Zn(s) + CuSO_4(aq) \rightarrow ZnSO_4(aq) + Cu(s)$
E) $BaCl_2(aq) + Na_2SO_4(aq) \rightarrow BaSO_4(s) + 2NaCl(aq)$

CHAPTER 3: METALS IN OUR LIFE

3.1 CORROSION

Why do knives and spoons not rust?

You will:

- know the meaning of corrosion;
- understand why some metals corrode;
- understand that some metals corrode faster than others;
- know the reasons for corrosion.

Almost 80% of all elements in the Periodic Table are metals. That is why the role of metals is great in the modern world. Even people are able to create amazing materials; metals remain the most important elements for production of electronics, cars, jets, rockets, technics, construction materials.

Metals are wide spread in nature. Lithosphere contains aluminium, iron, calcium, magnesium, sodium, potassium. These metals, oxygen and silicon are the 99% by mass of the Earth`s crust. The water of seas and oceans contains salts of many metals: sodium, magnesium, calcium, etc.

Metals play important role in the biosphere. Almost all important processes in living organisms are impossible without metals. People need calcium for bones and tooth. Blood contains iron. Magnesium is in the chlorophylls of plants.

Rusting of two old iron ships in Aral desert.

Corroded old large water pipes after many years of uses

Rusty train in the cemetery of old trains in Bolivia

Corrosion

How do people produce metals? We can get them by smelting metal ores. Ores are compounds of metals with nonmetals like oxygen, hydrogen, sulfur, carbon and others.

Only metals like gold and platinum, sometimes silver and copper can be found on the Earth in free metallic form. These metals are not active. They generally do not produce compounds in nature. But all other metals exist in nature in forms of compounds. People have to smelt ores of those metals to produce pure iron, aluminium, zinc, manganese, lead, etc. By smelting metals from ores, we turn them from a stable state to unstable. That is why over time metals want to return to their stable states. Metals chemically interact with water, oxygen, microorganisms, etc. We call this process corrosion. Rusting is corrosion of iron or its alloys.

Corrosion leads to the destruction of many metallic materials such as kitchenware, household items. But sometimes corrosion can be a reason for big accidents such as plane, train, ship and car crashes, destruction of bridges, oil pipes. It is important to understand the nature of the corrosion process and learn how to prevent it.

Today people know how to protect metals with different methods. We can protect metals by making alloys, coatings with metals, nonmetals and painting.

Research time:

Take four beakers (50-100 ml), fill them with following solutions:

1. Tap water
2. 3% hydrogen peroxide solution (disinfectant in first-aid kit)
3. 10% sodium chloride solution (table salt)
4. 10% acetic acid solution (vinegar)

Put into the filled beakers 4 iron nails and leave them for 1 day. After that, take nails with tweezers. Arrange iron nails according to increasing of rusting effect. Take photos of nails. Discuss, share and compare results with your classmates.

Literacy

1. Aluminium is one of the active metals. But that metal is widely used in a production of technics, household items because it is resistive to corrosion. Search and explain why aluminium is so stable.
2. The Eiffel Tower in Paris was built in 1889. It is made of ordinary steel. That is why it rusts over time. To protect The Eiffel Tower against corrosion, it was the painted several times. One painting gives 60 tons of extra mass.

Initial mass of Tower was 9000 tons. But today it weighs about 10150 tons. How many times was the Eiffel Tower painted?

Facts

In the middle of 19th -century aluminium metal was very rare, so rare that it was even more expensive than gold. Napoleon III, President of the French Second Republic, used aluminium kitchenware for himself and other important guests. But other guests of less importance used golden spoons and knives! But today it is known that aluminium is the most abundant metal in the Earth's crust.

Facts

On April 28, 1988, Boeing 737 had an accident in Honolulu. During the flight, a front part of the plane was ripped away as a result of metal corrosion. One person was ejected from the plane.

Terminology

- corrosion - коррозия / коррозия;
- to rust - тот басу / ржаветь;
- ore - қазба байлық / руда;
- to smelt - балқыту / выплавлять;
- tweezers - пинцет / пинцет;
- steel - болат / сталь;
- resistive -төзімділік / устойчивость;
- to eject - лақтыру / выбрасывать;
- first-aid kit - дәрі-дәрмек / аптечка;
- rare - сирек / редкий.

3.2 REACTIONS OF METALS

What are the reasons for metal corrosion?

You will:

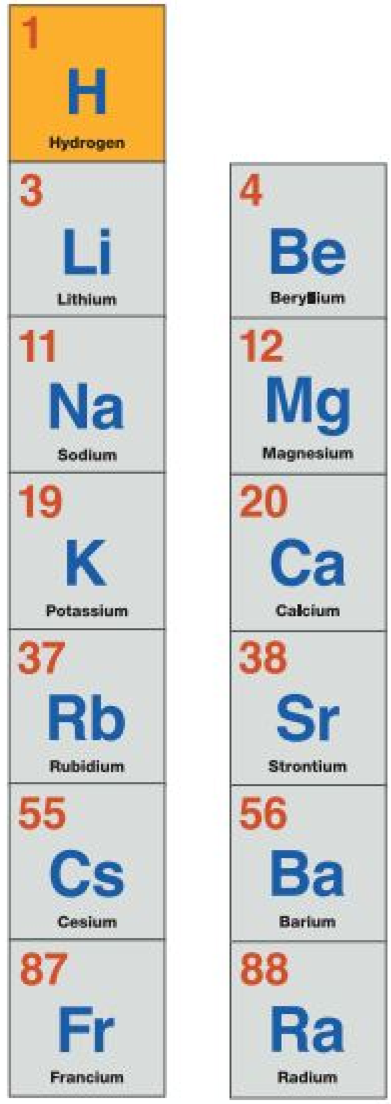
- compare reactivities of metals;
- describe the reaction of metals with water and acids.

Metals of Group 1 (Alkali metals) and some metals of Group 2 (Alkaline earth metals) are very active. They do not exist in elemental form on the Earth because they oxidize easily, and turn into compounds. All alkali metals and some of the alkaline earth metals such as calcium, strontium, barium react fast even with cold water to produce hydrogen gas and metal hydroxide. Magnesium reacts only with hot water. The reaction with water is the same in each case.

Metal + Water = Metal Hydroxide + Hydrogen Gas

For example:

Sodium (Na) + Water (H2O) = Sodium Hydroxide (NaOH) + Hydrogen Gas (H2)



Alkali metals (group 1) and alkaline earth metals (group 2)

The reaction of an alkali metal with water

Some metals like iron or zinc do not react with cold and hot water, but they can react with water steam at high temperatures. Products of these reactions are metal oxides and hydrogen gas. Iron and zinc are metals of medium activity.

Metal + Water Steam = Metal Oxide + Hydrogen Gas

For example:

Iron (Fe) + Water Steam (H_2O) = Iron Oxide (Fe_3O_4) + Hydrogen Gas (H_2)

Acidic solutions can dissolve metals of medium activity at room temperatures. For example, iron reacts with diluted solutions of strong acids like hydrochloric or sulfuric acid.

Iron (Fe) + Sulfuric Acid (H_2SO_4) = Iron Sulfate ($FeSO_4$) + Hydrogen Gas (H_2)

Iron (Fe) + Hydrochloric acid (HCl) = Iron Chloride ($FeCl_2$) + Hydrogen Gas (H_2)

There is the third group of metal that do not dissolve in most of the acids (inert metals). They can be dissolved only in concentrated solutions of strong acids. For example, copper or silver metals can react with concentrated nitric acid to produce salt, nitrogen dioxide gas and water.

Silver (Ag) + Nitric Acid (HNO_3) = Silver Nitrate ($AgNO_3$) + + Nitrogen Dioxide (NO_2) + Water (H_2O)

Activity:

The reactions of metals with water

Materials:

metallic sodium, copper, magnesium, Petri dishes, phenolphthalein indicator, tweezers.

Procedure:

1. Fill dishes with water.
2. Add 2-3 drops of an indicator in each dish.
3. Drop a small piece of sodium metal.
4. Repeat the tasks with a hot water for copper and magnesium.

NOTE: Dropping process sodium must be done by a teacher.

Observation & questions:

1. What are the colours of metals?

   Sodium - .... Magnesium - .... Copper - ....

2. What did you observe after dropping of metals into the water?

3. Write products of reactions:

   a. Magnesium + water =
   b. Sodium + water =
   c. Copper + water =

4. Arrange metals in order of decreasing activity: .... > .... > ....

Cross section of sodium metal

Lab work

№ 3. Reactions of metals with acids

Introduction:

Acids react with active metals and metals of medium activity to produce salts and hydrogen gas.

Materials:

iron, aluminium and copper metals, solution of acetic acid, test tubes.

Procedure:

1. Put a sample of iron, aluminium, copper metals into the test tubes.
2. Add acetic acid solution to the metals. (If necessary heat).

Observation & questions:

Which metal does not react with an acid?
Which metal is the most active?
Arrange metals in order of decreasing activity: .... > .... > ....

Facts

Aluminium will not react with water at room temperature conditions. But if you mix aluminium with mercury and add some water, it will react. Products of that reaction are aluminium hydroxide and hydrogen gas. The reaction is similar to the reaction of alkali metals and alkaline earth metals with water.

Terminology

- to tarnish - қараю / тускнеть;
- to dissolve - еру / растворяться;
- alkali metals - сілтілік металдар / щелочные металлы;
- alkaline earth metals - сілтілік жер металдар / щелочно-земельные металлы;
- diluted - сұйылтылған / разбавленный.

3.3 ACTIVITY SERIES OF METALS

Which sword will be harder and more stable over time? A sword made of copper or gold? Why?

You will:

- understand how active metals displace passive metals from their salts;
- understand and write metal displacement reactions;
- develop activity series of metals;
- predict the possibility of reactions by using activity series of metals.

Metals have different reactivity. Active metals do not exist in the metallic form in nature, while inert metals can exist in metallic form.

An activity series is a list of metals arranged in order of relative reactivity. For example, aluminium metal can displace copper metal from its salt solution, so it is more reactive than copper:

$$2Al(s) + 3CuCl_2(aq) \rightarrow 2AlCl_3(aq) + 3Cu(s)$$

Iron can also displace copper metal from its salt solution:

$$Fe(s) + CuCl_2(aq) \rightarrow FeCl_2(aq) + Cu(s)$$

So iron is also more active than copper. But aluminium metal can also remove iron from its salt solution:

$$2Al(s) + 3FeSO_4(aq) > Al_2(SO_4)_3(aq) + 3Fe(s)$$

Aluminium is more active than iron, and the activity series of these elements would be Al > Fe > Cu. The following activity series built up similarly. The most active metals are at the left of series; the least active are at the right. Each metal is able to displace metals after it in a series from solutions of their compounds.

Activity series of metals

Li K Ba Ca Na Mg Al Mn Zn Cr Fe Co Ni Sn Pb (H) Cu Ag Hg Pt Au

Active *Medium active* *Passive*

The largest meteorite in the world contains iron, nickel, cadmium and other metals. Grootfontein, Namibia.

Facts

Lead is cheap and relatively not active metal. That is why Ancient Romans used lead kitchenware and built lead water pipes. After a while, many people in Rome got different illnesses such as weakness, apathy, dementia. Today it is known that all lead compounds are poisonous. Some people for falling off the Rome Empire is the lead metal!

The Taykazan was smelt in 1399 in Turkestan. Diameter is 2,45 m, weight - 2 tons. Kazan consists of seven metals: iron, zinc, tin, lead, copper, silver and gold.

"The Golden Man" found in Issyk kurgan (500 BC)

Facts

It is known that inert metals such as gold, platinum are insoluble in all types of acids. But they are soluble in a solution of concentrated nitric and concentrated hydrochloric acids. Because of that chemists call that solution as "King-water". However, there are four metals that are still insoluble even in a "King-water". They are osmium, iridium, rhodium and ruthenium.

Practice work

№1. Comparison of the activity of metals

Introduction:

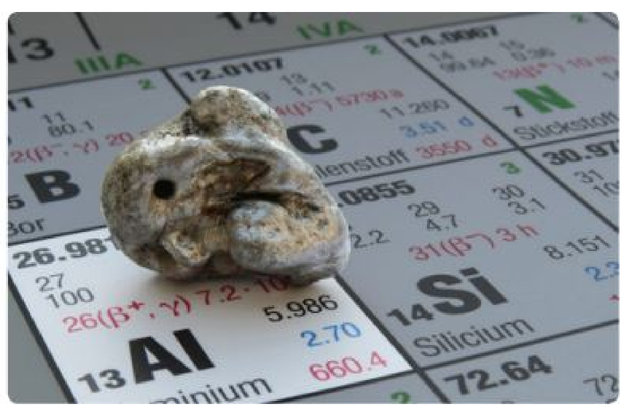
There are numbered solutions of copper sulfate, zinc sulfate and magnesium sulfate. Determine what solution is in each of the tubes by using copper, zinc and magnesium metals.

Materials:

solutions of copper sulfate, zinc sulfate and magnesium sulfate, zinc, copper, magnesium metals, test tubes, tweezers.

Procedure and questions:

1. Take solutions of salts and pour them into 3 test tubes.
2. By using tweezers put zinc, copper, magnesium metals into the test tubes with salt solutions.
3. Wait for 2 minutes. Then take out metals and observe them.
4. Write all possible reactions between salts and metals, balance them.
5. Arrange metals in order of decreasing activity: .... > .... > ....
6. Identify copper sulfate solution without providing any reaction.



Reflection

Reflection for the 1st quarter

The most difficult topic for me was

....

The easiest topic for me was

....

Rate yourself on 10-points scale

1. I can help others ....
2. I need more practice ....
3. I need extra lessons ....

Literacy

Write down the possible reactions and balance them:

a) $Fe(s) + CuCl_2(aq) \rightarrow$
b) $Zn(s) + AgNO_3(aq) \rightarrow$
c) $Fe(s) + Pb(NO_3)_2(aq) \rightarrow$
d) $Pb(s) + CuSO_4(aq) \rightarrow$
e) $Mg(s) + SnCl_2(aq) \rightarrow$
f) $Al(s) + Cr(NO_3)_3(aq) \rightarrow$
g) $Mg(s) + ZnCl_2(aq) \rightarrow$

h) $Au(s) + AgNO3(aq) \rightarrow$
i) $Mn(s) + NiBr2(aq) \rightarrow$

Terminology

- activity series - белсенділік қатары / ряд активности;
- passive - пассивті / пассивный;
- displacement - орынбасу / замещение ;
- sword - қылыш / меч;
- reactivity - реактивтілік / реактивность;
- ranked - реттелген / расположен;
- to remove - жою / удалить;
- least active - белсенділігі төмен / малоактивный;
- “King’s water”-“Патша сұйықтығы”/ “Царская вода”;
- inert - инертті / инертный

Problems: Activity of metals

1. What are the effects of corrosion?

2. Which metals have the highest corrosion resistance?

3. Study the main properties of metals.

4. Name useful metals that we use in our daily life.

5. Match the following:

I. Iron Fe
II. Copper Cu
III. Aluminium Al
IV. Mercury Hg
V. Gold Au
VI. Silver Ag

A. Airplane body, cans, foils
B. Thermometer
C. Bridges, wagon, car bodies
D. Jewelry, monetary unit, electronic microchips
E. Electrical wires, coins.
F. Jewelry, coins, antibacterial

6. Explain why active metals (sodium, potassium, calcium) only can be found in compounds in nature? Why is calcium metal never found in minerals on the Earth in its elemental form, but copper is found in its free form?

7. Which one is more expensive, platinum or gold? Explain.

8. Which one of the following metals react more vigorously with cold water?

A) Sodium
B) Iron
C) Magnesium
D) Copper
E) Zinc

9. Which one of the following metals will produce iron metal, if heated with iron oxide?

A) Copper
B) Lead
C) Aluminium
D) Gold
E) Silver

10. Which one of the following equations is correct?

A) Cu(s) + FeSO4(aq)→ CuSO4(aq) + Fe(s)
B) Zn(s) + CuCl2(aq) → Cu(s) + ZnCl2(aq)
C) Pb(s) + ZnSO4(aq) → PbSO4(aq) + Zn(s)
D) Au(s) + AlCl3(aq) → AuCl3(aq) + Al(s)
E) Cu(s) + KBr(aq) → K(s) + CuBr2(aq)

11. Write products of the following reactions (metal+salt):

- Fe + AgNO3 -->
- Al + AgNO3 -->
- Fe + CuSO4 -->
- Al + CuSO4 -->

12. Why do dentists not recommend to put a dental crown made of steel near the golden crown? Explain.

13. The bottom of the ship is generally made of iron. It is known that people attach a piece of more active metal to the bottom. Sailors call that piece as "protector". How do you think why it is important to attach a piece of metal to the bottom of the ship?

CHAPTER 4: MOLE

4.1 MOLE CONCEPT. AVOGADRO'S NUMBER

Are there more stars in Space than grains of sand on the Earth, or not?

You will:

- understand the importance of a number of atoms in chemistry;
- understand the calculation of molecules by using weighting method;
- know the mole as a unit.

Mole

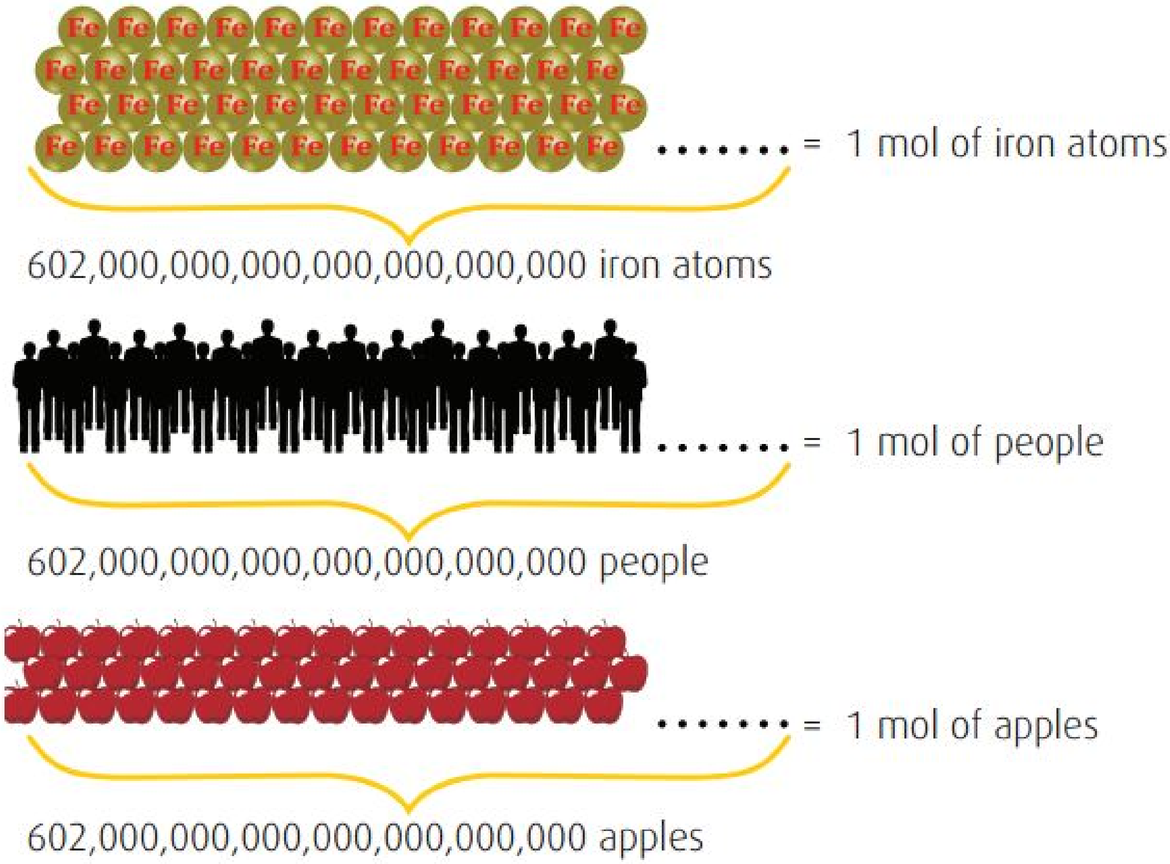
In daily life, instead of buying 60 strawberries from your market, isn't it easier to buy them in kilograms? Or, instead of packets of refined sugar, would not you like to buy 240 lumps in a supermarket?


Strawberries


Refined sugar

Similarly, when we study small particles in chemistry we use a special unit known as the mole (mol).

One of the most important units in chemistry is the mole. One mole is accepted as 6.02*1023 particles. Here, the particles may be atom, molecule or pencil. Scientists use the mole to make counting large numbers of particles easier.



Facts

There are 1.67 • 10^{21} H2O molecules in a drop of water.

Avogadro's number

602 000 000 000 000 000 000 000 is a very large number, known as Avogadro's number. It is symbolised as NA. Why do we use such huge numbers in chemistry? The answer is quite simple: because sizes of paricles are very small and number of these particles is very big.

For example, 1 hydrogen atom weighs about

1 atomic mass unit (amu) =
0.00000000000000000000000166 g

How is it possible to weigh this amount in a laboratory?

That is why, Avogadro's number, 6.02 • 1023, has proved to be a very good conversion factor. It makes our calculations easier.

$$1 \text{ gram of H} = 6.02 \cdot 10^{23} \text{ amu}$$

or

$$1g = N_A \cdot \text{ amu} = 1 \text{ mol of H}$$

Let's remember the example of the hydrogen atom again:

1 hydrogen atom is 1 amu.

$$\underbrace{6.02 \cdot 10^{23} \text{ of hydrogen atoms is 1 gram}}_{1 \text{ mol}}.$$

or 1 mol of hydrogen atoms is 1 gram, it's that simple.

Similar to hydrogen, this conversion can be used for all atoms or molecules. Let's look at the following examples,

I. The atomic mass of a carbon atom is 12 amu, or 1 mol of carbon atoms is 12 g.
II. The atomic mass of a calcium atom is 40 amu, or 1 mol of calcium atoms is 40 g.
III. The atomic mass of a platinum atom is 195 amu, or 1 mol of platinum atoms is 195 g.

Molar mass (M)

The mass of 1 mol (6.02 •1023) of substance in grams is defined as its molar mass.

1 mol of sodium atoms (Na) = 6.02 • 1023 Na atoms = 23 g

1 mol of zinc atoms (Zn) = 6.02 • 1023 Zn atoms = 65.4 g

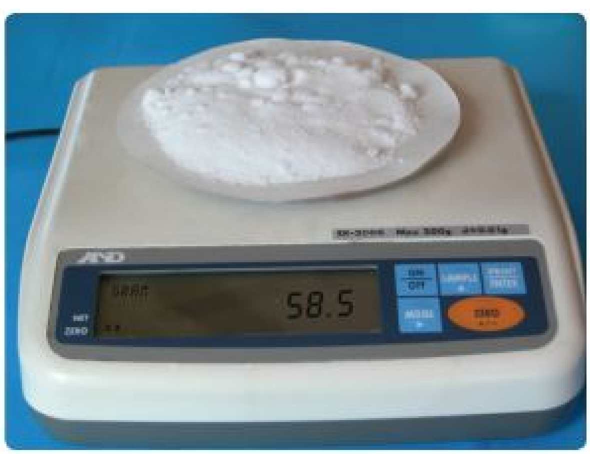
1 mol of oxygen molecules (O2) = 6.02 • 1023 O2 molecules = 32 g

1 mol of carbon dioxide molecules (CO2) = 6.02 • 1023 CO2 molecules = 44g

1 mol of sodium chloride (NaCl) = 6.02 • 1023 NaCl formula = 58.5 g

1 mol of hydrogen ions (H+) = 6.02 • 1023 H+ ions = 1 g

1 mol Zn (metal pieces)



1 mol NaCl (granules)

Keep in mind

Avogadro’s number is also known as Avogadro’s constant, which refers to 6.02 • 1023 particles per one mole.

Example

Calculate the molar mass of water, H2O.

Solution

The formula of water, H2O, is composed of 2 hydrogen atoms and 1 oxygen atom. By looking at the Periodic table you can find the mass of a hydrogen atom as 1 amu, and the mass of an oxygen atom as 16 amu.

Molar Mass of H2O = 2 • (mass of the H atom) + 1 • (mass of O atom)

Molar Mass of H2O = (2 • 1) + (1 • 16) Molar Mass of H2O = 18 amu

If water molecule is 18 amu, then 1 mole of water molecule is 18 g.

Literacy

What are the molar masses of HCl, NH3, H2CO3, Al(OH)3, CaCO3, Mg3(PO4)2?

Terminology

- mole – зат мөлшері / количество вещества;
- Avogadro’s number – Авогадро саны / число Авогадро;
- suitable – сәйкес / подходящий;

- quantity – мөлшер / количество;
- unit – өлшем бірлік / единица измерения;
- particles – бөлшектер / частицы;
- conversion – өзгеріс / превращение.

4.2 THE MOLE CONCEPT CALCULATIONS

The approximate population of the Earth is 7,5 billion people. How many moles of people are there on the Earth?

You will:

- calculate mass, mole, number of atoms and molecules by using the formula the of mole.

The number of moles, which is represented by n, is used for various calculations in chemistry. The number of moles is related to the number of particles, mass or volume of substances.

Little cute mole

Crowd of people

The Milky Way is the galaxy that contains our Solar System

Mole - mass relationship

The number of moles of a substance can be calculated with the help of its molar mass and mass. The following formula shows the relationship between the number of moles and mass.

$$\text{Number of moles} = \frac{\text{Mass}}{\text{Molar mass}} \qquad n = \frac{m}{M}$$

Units are n - mol, m - gram, M - g/mol.

Example 1

What is the mole number of 11,5 g of nitrogen dioxide (NO2) gas?

Solution

First, the molar mass of NO2 is calculated.

M(NO2) = 1 • 14 + 2 • 16 = = 46 g/mol.

Then, the number of moles is calculated by using the n= m / M formula.

$$n = \frac{11{,}5\ g}{46\ g/mol} = 0{,}25\ mol$$

Example 2

What is the mass of 1,5 moles of potassium hydroxide (KOH)?

Solution

M(KOH)= (1 • 39) + (1 • 16) + (1 • 1) = 56 g/mol

Then, the mass of KOH can be calculated by using the formula

m = n • M

m = 1,5 • 56 = 84 gram

Mole - number of particles relationship

If the number of particles (atoms, molecules, ions) for a substance is known, the mole number of that substance can easily be calculated, using the following formula:

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

here N - number of particles, N_A - Avogadro's number

Example 3

What is the number of moles of 3.01 • 1022 atoms of helium (He)?

Solution

By using the formula

$$n = \frac{N}{N_A}, \ n(He) = \frac{3,01 \cdot 10^{22}}{6,02 \cdot 10^{23}} = 0,05 \text{ mol}$$

Example 4

What is the total number of atoms found in two moles of a H2SO4 molecule?

Solution

By using the formula

$n(H2SO4)=N/N_A$

$2 = N/ (6.02*10^{23})$

$N = 1,204 \cdot 10^{24}$ H2SO4 molecules

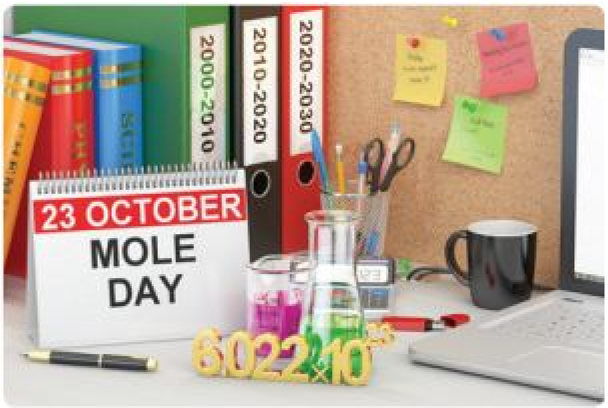
A H2SO4 molecule is composed of 7 atoms (2 Hydrogen, 1 Sulfur and 4 Oxygen).

Total number of atoms:

$Ntotal = 1,204 \cdot 10^{24} \cdot 7 = 8,428 \cdot 10^{24}$ atoms

Facts

Did you know? In some countries, Mole Day has celebrated annually on October 23 from 6:02 am to 6:02 pm. (To commemorate Avogadro's number 6.02 • 1023) On this day, schools have different activities related to the mole concept or chemistry.



Literacy

1. How many grams are there in 0.7 mol of Fe(NO3)3?
2. How many molecules are there in 0.06 mol of KI?
3. How many grams are there in 1.806 • 1022 molecules of MgCl2
4. 0.08 mol of compound X2O5 has mass 11.36 g. What is the atomic mass of element X?

Activity

Calculations by using weighting method

When a metal reacts with oxygen (burning) metal oxide is produced. In this experiment, magnesium metal reacts with oxygen (in air).

$$2Mg(s) + O2(g) \rightarrow 2MgO(s)$$

Materials:

scales, magnesium Mg metal, holder, burner.

Procedure:

1. Weigh the magnesium metal.
2. Light the magnesium using a burner.
3. Reweigh the mass of product after reaction.

Observation & questions:

1. How many grams of oxygen react with magnesium?
2. Find mole of magnesium.
3. The colour of magnesium oxide - ....

Terminology

- population – халық саны/ население;
- represented – көрсетеді / представлять;
- related – байланысқан / связанный;
- relationship – өзара байланыс / взаимосвязь.

Problems: Mole

1. Why do we need the Avogadro's number in chemistry?

2. Compare 6.02 • 1023 (the Avogadro's Number) and the population of the Earth, which is about 7.5 billion. How many planets (like Earth) would we need populate 6.02 • 1023 people?

3. Astronomers estimate our universe could be the home to 300,000,000,000,000,000,000,000 stars. How many moles of stars are there?

4. Find the molar masses of the following compounds:

   a. MgO
   b. BCl3
   c. N2O
   d. K2CrO4
   e. KHCO3
   f. (NH4)2CO3
   g. H3PO4

5. Find the masses for the following substances in grams:

   a. 3.5 mol of water
   b. 15 mol of butane C4H10
   c. 0.9 mol of sulfuric acid H2SO4

6. Calculate how many atoms there are in each substance below: (NA= 6.02 *1023)

   a. 25 g of lithium Li
   b. 55 g of marble CaCO3
   c. 5.2 mol of sand SiO2

7. How many molecules are there in a full glass of water having a volume of 150 ml? (dwater = 1 g/ml)

8. 1.5 mol of compound Mg3X2 has mass 150 g. What is the atomic mass of element X?

9. 0.04 mol of element X weighs 2.24 g. Calculate the atomic mass of element X.

10. 1.82 g of element X contains 2.107*1022 atoms. What is the atomic mass of element X?

11. How many atoms of nickel are there in 118 g of nickel?

12. There is 150 g of sand SiO2.

a. How many moles of oxygen are there?
b. How many molecules are there?
c. How many atoms are there?

CHAPTER 5: CALCULATIONS IN CHEMICAL REACTIONS

5.1 CHEMICAL CALCULATIONS: STOICHIOMETRY, MOLAR VOLUME.

Which gas is heavier: 1 litre of hydrogen or 1 litre of oxygen?

You will:

- calculate the mass, mole and heat by chemical reactions;
- calculate the volume of gases by using molar volume.

Calculations for chemical reactions

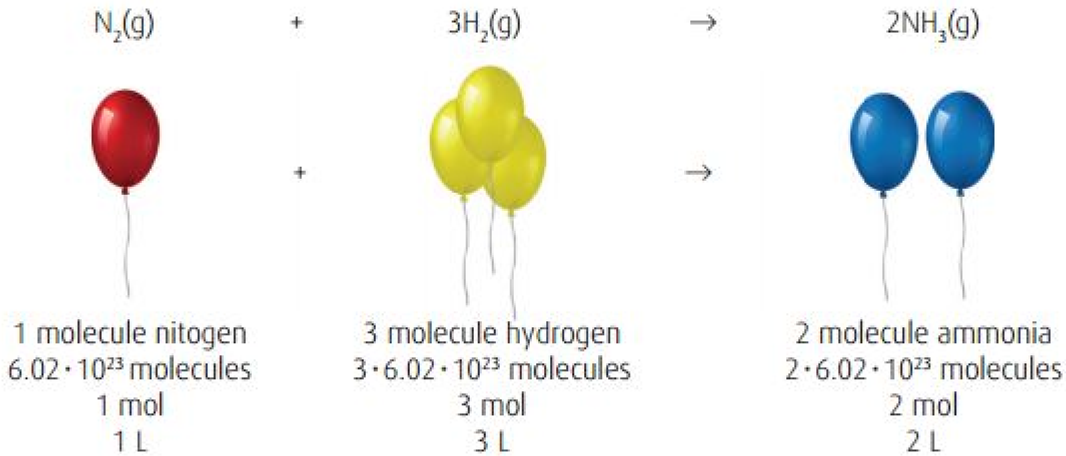
Until Antoine Lavoisier, who established chemistry as a quantitative science, alchemists had not paid attention to amounts during a reaction. Today, we use stoichiometry almost in every chemical work.

Antoine Lavoisier
(1743-1794)

Chemical calculation

Scientific report

In the previous chapters, you have seen how to write, balance and interpret chemical equations. As you know, there is a fixed proportion of the mole numbers of any two of the reactants or products. Consider the synthesis of ammonia, NH3, from its elements:



N2(g) + 2H2(g) --> 2NH3(g)

Proportions for this reaction can be written like:

$$\frac{n(N_2)}{n(H_2)} = \frac{1}{3} \qquad \frac{n(N_2)}{n(NH_3)} = \frac{1}{2} \qquad \frac{n(H_2)}{n(NH_3)} = \frac{3}{2}$$

The first equation shows that one mole of N2 reacts with three moles of H2 to give two moles of NH3. Thus we can say that the proportion of N2 to NH3 is one to two and the proportion of H2 to NH3 is three to two. Knowing these proportions, if you have the mole number of one of these three, you can find the mole numbers of the other two. For example, if we had four moles of N2 reacting, the number of moles of produced NH3 would be eight. To consume four moles of N2 completely, you need to have twelve moles of H2. Such calculations in which we use chemical equations and the coefficients to calculate the amount of one substance from a second substance are called stoichiometric calculations.

Example 1

Calcium reacts with nitrogen to give calcium nitride. Calculate the mole number of calcium nitride that can be obtained from 0.6 mol of calcium.

Solution

First, lets write and balance the reaction equation:

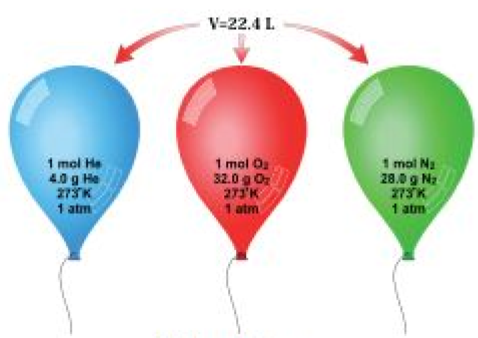
3Ca + N2 --> Ca3N2

We have the mole number of calcium and we need to find the mole number of calcium nitride. The equation reveals that the proportion between Ca and Ca3 is 3 to 1. Now we can find the mole number of Ca3N2:

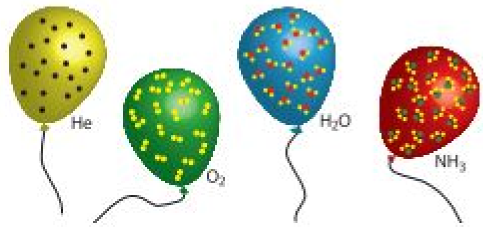
3 mol of Ca gives   1 mol of Ca3N2

0.6 mol of Ca   gives   x mol of Ca3N2

x = 0.6 *1/3 = 0.2 mol of Ca3N2



Molar Volume
STP (standard temperature and pressure):
22.4 L for 1 mol of any gas



Same volumes of gases present same number of particles

Molar volume of gases

For gases at STP (0OC and 1 atm), 1 mole of any gas occupies 22.4 L. Therefore, the number of moles of a gas can be calculated, if the volume of a gas is known at STP.

$$\text{Number of moles} = \frac{\text{Volume}}{22.4} \qquad n = \frac{V}{22.4}$$

here n-mol, V - litre, 22.4 - litre/mol.

Example 2

What is the number of moles of 112 L chlorine Cl2 gas at STP?

Solution

By using the formula of n = V/22.4, the number of moles of Cl2 can be calculated.

n= 112L / 22.4 L / mol = 5 mol

Example 3

How many litres do 3 moles of oxygen gas O2 occupy at STP?

Solution

$n=V/22.4$ $V=22.4*n$ $V=22.4*3=67.2$ L

Literacy

After the reaction of a certain amount of oxygen with hydrogen, 4.5 g of water is produced. Calculate the mass of oxygen gas.

Terminology

- stoichiometry – стехиометрия / стехиометрия
- molar volume – молярлық көлем / молярный объем
- established– қалыптасқан / основанный
- attained – жеткен / достигнутый
- proportion – қатынас / пропорция;
- to calculate – есептеу / вычислять
- to occupy – көлем алу / занимать;
- standard temperature and pressure (STP) – қалыпты жағдай (қ.ж.) / нормальные условия (н.у.).

5.2 THE RELATIVE DENSITY OF GASES. LAW OF COMBINING VOLUMES

Why do helium and SF6 gases make your voice sound different?

You will:

- calculate the relative density of gases;
- calculate molar masses by using relative density;
- use the law of combining volumes for calculations.

The relative density of gases

Different gases have different molar masses. For example, hydrogen M(H2) = 2 g/mol, oxygen M(O2) = 32 g/mol, ammonia M(NH3) = 17 g/mol, etc.

The relative density is the ratio of the molar mass of a first gas to the molar mass of a given second gas. For example, the relative density of oxygen O2 gas according to hydrogen H2 is 16:

$$D_{H_2}(O_2) = \frac{M(O_2)}{M(H_2)} = \frac{32\ g/mol}{2\ g/mol} = 16$$ *(heavier than hydrogen)*

It means that oxygen gas is 16 times heavier than hydrogen gas. Relative density of methane gas CH4 according to air (M(air) = 29 g/mol) is

$$D_{air}(CH_4) = \frac{M(CH_4)}{M(air)} = \frac{16\ g/mol}{29\ g/mol} = 0.552$$ *(lighter than air)*

Gas	Molar mass
Hydrogen (H_2)	2 g/mol
Helium (He)	4 g/mol
Carbon monoxide (CO)	28 g/mol
Nitrogen (N_2)	28 g /mol
Air	29 g/mol
Carbon dioxide (CO_2)	44 g/mol
Chlorine (Cl_2)	71 g /mol

Relative densities of gases

Air ballons


Water vapour from a pipe

Example 1

What is the relative density of oxygen gas according to helium?

Solution

$$D_{He}(O_2) = \frac{M(O_2)}{M(He)} = \frac{32\ g/mol}{4\ g/mol} = 8$$

Example 2

The relative density of an unknown gas according to oxygen is 1.44. What is the molecular mass of unknown gas?

Solution

$$D_{O_2}(X) = \frac{M(X)}{M(O_2)} = \frac{X\ g/mol}{32\ g/mol} = 1.44 \qquad M(X) = 1.44 \cdot 32 = 46\ g/mol$$

Example 3

Relative density of XO gas according to neon is 1.4. What is the atomic mass of X element in gas XO?

Solution

$$D_{Ne}(XO) = \frac{M(XO)}{M(Ne)} = \frac{(X+16)\ g/mol}{20\ g/mol} = 1.4 \quad M(X+16) = 1.4 \cdot 20 = 28\ g/mol$$

$$X + 16 = 28 \qquad X = 28-16 = 12\ g/mol$$

$$M\ (CO) = 28\ g/mol \quad \text{(carbon monoxide)}$$

The law of combining volumes

French chemist Gay-Lussac discovered the law of combining volumes by measuring volumes of gases after reaction.

The law of combining volumes states that the ratio of the different reactants (gases) will always be constant. When gases combine during a chemical reaction at a fixed temperature and pressure, the ratios of their volumes are simple whole number ratios.

For example,

2C2H6 + 7O2 --> 4CO2 + 6H2O

2 moles of ethane C2H6 gas react with 7 moles of oxygen. How many moles of ethane react with 21 moles of oxygen?

Since we tripled the number of moles of oxygen, triple the number of moles of ethane too so that the ratio remains constant. And answer will be 2 mol * 3 = 6 mol.

Example 4

When propyne gas $C3H4$, burns in oxygen, carbon dioxide and water are produced:

a) Write the balanced equation representing the reaction.
b) How many moles of $O2$ are required to burn 11 L of $C3H4$?
c) How many moles of $C3H4$ must be burned to produce 1.2 mol of $CO2$?
d) How many grams of water are produced from 8 g of $C3H4$?

Solution

a) $C3H4 + 4O2 \rightarrow 3CO2 + 2H2O$

b) 1 mol of C3H4 --------- 4 mol of O2

11 L of C3H4 --------- X L of O2

$X=11*4/1 = 44$ L of O2

c) 1 mol of C3H4 --------- 3 mol of CO2

X mol of C3H4 --------- 1.2 mol of CO2

$X=1*1.2/3=0.4$ mol of CO2

d) Mole number of C3H4:

$n(C3H4) = m / M(C3H4) = 8g / 40\ g/mol = 0.2\ mol$

1 mol of C_3H_4 --------- 2 mol of H_2O

0.2 mol of C_3H_4 --------- x mol of H_2O

$X=0.2*2/1 = 0.4$ mol of H_2O

Mass of water: $m(H_2O) = n \cdot M(H_2O) = 0.4 \cdot 18 = 7.2$ g

Literacy

1. Find relative density of following gases according to hydrogen gas H_2:

   a. SO_2 b. C_2H_4 c. NH_3 d. B_2H_6

2. Relative density of X_4H_{10} gas according to air is 2. Find atomic mass of element X.

3. There is a mystical cave near the city of Naples in Italy. It is named as "Grotta del Cane" that means "Dog's cave". Dogs suffocate in that cave while men does not. Which gas does cause that? How is it related to the height of living things?

Mystical cave

Terminology

- relative density – салыстырмалы тығыздық / относительная плотность;
- combining volumes – көлемдік қатынас / объёмные отношения;
- according – қатысты / в соответствии;
- ratio – қатынас / соотношение;
- to remain – сақталу / оставаться

Problems: Calculations in chemical reactions

1. How many liters are there in 0.5 mol of gas at S.T.P conditions?

2. Calculate the volume 454.4 g of SO_2 gas at S.T.P conditions.

3. What is the mass of oxygen in 112 L of NO_2 gas at S.T.P conditions?

4. How many moles are there in 2.709*1021 molecules of gas?

5. What is the relative density of argon Ar gas according to ammonia NH_3?

6. Calculate the relative density of N_2O gas according to hydrogen H_2.

7. The relative density of gas XH_4 according to helium is 4. Determine the atomic mass of element X?

8. How many moles of CO_2 and water can be produced from the decomposition 0.7 mol of soda?

   $2NaHCO_3 \rightarrow Na_2CO_3 + CO_2 + H_2O$

9. How many moles of aluminum sulfide Al_2S_3 can be produced from the reaction of 0.12 mol aluminum with an excess amount of sulfur? How many moles of sulfur do react with aluminum?

$2Al(s) + 3S(s) \rightarrow Al_2S_3(s)$

10. How many litres of oxygen gas at S.T.P can be produced from the decomposition of 28.8 g of water?

$2H_2O \dashrightarrow 2H_2 + O_2$

11. Calculate the mass of oxygen that can be obtained from decomposition 54 g of mercury (II) oxide HgO?

$2HgO \dashrightarrow 2Hg + O_2$

12. How many litres of oxygen at S.T.P would be produced, if 245 g of $KClO_3$ is completely decomposed?

$2KClO_3 \dashrightarrow 2KCl + 3O_2$

CHAPTER 6: THERMOCHEMISTRY

6.1 COMBUSTION OF FUELS AND ENERGY FORMATION

What is a combustion reaction? Why is it important?

You will:

- understand that energy is produced in a combustion reaction;
- understand the carbon monoxide, carbon dioxide as the final products of combustion;
- understand the causes of the greenhouse effect.

Energy and heat

Combustion is the chemical reaction of substances with oxygen. Combustion is commonly called burning. When fuel (oil, petrol, diesel, coal) burn, they give heat and light. We use combustion to produce energy in daily life: to move cars and transports, to heat our houses, to cook, etc. The main sources of energy are coal, wood, natural gas and petroleum products.

Types of car fuels

Coal mining in Ekibastuz

Combustion products

The most common example of combustion process is a bonfire. Combustion products have many negative effects on our health. If fuel reacts with an excess amount of oxygen carbon dioxide gas and water are produced:

$$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$$

However, if fuel reacts with the limited (small) amount of oxygen mixture of carbon dioxide (CO_2), carbon monoxide (CO) and carbon (C) will be produced:

$$\text{Petrol} + O_2(g) \rightarrow CO_2(g) + CO(g) + C(s) + H_2O$$

Blue flame of methane gas burning

Toxic gases pollute our atmosphere

Causes of the greenhouse effect

Greenhouse gases (CH4, CO2) keep the Earth temperature at the constant degree. But when the amount of greenhouse gases increases, the Earth's temperature also increases. The main causes of the greenhouse effect are:

1. Burning of fossil fuels like coal, petrol, natural gas.
2. Methane gas released from bogs and nitrous oxides produced from factories.

Activity

Work in groups. Discuss about which type of fuel is:

a. the most efficient
b. the cheapest
c. ecologicaly clean
d. found in your region

Activity

Fuel efficiency

Introduction

Coal, alcohol, urotropin and other types of fuels produce different amount of heat when they burn. In this experiment we will find out which fuel is more efficient that is produce more energy: ethyl alcohol or urotropin.

Materials: solid fuel (urotropin), 2 beakers, burner with ethyl alcohol, 2 tripods.

Procedure:

1. Pour 100 ml of water into two beakers. Place beakers on tripods.

2. Light solid fuel and burner, than place them under the tripods.
3. Observe which beaker will boil earlier.

Observation & questions:

1. What are colours of flames?
2. Which fuel is more efficient? Alcohol or urotropin?
3. Give examples for types of fuels in daily life.

Literacy

By using given table, choose the combustible and non-combustible substances:

Material	Combustible / non-combustible
Paper	
Charcoal	
Iron nails	
Glass	
Kerosene oil	
Rubber	
Plastic	

Terminology

- fuel – отын / топливо;
- combustible – жанғыш / горючий;
- ash – күйе / сажа;
- cause – себеп / причина;
- greenhouse effect – жылыжай
- эффекті / парниковый эффект;
- heat – жылу / тепло;
- to heat – қыздыру / нагревать;
- burning – жану, өртену / горение;
- bonfi re - от / костер;
- to emit - шығарады / испускают;
- source – қайнар көзі / источник;
- wood – ағаш / дерево;
- petrol – жанармай / бензин;
- petroleum – мұнай / нефть;
- charcoal - көмір / древесный уголь;
- bog – батпақ / болото.

6.2 EXOTHERMIC AND ENDOTHERMIC REACTIONS

Which types of fuels are less dangerous?

You will:

- know why combustion is exothermic and some reactions are endothermic;
- evaluate the capacities of fuels and its effects on the environment.

Exothermic and endothermic reactions

According to energy exchange all chemical reactions are divided into two groups: endothermic and exothermic. The exothermic reactions give out heat (release energy) and the endothermic reaction takes in heat (absorb energy). When it feels warm or hot it is an exothermic reaction. And when it feels cold it is an endothermic reaction. A combustion reaction (burning) is an example of the exothermic reaction. Wood burning produces energy that releases as heat:

$$\text{Wood} + O_2(g) \rightarrow CO_2(g) + H_2O(g) + \text{heat}$$

The thermite reaction between aluminium and iron oxide:

$$\text{Aluminium} + \text{iron oxide} \rightarrow \text{iron} + \text{aluminium oxide} + \text{heat}$$

$$2Al(s) + Fe_2O_3(s) \rightarrow Al_2O_3(s) + 2Fe(l) + 841\ kJ$$


The thermite mixture explosion

In the reaction we get 841 kJ of the heat. This is a huge amount of energy, so that we produce iron in molten state.

Decomposition of calcium carbonate CaCO3 is a good example of an endothermic reaction:

$$CaCO_3(s) \rightarrow CaO(s) + CO_2(g) - 169{,}5\ kJ$$

Dissolution of ammonium nitrate (NH4NO3) is an example for the endothermic process.

Tourist breakfast cooking on a bonfire in the mountain forest

Firework is also an example of exothermic reaction

Decomposition of apples in autumn

Fuel efficiency

Nowadays people use many types of fossil fuels. Fossil fuels are very important because they produce energy when burned. Common fossil fuels are coal, oil and natural gas. Coal and oil have been used from ancient times. Today people produce new products (fuels) from fossil fuels: ethanol, gasoline, kerosene, coke, etc.

When we burn coal and oils, they leave ashes and black gases. Natural gases and ethanol are more efficient, they burn cleaner and in most cases are still the cheapest.

№	Fuel	Heat of combustion, kJ/g	Price, approx (2017)
1	Natural gas	54	29 tg/m³
2	Coal	27	120 tg/kg
3	Wood	15	15000 tg/m³
4	Ethanol	29.8	350 tg/L
5	Diesel	45	128 tg/L
6	Gasoline	47	146tg/L
7	Hydrogen	142	184tg/kg

Literacy

The table shows the efficiency and prices of some fuels. Choose the most suitable fuel which will give more energy than others and be cheapier.

Facts

1 g of uranium fuel can produce much more energy than 1 000 000 g of coal!

Nuclear energy factory

Lab work

№ 4. Energy changes in chemical reactions

Some reactions release heat and others absorb it. In exothermic reactions the temperature increases, in endothermic reactions the temperature decreases.

Materials:

1M sodium hydroxide NaOH and 1M hydrochloric acid HCl solutions, 20% solution of citric acid C6H8O7, sodium bicarbonate NaHCO3, thermometer, beakers, stirring rod.

Procedure:

1. Pour 10 ml sodium hydroxide solution in a beaker, measure initial temperature.
2. Add 10 ml of hydrochloric acid, mix them, measure final temperature.
3. Pour 20 ml of citric acid solution in a beaker, measure initial temperature.
4. Add 12 g of sodium bicarbonate, mix them, measure final temperature.

Observation & questions:

1. Which is exothermic reaction and which is endothermic reaction?
2. Which type of reaction takes place between sodium hydroxide and hydrochloric acid?
3. Write chemical equation between sodium hydroxide and hydrochloric acid.

Terminology

- exothermic – экзотермиялық / экзотермический;
- endothermic – эндотермиялық / эндотермический;
- to release – бөліп шығару / выделять;
- to absorb – сіңіру / поглощать;
- molten – балқытылған / расплавленный;
- dissolution – еру / растворение;
- coke – кокс / кокс;
- effi cient – тиімді / эффективный;
- cheapest – ең арзан / самый дешевый;
- alcohol – спирт / спирт;
- solid fuel - “құрғақ жанғыш” / “сухое горючее”;
- kerosene - керосин / керосин;
- gasoline - жанармай / бензин.

6.3 THERMOCHEMICAL REACTIONS

Does energy change in every chemical reaction?

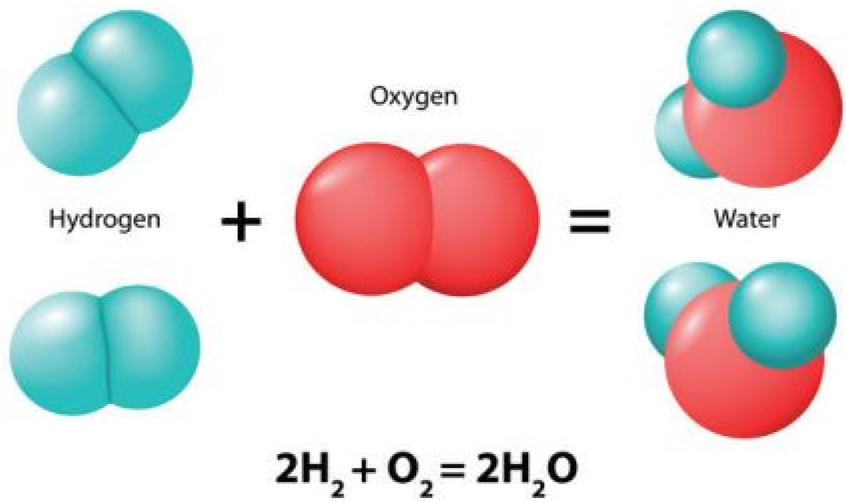
You will:

- understand the energy conservation in a chemical reaction;
- explain changes of energy in the reaction.

The energy conservation law

When wood burns, chemical energy is conserved into heat and light energy, this is an exothermic reaction. According to the first law of thermodynamics, energy can not be created or destroyed; it can only be transferred from one state to another.

Chemical reaction always involves a change in energy between products and reactants. By the law of energy conservation, we know that total energy of a system is not changed. For example, in the formation of water molecules energy is released as heat and light (total energy is conserved):



Thermochemical reactions

Chemical reactions often produce changes in energy. Chemical energy is transforned to heat energy in any exothermic and endothermic reaction, such as the burning of propane gas:

C3H8(g) + 5O2 --> 3CO2(g) + 4H2O(g) + heat

Chemical energy can also change to light energy. For example, fireworks reactions:

2Mg(s) + O2(g) --> 2MgO(s) + heat + light

Bengal lights of burning magnesium

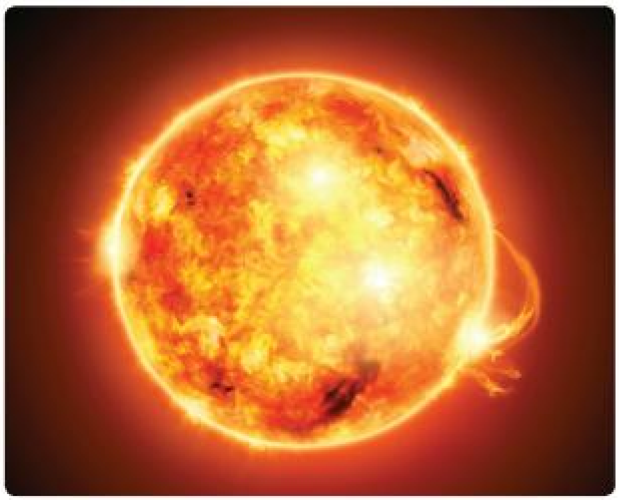
Chemical energy can be converted to electrical energy. Any electrochemical cell is usually called a “battery”:

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

Alkaline battery

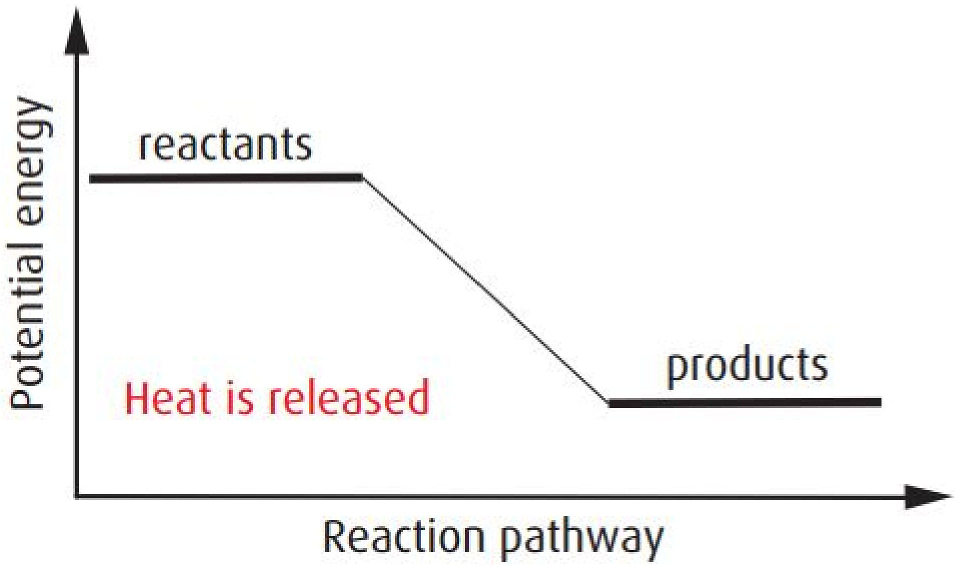
Modern electric grid lines

Energy saving and ordinary light bulbs

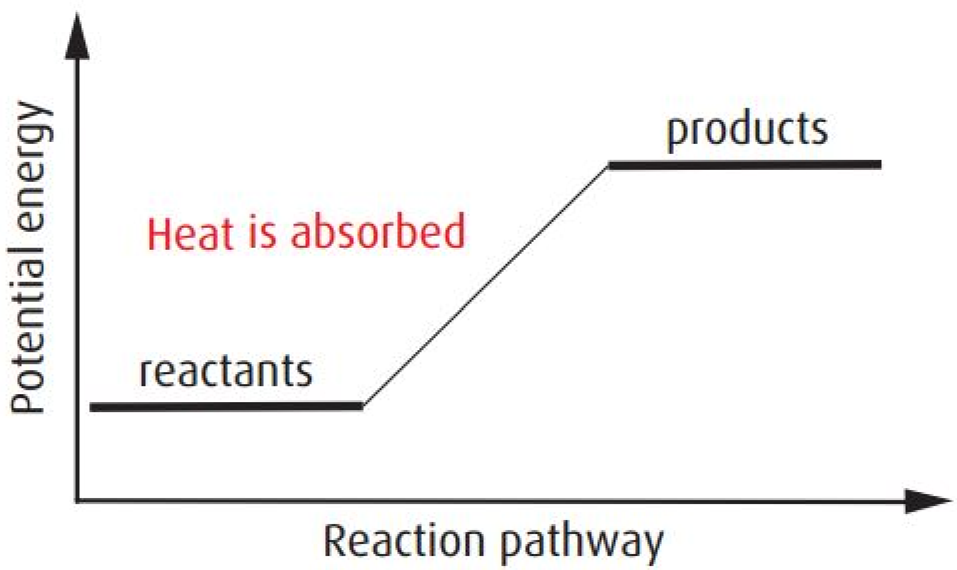


The Sun is the main source of energy for our Solar System

According to the kinetic-molecular theory, heat energy obtained by a body is transformed into increased kinetic energy of the molecules of the body. We see this increased kinetic energy when a solid, a liquid or gas expands on heating. Increase a kinetic energy will cause the particles of a solid or liquid to become a gas.



Exothermic reaction diagram



Endothermic reaction diagram

Literacy

1) Indicate the following reactions as endothermic or exothermic reactions:

$C_5H_{12}(l) + 8O_2(g) \rightarrow 5CO_2(g) + 6H_2O(g) + 3523$ kJ
$H_2(g) + Cl_2(g) \rightarrow 2HCl(g) + 185$ kJ
$2CO_2(g) + \text{heat} \rightarrow 2CO(g) + O_2(g)$
$N_2O(g) + H_2(g) \rightarrow N_2(g) + H_2O(g) + \text{heat}$
$2Al_2O_3(s) + \text{energy} \rightarrow 4Al(s) + 3O_2(g)$

2) The reaction below, which is known as a thermite reaction, is highly exothermic:

$2Al(s) + Fe_2O_3(s) \rightarrow 2Fe(l) + Al_2O_3(s) + 841$ kJ

If 54 gram of aluminium reacts with iron oxide to give 841 kJ energy. How much heat is produced when 16.2 gram of Al reacts with excess Fe_2O_3?

3) To produce 30.4 g of CS_2, how much heat must be gained by the reaction? (When 76 g of CS_2 produced, 89 kJ energy is absorbed)

$C(s) + 2S(s) + 89\ \text{kJ} \rightarrow CS_2(l)$

Activity

Group discussion about “Fuel for the future”.

Terminology

- conservation – сақталу / сохранение;
- to destroy – бұзылу / разрушение;
- to transfer – тасымалдау / перевозить;
- formation – түзілу / формирование;
- place – орын / место;
- to place – қою / ставить;
- fireworks – ұшқын / фейерверк;

- kinetic energy – кинетикалық энергия / кинетическая энергия;
- to gain – алу / получать;
- ordinary - қарапайым / обычный.

Problems: Thermochemistry

1. Explain the terms “exothermic” and “endothermic”.

2. Why do we feel warmer when it snows in winter? Explain.

3. Classify the following processes as exothermic or endothermic:

    a. When NH_4NO_3 dissolves, the solution becomes cold;
    b. The burning of paper;
    c. When concentrated H_2SO_4 is added to water, the solution gets warmer;
    d. Photosynthesis.

4. For the reaction equation below:

    $S(s) + O_2(g) \rightarrow SO_2(g) + 296\ kJ$

    What kind of reaction is the oxidation of sulfur in terms of heat exchange?

5. Which of the following reactions are exothermic or endothermic:

    a. $2SO_2(g) + O_2(g) \rightarrow 2SO_3(g) + 198\ kJ$
    b. $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g) + 92\ kJ$
    c. $2CO_2(g) \rightarrow 2CO(g) + O_2(g) - 566\ kJ$
    d. $2NO(g) + O_2(g) \rightarrow 2NO_2(g) + 112\ kJ$
    e. $CaO(s) + H_2O(l) \rightarrow Ca(OH)_2(l) + 65.2\ kJ$

6. What do you think?

- How is the Sun’s energy given off?

- Why leaves turn yellow in autumn?
- Why is it hot in summer and cold in winter?

7. Give examples of exothermic reactions in daily life.

8. Which of the following reactions are exothermic and which ones are endothermic?

- cooling of volcanic lava
- melting of ice
- lighting process
- corrosion of iron metal.

9. What types of food can give you more energy?

10. What types of energy does the world use nowadays?

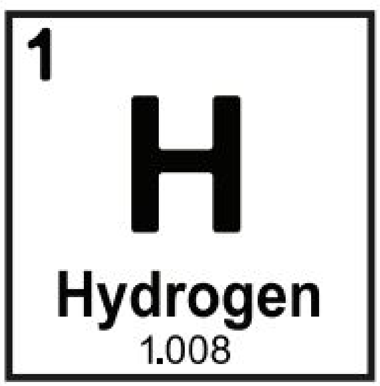
CHAPTER 7: HYDROGEN AND OXYGEN

7.1 HYDROGEN

Is it possible to use hydrogen as a fuel in our country?

You will:

- prepare and study properties of hydrogen gas.



Hydrogen in the Periodic table

Hydrogen gas containers

Hydrogen is a colourless, odourless and tasteless gas. Hydrogen gas is lighter (d = 0.0899 g/L at STP) than other gas molecules.

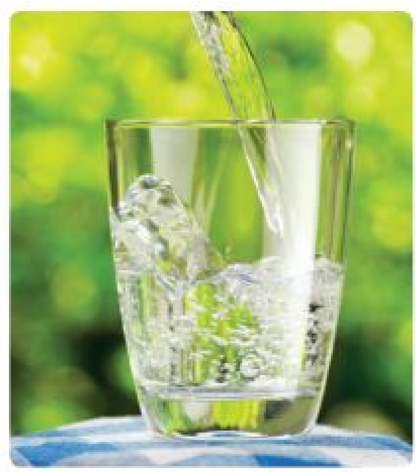
Hydrogen forms ionic hydrides with active metals, such as potassium hydride, KH. It forms covalent compounds with nonmetals, for example, HF, HCl, H2O, etc. Electronegativity of hydrogen is higher than that of metals but less than that of nonmetals.

Occurrence

Hydrogen occurs in the form of free diatomic molecules (H2) and its compounds. Free hydrogen occurs in nature only in negligible amounts, for example, in volcanic gases. Hydrogen gas easily escapes from the Earth's gravitation to enter space beyond the atmosphere. It makes up about 0.15% by mass of the Earth's crust.

The most important compound of hydrogen is water (H2O). It is also found as a component of organic substances such as hydrocarbons, oil, coal, and natural gas. Clays and certain hydrates are common inorganic compounds which contain hydrogen.

Hydrogen is everywhere



Glass of water

Chemical properties

Hydrogen is used to produce ammonia in industry. Nitrogen and hydrogen are reacted under high pressure and temperature to produce ammonia, according to the reaction below:

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

H_2 gas is a good reducer. Because of this property, it is widely used in the production of metals from their oxides. For example, metallic iron, copper are produced from their oxides in this way.

$$FeO(s) + H_2(g) \rightarrow Fe(s) + H_2O(l)$$

$$CuO(s) + + H_2(g) \rightarrow Cu(s) + H_2O(l)$$

Since the reaction of hydrogen with oxygen is an exothermic process:

$$2H_2(g) + O_2(g) \rightarrow 2H_2O(g)$$

Hydrogen may be an alternative energy source in the future.

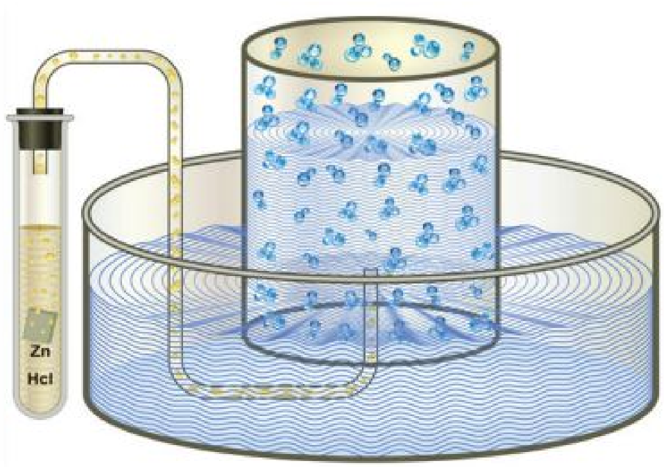
Facts

Hydrogen is the most abundant element in the universe. The Sun and all stars mostly consist of hydrogen.

Practice work

№ 2. Preparation of hydrogen gas and its properties

When acid reacts with metal, hydrogen gas is released.Hydrogen is the lightest gas.



Materials:

hydrochloric acid HCl and sulfuric acid H2SO4 solutions, magnesium (or zinc) metal, test tubes.

Variant I

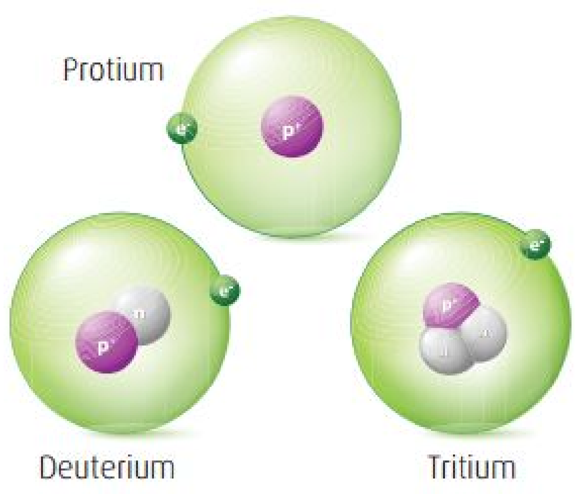
1. Take a 5 g sample of magnesium (or zinc) into a test tube. Add 30 ml of hydrochloric acid solution to the test tube.
2. Write properties of hydrogen gas.

Variant II

1. Take a 5 g sample of magnesium into a test tube. Add 30 ml of sulfuric acid to the test tube.
2. Write reactions between acid and metal.

Keep in mind

Hydrogen has 3 isotopes –protium (11H), deuterium (12D) and tritium (13T). The most abundant isotope of hydrogen, protium, 1 1H constitutes 99.985% of naturally occurring hydrogen. Deuterium, 12H (12D), which is stable constitutes 0.015%. Tritium,13H (13T), which is radioactive, is found in trace amount in nature.



Terminology

- hydrogen - сутек / водород;
- diffusion - диффузия / диффузия;

- negligible – елеусіз / незначительный;
- isotope - изотоп / изотоп;
- occurrence - таралуы / распространение;
- ammonia - аммиак / аммиак;
- alternative - баламалы / альтернативный;
- universe - әлем, ғалам / космос;
- reducer – тотықсыздандырғыш / восстановитель.

7.2 OXYGEN AND ITS PROPERTIES

You will:

- prepare and study properties of oxygen gas.

What would happen, if oxygen gas was not soluble in water?

Oxygen was discovered by Priestly in 1774. The name oxygen, which means "acid-producer", comes from Latin. Oxygen is the first member of group 16 (VI) with electron configuration 1s22s22p4. It is a nonmetal and the most active element of the group.

Oxygen is a colourless, tasteless, odourless gas and it exists in a diatomic structure (O2). The density of oxygen is greater than air. The boiling point of oxygen is -183oC and its melting point are -218.3oC. It dissolves slightly in water: 0.03 g of oxygen dissolves in 1 L of water at STP. Oxygen is the most abundant element in the Earth crust. It occurs in nature in both the free and combined states. Free oxygen constitutes about 21% by volume of atmospheric air, and about 33% by volume of dissolved air. In compounds, oxygen accounts for about 50% of the mass of the Earth’s crust, oceans and air. Oxygen is present as oxides of both metals and nonmetals, which make up the rocks and clays. Water, one of the most abundant compounds on the earth, contains 88.9% oxygen by mass.

Oxygen ballons

A man doing breathing exercises

Preparation of oxygen

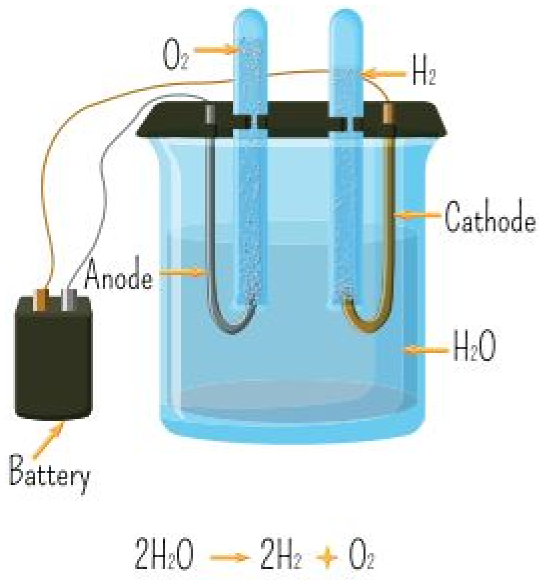
1. Heating of metal oxides with low activity such as Ag2O and HgO:

2HgO(s) --> 2Hg(l) + O2(g)

2Ag2O(s) > 4Ag(s) + O2(g)

2. Electrolysis of water:

2H2O(l) --> 2H2(g) + O2(g)



Chemical properties of oxygen

Oxygen combines with all elements (except the noble gases, some halogens and some unreactive metals) to form oxides (oxygen is strong oxidizing agent):

1. Reactions with metals:

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

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

2. In general, all nonmetals react with oxygen gas:

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

$$N_2(g) + O_2(g) \rightarrow 2NO(g) \text{ (at high temperature)}$$

3. Oxygen gives combustion reactions with organic compounds:

$$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$$

Combustion reaction

Ozone

Ozone (O_3) is a light blue coloured gas with a sharp, pleasant odour. It may be liquefied at -112oC and may be solidified at -193oC. Ozone is slightly soluble in water. Ozone can be prepared by passing pure oxygen gas through an electrical discharge.

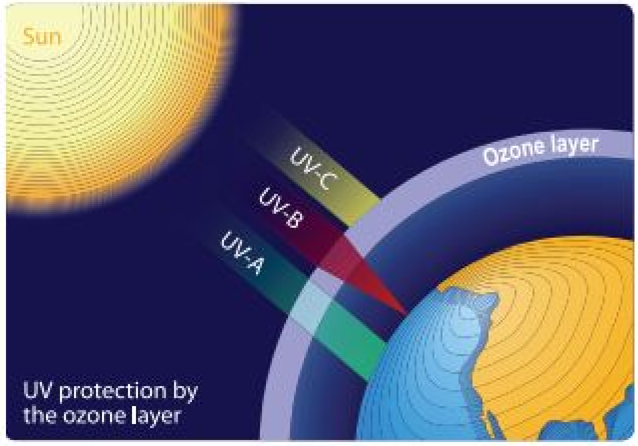
The electrical energy breaks the bonds in some O_2 molecules to give oxygen atoms, which react with other O_2 molecules to form O_3:

$$O_2(g) \leftrightarrow 2O^*$$

$$O_2(g) + O^* \leftrightarrow O_3(g)$$

Ozone exists naturally in the upper atmosphere of the Earth. The ozone layer is especially important because it absorbs ultraviolet light, acting as a screen to block this radiation, which can cause skin cancer. When an ozone molecule absorbs this energy, it splits into an oxygen molecule and an oxygen atom:

$$O_3(g) + energy \leftrightarrow O^* + O_2(g)$$



UV protection by the ozone layer

Facts

Oxygen is present in water molecules, and water is essential for all life forms. Oxygen is present in many organic compounds. Most living organisms use oxygen for respiration. Oxygen makes up ¼ of the atoms in living organisms.

Red Blood Cell with Oxygen

Practice work

№ 3. Preparation of oxygen gas and its properties

Materials:

hydrogen peroxide solution (20%), manganese (IV) oxide (MnO_2) powder, beaker.

Variant I

1. Pour 20 ml of hydrogen peroxide solution into the beaker. Put 1 g of MnO_2 into the peroxide.
2. Check the formed gas with a glowing splint.

Variant II

1. Write main properties of oxygen gas.
2. Finish the following reactions:

- $S + O_2 \rightarrow$
- $C + O_2 \rightarrow$
- $Zn + O_2 \rightarrow$

Terminology

- oxygen - оттегі / кислород;
- discover - жаңалық ашқан / открыл (наука);
- slightly - аздап / немного;
- essential - қажетті / необходимый;
- respiration - тыныс алу / дыхание;
- to breath - дем алу / дышать;
- oxidizing agent – тотықтырғыш / окислитель;
- rocks - тау жыныстары / горные породы.

Reflection

Reflection for the 2nd quarter

The most diffi cult topic for me was ....

The easiest topic for me was ....

Rate yourself on 10-points scale

1. I can help others ....
2. I need more practice ....
3. I need extra lessons ....

Problems: Hydrogen and Oxygen

1. What is oxygen?

2. The chemical symbol of oxygen:

3. Oxygen forming the molecule O_3 is called: ....

4. Approximately how much of the human body mass consists of oxygen?

5. What is the location of oxygen on the Periodic table?

6. What is the percentage of O_2 gas by volume in the Earth's atmosphere?

7. Calculate the mass percentage of oxygen in sulfuric acid H_2SO_4.

8. Which compound contains the highest percentage of oxygen?

   A) H_3PO_4
   B) $CaSO_4$
   C) $NaHPO_4$
   D) CO_2
   E) H_2SO_4

9. How many oxygen moles are present in 2.0 grams of oxygen gas?

10. Determine the number of moles of oxygen atoms in each of the following?

a. 3 mol of H_2O,
b. 2.3 mol of Na_2O_2
c. 5 mol of H_3PO_4

11. What is the product of a typical metal, like calcium, reacting with O_2?

12. I. Ozone is an allotrope of oxygen.
II. Oxygen is lighter than air.
III. Oxygen was discovered in 1774.
IV. Oxygen has three main isotopes.

Which one(s) of the above statements is/are correct for oxygen?

A) I only
B) I and III
C) III and IV
D) I, III and IV
E) I, II, III and IV

13. Which one of the following statements is not correct for oxygen?

A) Oxygen forms ozone.
B) Oxygen is used in metallurgy.
C) Oxygen is used in diving.
D) Oxygen is needed for combustion.
E) Oxygen is a flammable gas.

14. Write the common names of compounds that are natural sources of hydrogen:

a. H_2O ....
b. H_2O_2 ....
c. NH_3 ....
d. HCl ....

15. Which statement is related to a property of hydrogen molecule?

A) Hydrogen is coloured gas
B) The relative molecular mass of hydrogen is 1
C) Hydrogen is the heaviest gas
D) Hydrogen exists in a diatomic form
E) Table salt contains hydrogen

16. Which of the following is/are true for hydrogen?

I. Cavendish discovered hydrogen
II. Hydrogen soluble in water
III. Hydrogen is found in air

A) I
B) I and II
C) I and III
D) II and III
E) I, II and III

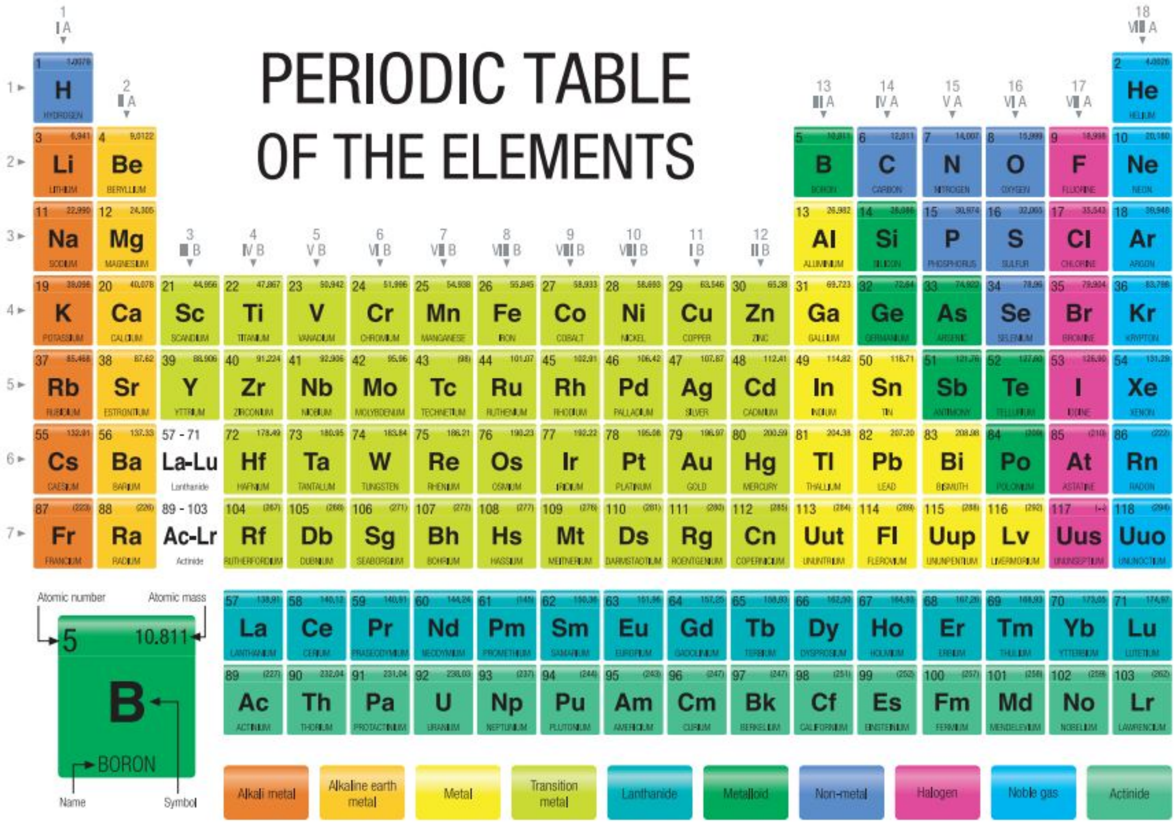
CHAPTER 8: PERIODIC TABLE OF CHEMICAL ELEMENTS

8.1 STRUCTURE OF PERIODIC TABLE

You will:

- describe the structure of the PT by use of terms as group and period;
- know that PT has got some important numbers as atomic number, a number of group and period;
- know that position of an element in the PT can show the number of valence electrons.

Have you ever thought why the Periodic Table (PT) is so important to all humankind?



The modern periodic table contains all known elements. It shows us physical and chemical properties of elements.

When the elements are arranged in the order of increasing atomic numbers, there is a periodic repetition in the properties of these elements.

A simple periodic table contains the symbols, atomic numbers and the relative atomic masses of the elements. You can also find detailed periodic tables containing some physical and chemical properties (such as melting point, boiling point, oxidation state).

Each horizontal row in the Periodic table is called a period. There are seven periods in the modern periodic table and each period begins with alkali metal and ends with a noble gas. However, the first element of the first period (hydrogen) is not a metal.

Each vertical column in the Periodic table is called a group. Since the chemical and physical properties of the elements in a group are similar, they are sometimes also called a family. There are eighteen groups in the Periodic table.

Electron arrangement of atoms shows the exact position of the element in the PT.

- The number of electrons in the outer shell is the number of a groups;
- The number of electron shells shows the period. For example, sodium (Na) has got 3 electron shells and located in the 3rd period;
- The number of electrons in the outershell is also known as valence electrons;

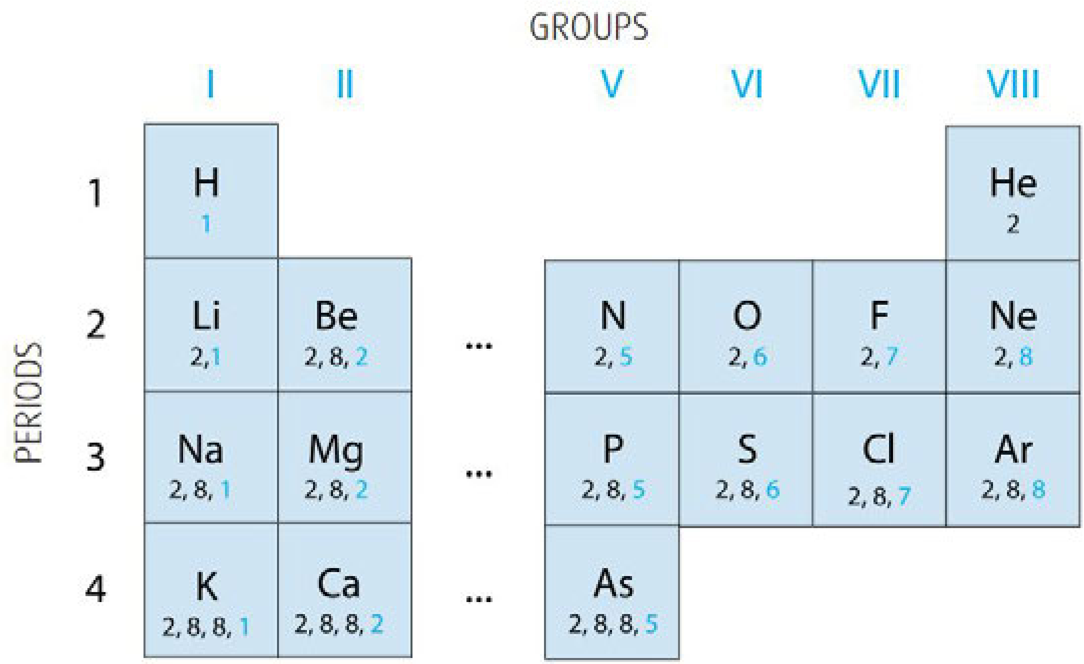
Facts

Dmitri Ivanovich Mendeleev (1834-1907) is considered as a father of Periodic table.

The monument to D. I. Mendeleev in the garden. Russia, Saint-Petersburg

Keep in mind

Atomic number is the number of an element in the PT. The vertical columns are called groups. The horizontal rows are called periods



The relationship between electron arrangement and location of the atom in PT

D.I.Mendeleev was a Russian chemist who wrote more than 400 articles in chemistry, physics, pedagogy, agriculture, etc. The most valuable discovery was in 1869 when he published the periodic law and invented the Periodic Table of elements.

Science in context

Nuclear scientists use the Periodic table to discover new chemical elements.

Nihonium-113, Moscovium-115, Tennessine-115 and Oganesson-118 - new chemical elements in the Periodic table

Literacy

1. Guess the elements

- The most abundant metal in the Earth's crust. It is light and used in airplane construction, food packaging, car industry.
- An excellent conductor of electricity. Used in electrical wires and the main component of the bronze alloy. Main ores are located in Zhezkazgan region.
- Purple-black solid. Found in seafood. Used as a disinfectant and as a component of table salt.

2. Find elements which are named after:

- Scientists
- Planets
- Geographical places

Terminology

- group - топ / группа;
- period - период / период;
- relative - салыстырмалы / относительный;
- relationship - байланыс / взаимосвязь;
- horizontal row - көлденең қатар / горизонтальный ряд;
- vertical column - тік бағана / вертикальный столбец;
- melting point - балқу температурасы / температура плавления;
- boiling point - қайнау температурасы / точка кипения;
- transition metals - ауыспалы металдар / переходные металлы;
- consider - саналу / считаться.

8.2 ELECTRON CONFIGURATION

You will:

- write the electron configuration for elements;
- predict the properties of elements just by the use of PT;
- know which atoms are the most stable and group names;
- know shapes of s- and p-orbitals.

Why are 18 group elements called "Noble gases"?

Electron configuration

We know that the elements are arranged in the order of increasing atomic numbers. In a neutral atom atomic number is equal to a number of electrons. All electrons are distributed among the shells and subshells. The electron configuration repserents the way as they arranged. Their unique electron configurations can explain the physical and chemical properties of elements. The valence electrons are the determining factor for the special properties of the element.

The electron configuration simply is an order of orbitals which hold electrons. There are four orbitals: s-, p-, d-, f-orbitals. Each orbital can contain a different number of electrons. For example, s-orbital can hold 2 electrons, p-orbitals 6 electrons, d-orbitals 10 electrons and f-orbitals can hold 14 electrons.

1s2, 2s2, 2p6, 3s2, 3p6, 4s2, 3d10, 4p6, 5s2, 4d10, 5p6, 6s2, 4f14, 5d10, 6p6, 7s2, 5f14, 6d10, 7p6 ....

The electron configurations for first 10 elements are shown in the table below.

Atomic Number	Symbol Name	Electron in the shells	Electron configuration
1	H Hydrogen	1)	$1s^1$
2	He Helium	2)	$1s^2$
3	Li Lithium	2) 1)	$1s^22s^1$
4	Be Beryllium	2) 2)	$1s^22s^2$
5	B Boron	2) 3)	$1s^22s^22p^1$
6	C Carbon	2) 4)	$1s^22s^22p^2$
7	N Nitrogen	2) 5)	$1s^22s^22p^3$
8	O Oxygen	2) 6)	$1s^22s^22p^4$
9	F Fluorine	2) 7)	$1s^22s^22p^5$
10	Ne Neon	2) 8)	$1s^22s^22p^6$

The electron configuration of first 10 elements

Keep in mind

Here is the order of filling electrons in shells:

s-orbital	2e
p-orbital	6e
d-orbital	10e
f-orbital	14e

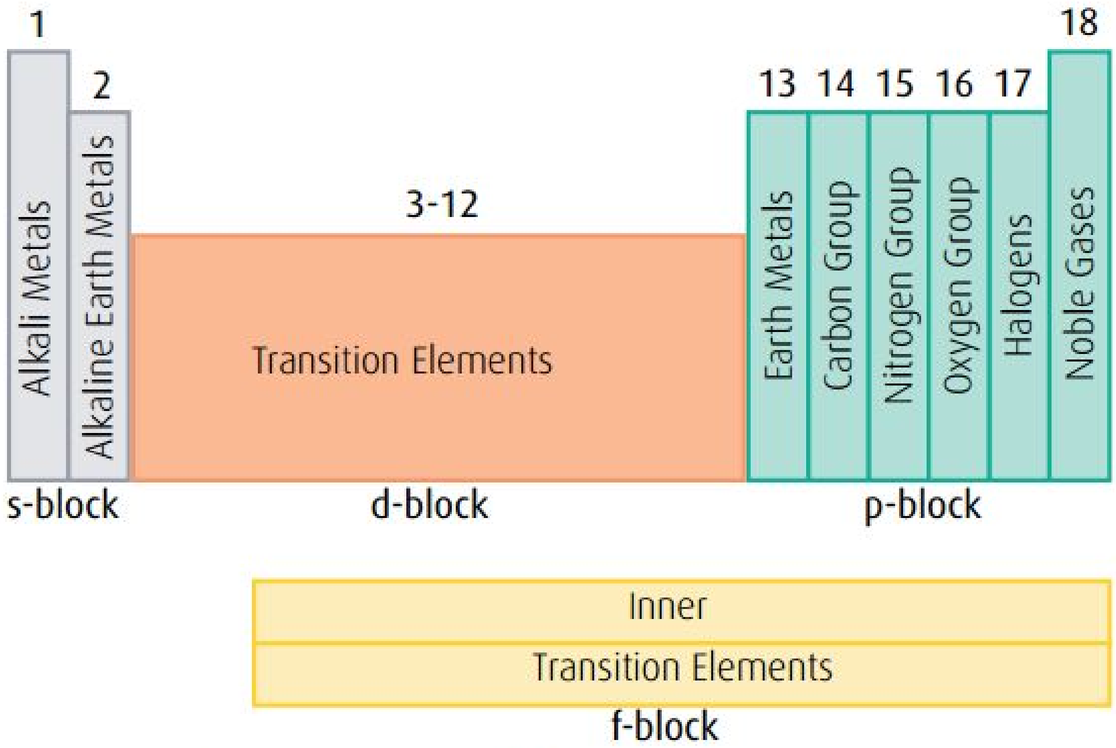
Science in context

Alkali metals and halogens are the most active metals and nonmetals respectively. That is why they are not found in elemental form in nature.

Science in context

Iodine and its compounds are primarily used in medicine, photography and dyes.

Medical iodine and swabs



Families and the s, p, d, f blocks in the Periodic table

Group 1 (I): Alkali Metals (ns1)

This group contains the elements hydrogen (H), lithium (Li), sodium (Na), potassium (K), rubidium (Rb), cesium (Cs), and francium (Fr). Although hydrogen is a nonmetal, it is placed in this group because of its electron configuration, 1s1. Alkali metals are chemically the most active metals.

Group 17 (VII): Halogens (ns2np5)

This group contains the elements fl uorine (F), chlorine (Cl), bromine (Br), iodine (I) and astatine (At). These elements occur naturally in a diatomic structure (F2, Cl2, Br2, I2, At2). Fluorine and chlorine are gases, bromine is a liquid and iodine is a solid. Astatine is a radioactive and solid element. Halogens are the most active nonmetals.

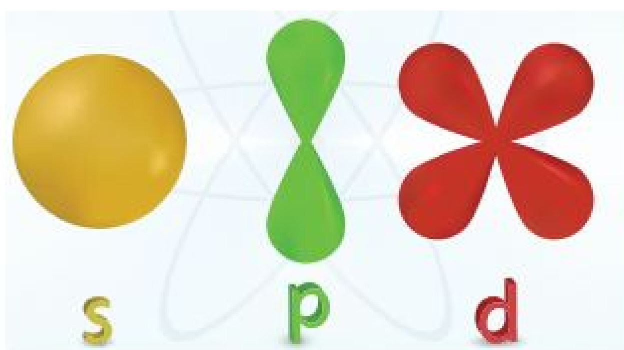
Group 18 (VIII): Noble Gases (ns2np6)

Since they do not tend to react chemically, the elements of this group are called noble gases, or inert gases. All noble gases are colourless, odourless and water-insoluble. Their electron configurations end with ns2np6, except helium, which ends with ns2. They are the most stable elements in nature. Therefore, all other elements try to make their electron configurations similar to noble gases: either by gaining or losing electrons. This is known as the octet rule.

Shape of s- and p- orbitals

s-orbital has a shape of a "sphere" or a "ball". And there is a nucleus in a center of the orbital.

p-orbital is composed of two parts. There is a nucleus between them. It looks like a "dumbbel" or "infinity sign"



Shapes of s-, p- and d- orbitals

Literacy

1. The most stable elements are noble gases. Why?
2. Write electron confi gurations of: 11Na; 16S; 20Ca; 26Fe; 35Br
3. Define the element with electron configurations:

- 1s22s22p63s23p64s23d104p5
- 1s22s22p63s23p64s23d7
- 1s22s22p63s23p64s23d104p65s1

Terminology

- electron configuration - электрондық конфигурация / электронная конфигурация;
- radioactive - радиоактивті / радиоактивный;
- tendency - қабілет / стремление;
- unique - бірегей / уникальный;
- octet rule - октет ережесі / правило октета;
- dumbbel - гантель / гантель

8.3 TRENDS IN PERIODIC TABLE

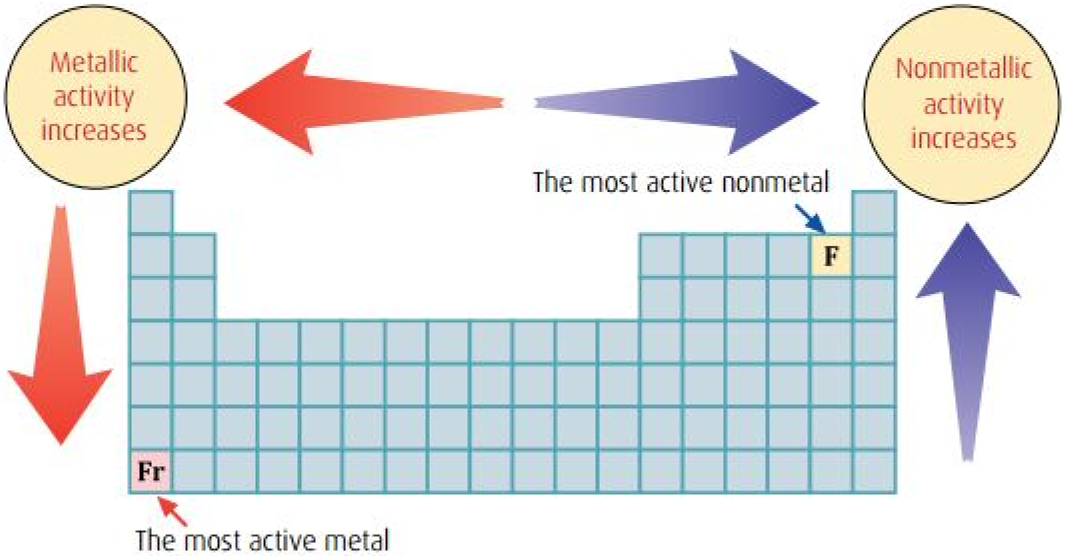
You will:

- know how are properties of elements changes among groups and periods;
- predict properties of an element by the place in the Periodic Table.

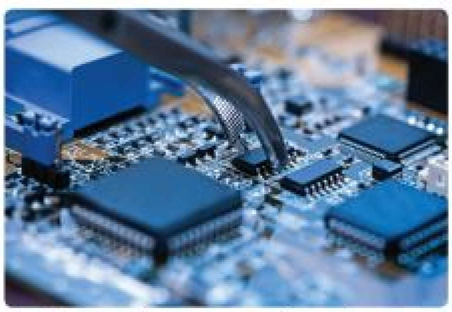
Is it possible to predict properties of an element just by looking at the Periodic Table?

Metallic and nonmetallic properties

Metallic and nonmetallic properties are related to the number of valence electrons and the radius of an atom. Within a period, as the metallic properties decrease from left to right, the nonmetallic properties increase. Within a group, as the metallic properties increase, the nonmetallic properties decrease from top to bottom.



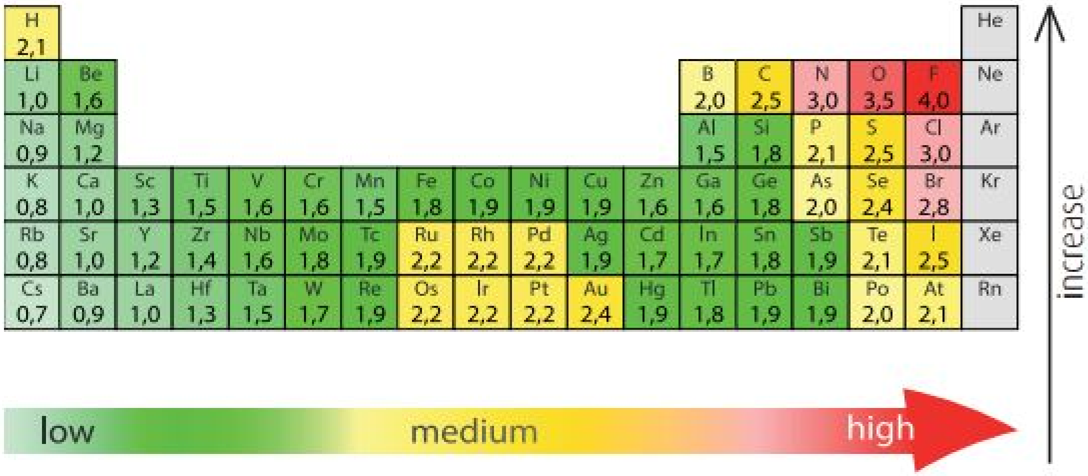
The metallic and nonmetallic properties in the Periodic table.


Germanium as a semiconductor


Tc radioactive isotopes used in medical tests

Electronegativity

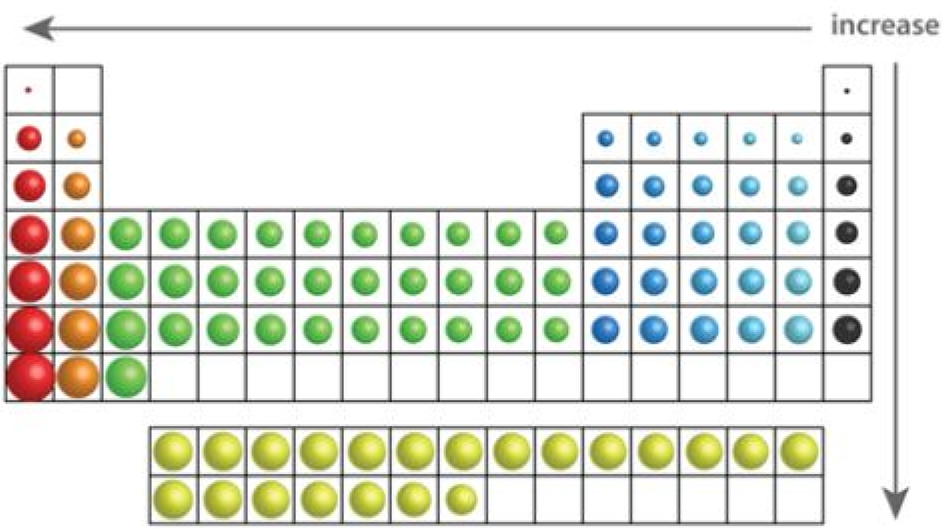
Electronegativity is a measure of an atom's ability to attract electrons within a covalent bond in its molecule. Electronegativity is a relative quantity, and it does not have a unit. According to the Pauling's scale, the most active metal, francium, has a 0.7 value and the most active nonmetal fluorine has a 4.0 value.



The Periodic table of elements with electronegativity values (by Pauling)

Atomic radius

The atomic radius is practically defined by assuming the shape of the atom as a sphere. The atomic radius is the distance between the nucleus and the outermost electron.



The atomic radii of elements in the Periodic table

Keep in mind

- Francium would be expected to have the strongest metallic properties.
- Fluorine the element with the strongest nonmetallic properties
- Electronegativity increases from left to right and decreases from top to bottom in the Periodic table.

Example

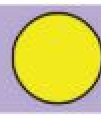
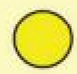
Describe properties of two elements X and Y with atomic numbers 11 and 17 respectively.

Solution

There is 1 electron in outer shell of element X, so it has got 1 valence electron, and group number will be I. The element Y has 7 electrons in the outershell, there are 7 valence electrons and the group number is 17 (VII), respectively. Both of them are located in 3rd period because they have 3 shells.

The element Y is located in a top right corner of the PT. Therefore the electronegativity will be greater compared to the element X. The atomic radius of element X will be much greater than that of the element Y. Because in located on the left corner of the PT.

The element X is active metal because located in left side of the PT, while the element Y will show opposite properties (active nonmetal).

Element	$_{11}X$	$_{17}Y$
Electron configuration	$1s^2 2s^2 2p^6 3s^1$	$1s^2 2s^2 2p^6 3s^2 3p^5$
Valence electrons	1	7
Group Period	1 3	17 3
Electronegativity	0.9	3.0
Atomic radius		
Metal / nonmetal	Active metal	Active nonmetal
Physical properties	Solid	Gas

Comparing a metal and a nonmetal atoms

Facts

D. Mendeleev predicted properties of several metals (Ge, Sc, Ga, Tc) even before they were discovered. For example:

Properties	Eka-silicium Es	Germanium Ge
Molar mass	72 g/mole	72.6 g/mole
Density	5.5 g/cm^3	5.35 g/cm^3
Oxide	EsO_2	GeO_2
Melting point, ^{0}C	high	947
Colour	dark grey	grey

Literacy

1. According to the Periodic trends in metallic properties, which element have the greater atomic radius?
2. Sort the elements in order of increasing metallic properties: Ca,Mg, Sr, Be, Ba
3. Why is the electronegativity value of most noble gases zero?
4. A nonmetal has a smaller ionic radius compared with a metal of the same period. Do you agree? Why?

Terminology

- to predict - болжау / предсказывать;
- electronegativity - электртерістік / электроотрицательность;
- Pauling's scale - Полинг шкаласы / шкала Полинга;
- value - шама / значение;

- to assume - елестету / представлять;
- sphere - шар / сфера;
- several - бірнеше / несколько;
- located - орналасқан / расположенный;
- therefore - сондықтан / поэтому;
- increase - өсу / увеличение.

8.4 ELEMENTS: METALS AND NONMETALS

You will:

- know physical and chemical properties of metal, nonmetal and amphoteric elements.

Have you ever heard that metals have a memory?

When we classify the elements as metals and nonmetals we see that metals occupy most of the part (about 80%) of the Periodic table. The elements in groups 1-13 (except hydrogen and boron) are metals. Only eleven elements H, C, N, O, P, S, Se, F, Cl, Br and I are nonmetals, and elements in group 18 are noble gases. However, among these elements, B, Si, Ge, As, Sb, Te, Po and At are metalloids and Sn, Pb, Bi and Be have metallic properties.

At room temperature, all metals have a silvery lustre and are in the solid state (except Hg which is in the liquid state). Nonmetals, which are dull, can be found in the solid state such as S (yellow) and I2 (purple-black), in the liquid state such as Br2 (reddish-brown) and the gaseous state, like N2 (colourless), O2 (colourless), F2 (light yellow) and Cl2 (yellowish-green).


White phosphorus

Some elements have properties of metals and nonmetals more at the same time. Such elements are called metalloids.

Comparison of physical properties

Main properties	Metals	Nonmetals	Metalloids
Colours	metallic shiny, grey colour (Au-golden, Cu-red)	dull colours	metallic shiny
Physical states	solid (except Hg)	solid, liquid and gaseous	solid
Conductivity of heat and electricity	good conductor	poor conductor (except graphite)	semiconductor
Hard or brittle?	malleable and ductile	brittle when solid	brittle

Comparison of chemical properties

Metals	Nonmetals
Have a tendency to donate electrons	Have a tendency to receive electrons
Displace hydrogen gas from dilute acids: zinc (Zn) + hydrochloric acid (HCl) → zinc chloride ($ZnCl_2$) + hydrogen (H_2)	Don't displace hydrogen gas from dilute acids
React with oxygen to produce basic oxides: sodium (Na) + oxygen (O_2) → sodium oxide (Na_2O)	React with oxygen to produce acidic oxides: carbon (C) + oxygen (O_2) → carbon dioxide (CO_2)
React with hydrogen to produce hydrides: calcium (Ca) + hydrogen (H_2) → calcium hydride (CaH_2)	React with hydrogen to produce covalent compounds: carbon (C) + hydrogen (H_2) → methane (CH_4)

Science in context

Noble gases are used in light lamps. Neon produces a reddish orange colour. Argon and helium are combined to produce dim blue light.

Argon and helium infinity shaped lamp

Facts

There are only two elements (mercury and bromine) in the Periodic table that are liquid at room temperature.

Mercury pouring from a pipette

Activity

Physical and chemical properties of metals, nonmetals and amphoteric elements

Materials:

helium balloon He, sulfur S, iodine I2 crystals, carbon C coal, red phosphorus P, sodium Na or potassium K metals, magnesium Mg, zinc Zn, copper Cu plate, iron Fe nail, aluminium Al foil, chlorine Cl2 gas, bromine Br2 solution and hydrochloric acid HCl solution.

Procedure:

1. Write main physical properties of metals and nonmetals in the table.
2. Add 1-2 lumps of each metal to acid.
3. Write reactions of metals with hydrochloric acid HCl.

Conclusion:

Physical properties of elements

	Colour	Melting point	Boiling point	Density
He	colourless			
C				
Mg				
Al			2519 °C	
P				
S	yellow			
Cl				
K				
Fe		1536 °C		
Cu				
Zn				7.14 g/cm³
I				

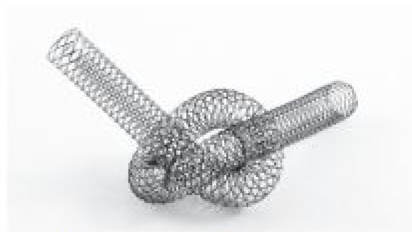
Chemical properties of metals and nonmetals

Al				C		
Zn	+ HCl →			P	+ O_2 →	
Fe				S		
Mg				I_2		

Facts

Is nitinol an alloy with memory?

Nitinol is typically composed of approximately 55% of Ni and 45% of Ti. Nitinol is a titaniumnickel wire that exhibits superelasticity. It can be out of shape and will spring back to its original shape. Nitinol is deformed at a low temperature, and heated to recover its original shape.



Braided nitinol self-expanding stent shaped into a knot

Terminology

- to occupy space - көлем алу / занимать пространство;
- lustre - жылтырақ / блеск;
- metalloid - металлоид / металлоид;
- dull - күңгірт / тусклый;
- conductivity - өткізгіштік / проводимость;
- brittle - морт, сынғыш / хрупкий;
- malleable - қақтауға төзімді / ковкий;
- ductile - созылмалы / тягучий.

Problems: Periodic table of chemical elements

1. Mendeleev left some places empty in his periodic table when he was arranging the elements according to increasing atomic weight. Why did he do so? Explain.

2. How many elements are there in first four periods respectively?

3. Which elements have similar chemical properties to chlorine Cl?

4. Which elements are found in the gaseous state in the form of monoatomic structure at room temperature?

5. Determine the group and period numbers of:

   a. Hydrogen, of which the electron configuration is 1s1
   b. Helium, of which the electron configuration is 1s2

6. Determine the place of aluminium Al element in the Periodic Table, if its electron configuration is 1s2 2s2 2p6 3s2 3p1.

7. Write down the electron configurations of the following elements: B, P, Zn and Ga.

8. Determine the places of the elements Sc, Fe, Ni and Cu in the Periodic Table.

9. What is the number of electrons of an element which is located in the 3rd period and group 4 of the Periodic Table?

10. What is the number of electrons of an element which is located in 4th period and group 14 of the Periodic Table?

11. A X^{3+} ion has 10 electrons. What are the group and period numbers of the X atom in the Periodic Table?

12. An Y^{3+} ion has 28 electrons. What are the group and period numbers of the Y atom in the Periodic Table?

13. An Z^{2-} ion has 18 electrons. What are the group and period numbers of the Z atom in the Periodic Table?

14. The atomic mass number of X is 70, and the number of neutrons of X is 39. What are the group and period numbers of element X in the Periodic Table?

15. For a neutral Br atom:

    a. Find the number of neutrons and protons in the nucleus.
    b. How many s electrons does it have in total?
    c. How many electrons does it have in 4p orbitals?
    d. Which type of orbital has the more electron than other?

16. The ions $_{21}X^{3+}$ and Y^{2-} have the same electron configuration. Find the place of Y in the Periodic Table.

17. Find the numbers of valence electrons for the elements magnesium ($_{12}Mg$), oxygen ($_{8}O$), silicon ($_{14}Si$) and zinc ($_{30}Zn$).

18. Among the 4th period elements, which of them have 4 valence electrons?

CHAPTER 9: CHEMICAL BONDS

9.1 COMPLETING OUTER SHELLS OF AN ATOM. "ELECTRON DOT REPRESENTATION" METHOD

You will:

- understand how the completion of the outer shell of an atom gives stability;
- explain how to complete outer shell of an atom.

How do atoms join to form compounds?

The noble gases (He, Ne, Ar, Kr, Xe, Rn) which form group 18 in the Periodic table are the most stable elements.

From lights to ballons we use noble gases

They all have the 8 electrons in the outershell of an atom. The other elements in the Periodic table have a tendency to gain the electron configuration of a noble gas and become stable. The tendency of atoms to make the number of their valence electrons 8, like noble gases is called octet rule. The rule is used for nonmetals, like carbon, nitrogen, oxygen and the halogens, and for metals such as sodium or magnesium. The inert gases are those which do not form chemical bonds or form very few bonds. When two or more element atoms attract each other and form a new compound, they form a chemical bond. This combination can occur either by sharing electrons or by transferring one or more electrons from one atom to another. There are two types of chemical bonds: covalent and ionic.

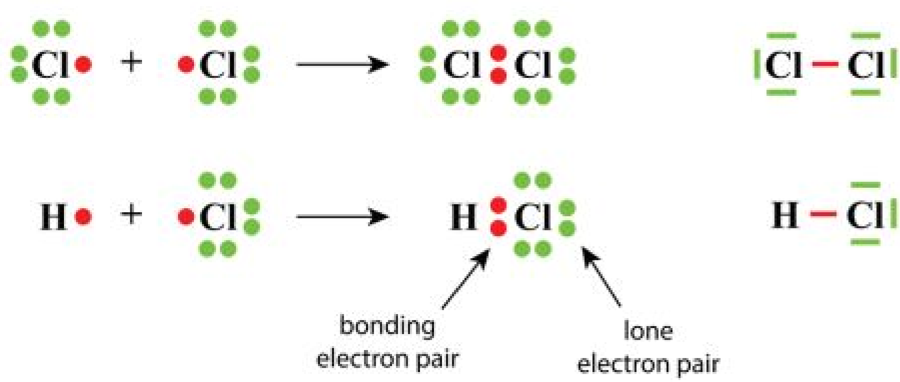
Before studying chemical bonds we need to become familiar with their representation. Chemical bonds may be represented in several ways. We are going to study electron dot representation and line representation. Let's examine these 2 types using the example of the hydrogen H2 and chlorine Cl2 molecules.

I. Electron dot representation

In this representation, valence electrons are shown as dots around the symbol of the element. When we look at the electron orbitals of the hydrogen atom, we see that it has one valence electron. The electron dot representation of hydrogen atom is -H though it can also be shown by H- or -H.

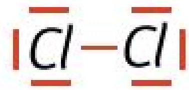
When 2 hydrogen atoms combine, H2 molecule forms:

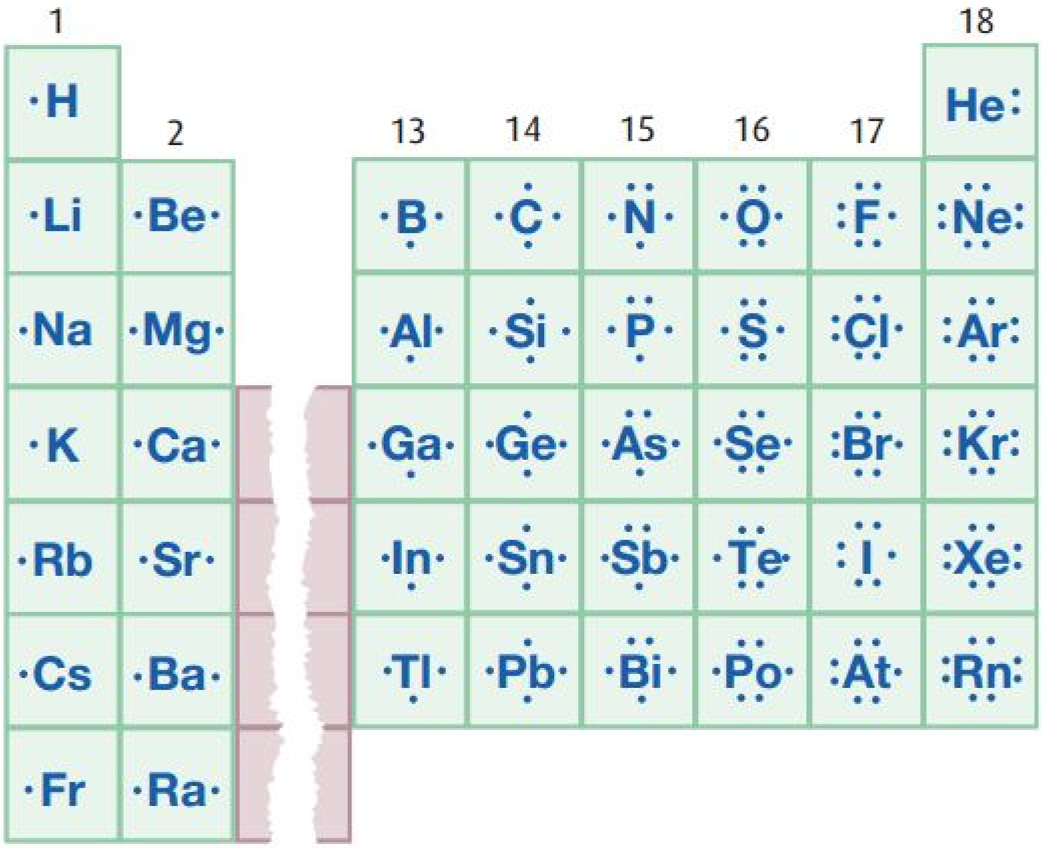
Chlorine atom has 7 valence electrons, and two chlorine atoms combined together and form Cl2 molecule:



II. Line representation

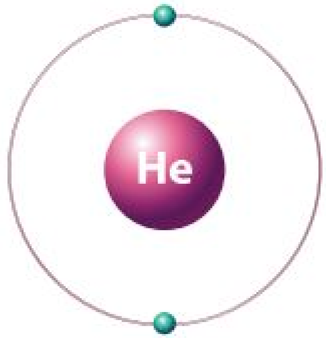
The bond structure can also be represented by lines. Aline shows each electron pair. In other words, two electrons ":" are shown by a line "–". So the line representation of the chlorine molecule Cl2 is





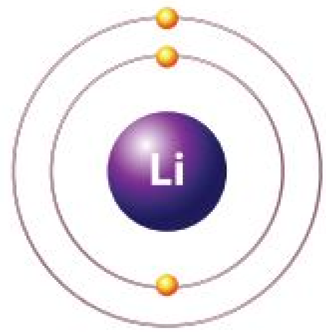
Valence electrons of main groups of elements

2 **Helium** He



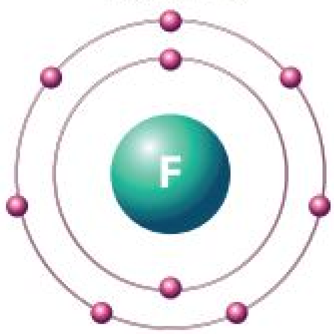
Atomic mass: 4
Electron configuration: 2

3 **Lithium** Li



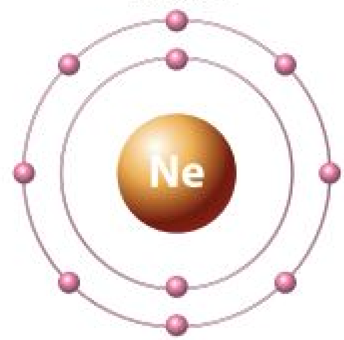
Atomic mass: 6.94
Electron configuration: 2. 1

9 **Fluorine** F



Atomic mass: 18.998
Electron configuration: 2. 7

10 **Neon** Ne



Atomic mass: 20.179
Electron configuration: 2. 8

Literacy

1. Which elements have full outershells of electrons in their atoms?
2. What is the maximum number of electrons in the outer shell of an atom?
3. How many electrons are in the outershell of the Ca, He, N, S, K, I atoms?

Terminology

- to complete – толтыру / заполнять;

- outershell – сыртқы қабат / внешняя оболочка;
- representation – бейнелеу, көрсету / представление;
- to attract – өзіне тарту / притягивать;
- to form – пайда болу / формировать;
- tendency – қабілет / стремление;
- valence – валенттік / валентный;
- chemical bond – химиялық байланыс / химическая связь;
- lone electron pair - байланыспаған электрон жұбы / несвязеобразующие электронные пары;
- bonding electron pair – байланысқан электрон жұбы / связеобразующие электронные пары.

9.2 IONIC BOND

You will:

- understand how atoms or ions gain/lose of electrons;
- draw the dot and cross diagrams of ionic compounds;
- understand the mechanism of formation of ionic bond and predict the properties of ionic compounds.

Why are ionic compounds crystalline?

Gain or lose of electrons

Ionic bond is formed by the transfer of electrons from one atom (usually a metal) to another atom (usually a nonmetal). After the transfer of electrons, the atom that lost electrons becomes positively charged and the atom that gained electrons becomes negatively charged. Ionic bond is formed between atoms that have an electronegativity difference greater than about 1.9.

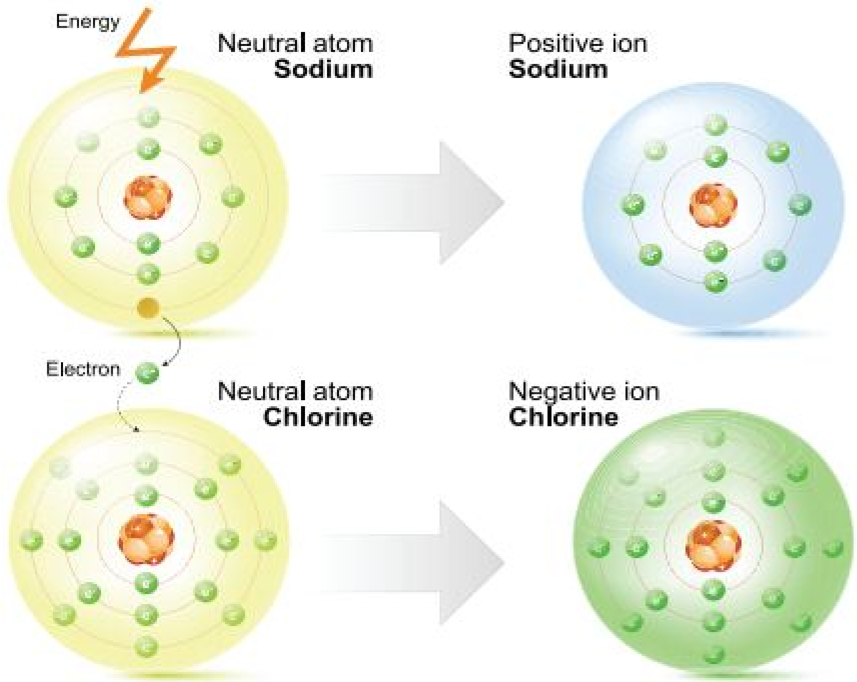
Let's consider the bond formation between sodium and chlorine, a metal and a nonmetal. The electronegativity values of sodium and chlorine 0.9 and 3.0. It means that sodium has a tendency to give electrons and chlorine has a tendency to take electrons.

When those 2 atoms come together under suitable conditions, to complete their octets, sodium gives one electron to chlorine:

$_{11}Na$: 2) 8) 1) $_{10}Na^{+}$ 2) 8)

$_{17}Cl$: 2) 8) 7) $_{18}Cl^{-}$ 2) 8) 8)

So the Na+ cation and Cl-anion are formed.



Formation of anions and cations

Why does salt melt ice?

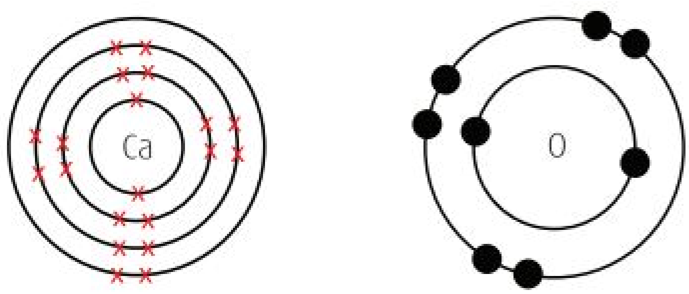
Salt will not melt frozen water, but if the ice starts melting in any way, added salt will lower the freezing point, and the water will not be able to refreeze. At this point, the salt water will also help melt the remaining ice which will then typically evaporate.


Table salt

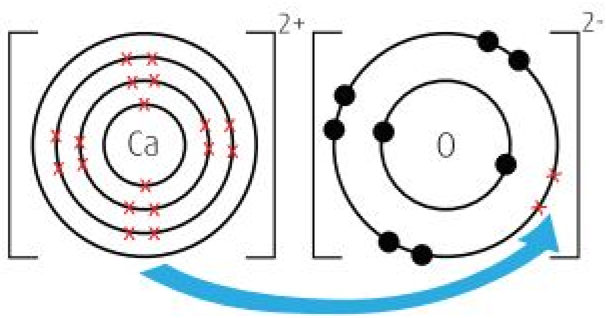

The Aral Sea is one of the main sources of salt in Kazakhstan

Drawing dot and cross diagrams for ionic bonding.

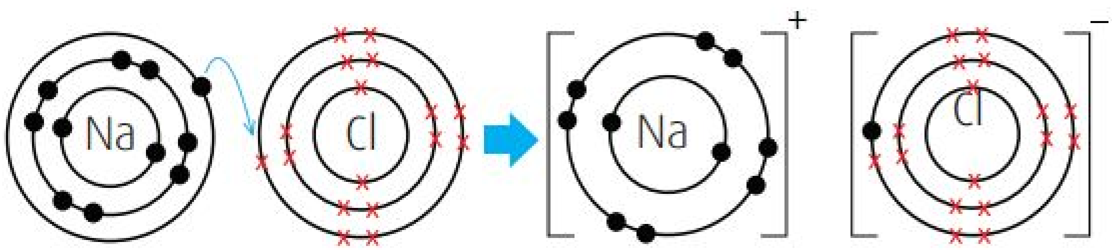
The dot and cross diagram for CaO. The electronic configurations of calcium and oxygen:



Ionic compound CaO is made of a metal and a nonmetal:



Dot and cross diagram for NaCl:



Ionic crystalline networks

Solids whose atoms or ions are arranged in a very regular sample in space are said to be “crystalline”. In sodium chloride, each sodium ion is neighbors with 6 chloride ions, all at the same distance from the sodium ion. Each chloride is neighbors with 6 sodium ions. The distance between the ions always the same, anywhere you go in the crystal. This regular position is called a crystal, so we say that the ionic compounds have a “crystalline”.

Literacy

1. Which of the following(s) is/are ionic crystalline solids?

Hg metal, water H2O, sodium iodide NaI, carbon dioxide gas CO2.

2. Which of the following elements lose electrons when react with each other: potassium and iodine, sulfur and sodium, magnesium and oxygen, fluorine and lithium?

Facts

The Dead Sea is also called salt sea. It contains about 30-35 kinds of minerals like potassium, magnesium, sodium, bromine, iodine, chlorine, etc. The high mineral and salt content of the waters make it impossible for fish or plants to live. Sea is so dense with salt that can easily float on the water without much effort.

Dead Sea, Isreal

Happy man relaxing in a water of the Dead Sea

Terminology

- ionic bond – иондық байланыс / ионная связь;
- to transfer – ауыстыру / переводить;
- melting – балқу / плавление;
- freezing – қату / замораживание;
- dot and cross – нүкте мен крест / точка и крест;
- crystalline network – кристалдық тор / кристаллическая решетка;
- neighbor – көрші / сосед.

9.3 COVALENT BOND

How do chemical bonds form between nonmetal atoms?

You will:

- understand the mechanism of formation of polar and nonpolar covalent bond based on the concept of electronegativity and valency;
- draw the dot and cross diagrams of covalent bonds.

Atoms and ions found connected in groups to form chemical bonds. What are reasons that cause iron to be solid, water to be liquid and hydrogen to bea gas at room temperature? Why is the diamond hard while the wax is soft?

For example, oxygen and sulfur are found within the same group in the Periodic table. Considering the trends in a group, we would expect the compounds of these two elements with hydrogen, H2S and H2O, todisplay similar properties. However, H2S is a gas while H2O is a liquid that has importance in the life cycle. What can be the reason for these two compounds being so different?

During the process of forming a chemical bond, energy is given out, and this energy is equal to that needed to break the same chemical bond. To gain a better understanding of chemical bonds we need to study electronegativity, a property that plays an important role in bond formation.

Oxygen and hydrogen gas ballons

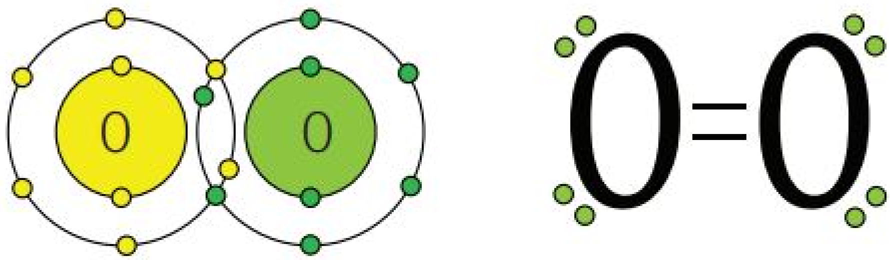

Hydrogen sulfide H_2S emits from volcanoes


Waterfall

Formation of covalent bonds

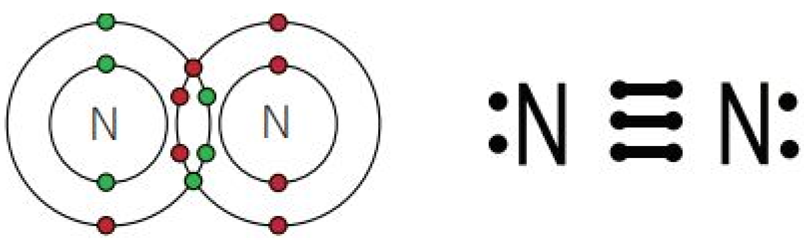
We know that the electronegativity difference between atoms must be greater than 1.9 to form an ionic bond. But if the electronegativity values of the atoms are similar, the tendency of the atoms to take or give electrons will also be same. The transfer of electrons is not possible between such atoms, so the atoms must share electrons to gain a stable octet. The bond that is formed as a result of electron sharing is called a covalent bond. Covalent bonds are formed between two nonmetals.

Let's examine the formation of an oxygen molecule from two oxygen atoms:



To be stable, the oxygen atom needs two more electrons and so it forms a double bond with another oxygen atom.

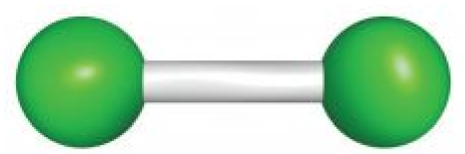
For example, the nitrogen atom needs to gain three electrons to reach stability and so it forms a triple bond with another nitrogen atom:



Covalent bonds can be classified into 2 groups: polar and nonpolar.

Nonpolar covalent bonds

These are bonds that are formed between two nonmetal atoms with the same electronegativity values. For example, the bonds in H2 (H - H), N2 molecule (N≡N), Cl2 molecule (Cl-Cl) and O2 molecule (O = O) are all nonpolar covalent bonds.

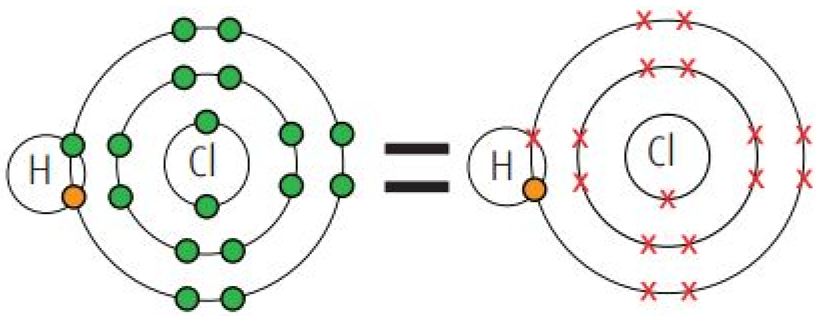


The molecule of chlorine gas

Nitrogen gas ballons

Polar covalent bonds

These are bonds that are formed between two nonmetal atoms with different electronegativity values. For example, let's examine the covalent bond between the H and Cl atoms:



Literacy

Fill in the blanks:

a) Ionic bond is formed between a metal and a nonmetal by .... electrons.
b) Covalent bond is formed between nonmetals by .... electrons.
c) Covalent bond is classified as ....and ....
d) .... bond is formed between same nonmetals.

e) .... bond is formed between different nonmetals.

Terminology

- to attract – өзіне тарту / притягивать;
- difference – айырмашылық / разница;
- similar – ұқсас / похожий;
- sharing – бөлісу / деление;
- covalent – ковалентті / ковалентная;
- polar – полярлы / полярная;
- nonpolar – полярсыз / неполярная;
- value – өлшем / величина.

9.4 THE RELATIONSHIP BETWEEN TYPES OF CHEMICAL BONDS AND PROPERTIES OF SUBSTANCES

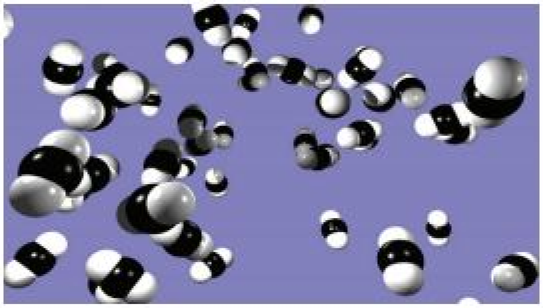
Why is diamond mineral very hard?

You will:

- understand that the structure of substances affects their properties.

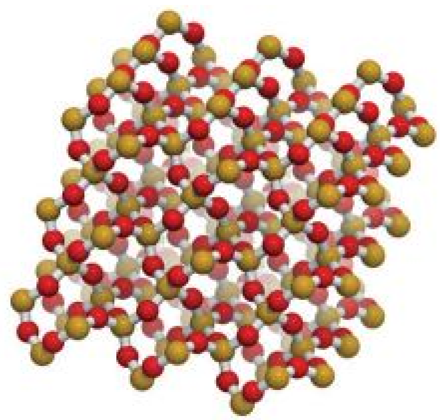
Differences between nonmetal compounds. Carbon and silicon

Carbon and silicon are in the same column in Periodic table. They both have 4 valence electrons but there is a difference in the properties of their oxides. Carbon and silicon have oxides: CO2 and SiO2 respectively. Carbon dioxide CO2 is a gas which exists as single molecules which are linked to each other by weak intermolecular forces. Silicon dioxide SiO2 is a very hard, high-melting solid. It is a network solid in which silicon is connected to 4 of its oxygen atoms to make a repeating pattern of silicon and oxygen atoms.



In molecular covalent compounds, intermolecular forces are very weak in comparison with ionic bonds. For this reason, most covalent substances with a low molecular mass are gaseous at room temperature. Others, with higher molecular masses, may be liquids or solids, though with relatively low melting and boiling point. In some covalent substances (network solids) atoms are bonded together in a way that forms a network structure.

Quartz is a mineral composed of SiO_2



Network solid structure of SiO_2

Substance	Intramolecular Forces	Attracting Particles	Physical Properties
Network crystals (Ex: C, SiC, SiO_2)	Covalent	Atoms	- very high melting point - very hard - do not conduct electricity (except graphite)
Metals (Ex: Li, Cu, Pt, Fe, Hg)	Metallic	Positive cations and mobile electrons	- hard or soft - high melting point - malleable and ductile - conduct heat and electricity
Network crystals (Ex: NaCl, $BaCl_2$, KNO_3)	Ionic	Positive and nega-tive ions	- hard and brittle - high melting point - aqueous solutions and -molten states conduct electricity

A summary of intramolecular forces

Facts

Diamond or graphite?

Both diamond and graphite are forms of carbon and have network covalent bonding. However, they are arranged differently. Graphite forms in thin layers. Imagine a stack of thin paper. Every time you press down on a pencil, a few layers rub off onto the surface you are writing on and stay there. Diamonds, on the other hand, form in much stronger and complex forms, which are almost impossible to break. This makes it one of the strongest substances on the Earth. Diamond is used to cutting other hard materials such as glass because of its hardness.

Diamond

Graphite pencils

Activity

Covalent, ionic, metallic bond construction models

Introduction:

Metallic bond networks formed between strong forces. The bond force of ionic and covalent bonds are weaker than metallic.

Materials:

small rubber balls, wires.

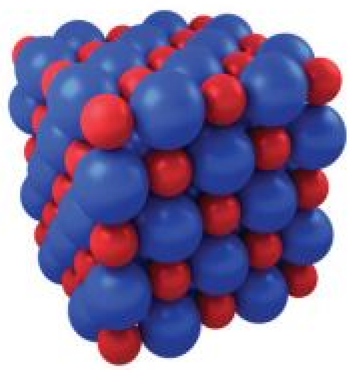
By using same small balls construct molecular models of some compounds.

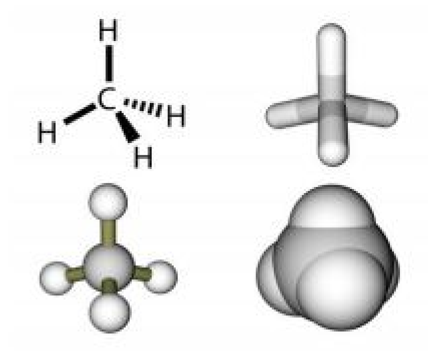
Procedure:

By using 2 types of atomic balls we construct ionic and covalent bonded compounds:

1. Sodium chloride NaCl, potassium bromide KBr, calcium oxide CaO.
2. Carbon dioxide CO2, methane CH4, water H2O, ammonia NH3, phosphine PH3, sulfur dioxide SO2, sulfur trioxide SO3 and phosphorus pentachloride PCl5.

Covalent bonded networks formed between 2 or more nonmetal atoms.





Literacy

Draw the dot-cross structures of H2S, HBr, BH3, PF3 molecules.

Terminology

- diamond – алмаз / алмаз;
- graphite – графит / графит;
- brittle – сынғыш / хрупкий;
- to exist – кездесу / существовать;
- intramolecular – молекула ішілік / внутримолекулярный;
- thin layer – жұқа қабат / тонкий слой;
- impossible – мүмкін емес / невозможно;
- rubber balls – резеңке шарлар / резиновые шарики.

Problems: Chemical bonds

1. Draw the dot-cross structures of H2O, HF, BCl3, NF3 molecules.

2. For the HCl molecule, show its

   a) electron dot representation
   b) electron numbers of each atom

3. Show the formation of ionic bonds between the following pairs:

- 11Na and 9F
- 20Ca and 8O

4. What kind of chemical bonds do the following compounds contain?

- H2O
- KCl
- Na3PO4

5. Place in order of increasing electronegativity: P, H, O, S, Na, Mg.

6. Explain the bond formation in Cl2 and O2 using electron dot representation (17Cl, 8O).

7. Draw the electron dot structures of the following elements:

   a) 5B
   b) 12Mg

c) 15P
d) 19K

8. Which of the following compounds contain ionic bond?

H_2O, Na_2O, KCl, $CaBr_2$, P_2O_5.

9. Which of the below molecules is/are polar?

I. H_2O
II. NH_3
III. CH_4

a) I only
b) II only
c) I and II
d) II and III
e) I, II and III

10. Which one of the following molecules has an ionic bond?

a) HCl
b) BrCl
c) PCl_3
d) MgF_2
e) CF_4

11. Which one of the following molecules has a nonpolar covalent bond?

a) NaCl
b) $MgCl_2$
c) $AlCl_3$
d) Cl_2
e) HCl

12. Fill in the gaps:

a) An ionic bond is formed between metal and nonmetal...............electrons.
b) The covalent bond is formed between nonmetals by .... electrons.
c) The covalent bond is classified as ....and ....
d) .... bond is formed between same nonmetals.
e) .... bond is formed between different nonmetals

CHAPTER 10: SOLUTIONS

10.1 SOLUTIONS. SOLUBILITY

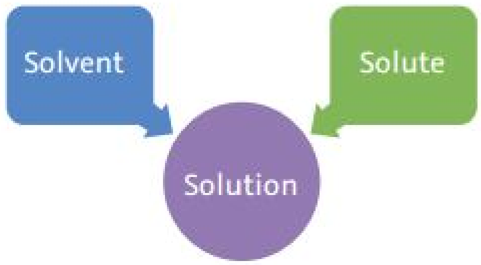
Why is sea water salty? Why is sugar more soluble in water than salt?

You will:

- classify the substances according to the degree of solubility;
- learn about solutions and their importance;
- determine the composition of salt solutions by using evaporation method;
- know and determine saturated solutions.

Solutions

A solution is a mixture where all components are mixed. Solutions are important for life and many processes. The components of a solution are the solvent and the solute. For example, when we dissolve a teaspoon of sugar in a glass of water, the sugar is the solute, and the water is the solvent. In tap water, the solvent is water, and the salts (NaCl, Ca(HCO3)2) are solutes.




Household ammonia solution


Dyes aqueous solution

Solubility

When you add a spoonful of sodium chloride (table salt) to a glass of water, it rapidly dissolves. As you continue to add more salt, however, there comes the point when it no longer dissolves. Instead, it collects at the bottom of the glass, even after mixing. When a solution contains as much solute as will dissolve, we say it is saturated. When the solution has some sodium chloride in it but can still dissolve more, it is said to be an unsaturated solution.

The solubility of a compound is the maximum amount of solute dissolving in a given solvent to form a saturated solution. Solubility data are reported in units of grams of solute per 100 g of water. Each solid has a different solubility in water. For example, the solubility of table salt NaCl is 36 g/100 g of water and sugar is 204 g/100 g of water at 20oC.

The solubility of table salt ($NaCl$) is 36 g/100 g of water at 20°C

The solubility of sugar is 204 g/100 g of water at 20°C

The solubilities of ionic salts have a wide range. For example, silver perchlorate $AgClO_4$ has a solubility of 55.7 g per 100 g of water, only 0.00018 g of silver chloride $AgCl$ can dissolve in 100 g of water. If the maximum amount of solute dissolved in 100 g of water is less than 0.1 g, this solute is said to be insoluble. The solute that has a solubility range from 0.1 g to 1 g is called slightly soluble. If the amount of solute is more than 1 g, then it is soluble.

Solutions of copper (II) sulfate with different concentrations

Facts

Some mineral salts have been carried to the oceans and seas by rivers for many centuries. These salts are soluble in water and produce ions such as Cl-, Na+, SO42- , Mg2+, Ca2+. These dissolved ions make sea salt.

Sea water

Lab work

№ 5. Solubility of substances

Solution consists of solvent and solute. In this experiment, we show solubility of substances.

Materials:

copper sulfate $CuSO_4 \cdot 5H_2O$, sugar, chalk $CaCO_3$, fl asks, water, mixer.

Procedure:

1. Take 100 g of each substance (copper sulfate $CuSO_4 \cdot 5H_2O$, sugar, chalk $CaCO_3$), and dissolve in 100 g of water. Prepare 3 different solutions.
2. Observe how much of substances dissolved in water.
3. Divide substance into 3 types: very soluble, soluble and slightly soluble.

Observation & questions:

1. Which substance is very soluble in water?
2. How much of chalk dissolved in water?

Copper (II) sulfate solution

Salt and water

Terminology

- solution – ерітінді / раствор;
- solubility – ерігіштік / растворимость;
- soluble – ерігіш / растворимое;
- slightly soluble – аз ерігіш / малорастворимое;
- insoluble – ерімейтін / нерастворимое;
- solvent – еріткіш / растворитель;
- solute – еригіш зат / растворенное вещество;
- spoonful – толы қасық / полная ложка;
- saturated – қаныққан / насыщенный;
- unsaturated – қанықпаған / ненасыщенный;
- wide range – кең көлемде / широкий диапазон.

10.2 SOLUBILITY OF SUBSTANCES. FACTORS AFFECTING SOLUBILITY

Why are salts more soluble at higher temperatures?

You will:

- grow salt crystals and mark the correct shape of crystals;
- know about supersaturated solutions and determine energy changes in crystallization;
- know and explain the effect of temperature on solubility.

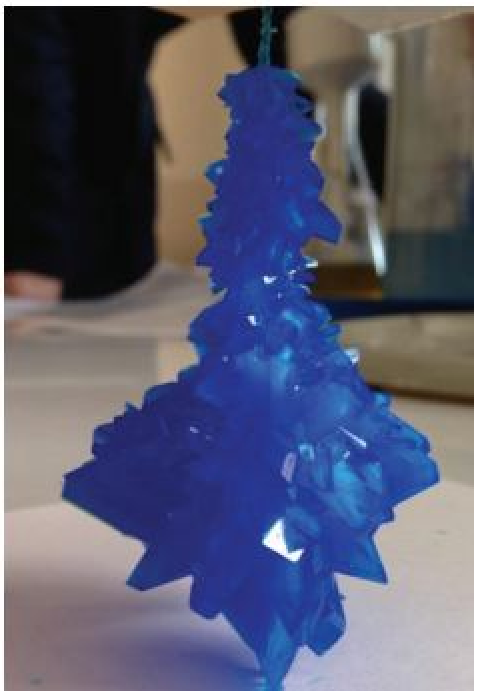
Growing salt crystals

Growing salt crystals is very interesting. If you decide to grow the crystals, you will need some materials:

1. Compound (may be salts, organic acids, other substances). You can buy them in pharmacy, in gardening store, in chemical stores, etc.
2. Room temperature conditions.
3. Desire and patience. Crystals do not grow in one day. Let's consider growing copper sulfate crystals. Copper sulfate is blue coloured salt. You can buy this salt in any gardening store. We need about 300 g of salt for experiment and a glass beaker. Put our copper sulfate into the beaker, and pour hot water. And dissolve the salt, prepare a supersaturated solution. Then filter the solution with filter paper or with a napkin. Put beaker with the solution in a cooler place. The next day, you will see little

crystals at the bottom of the beaker. Take the large crystals from the bottom. After that, filter the solution again. Hang up the selected crystal on a thread. Then put your crystal into the beaker. Filter the solution once or twice a week. And good luck!

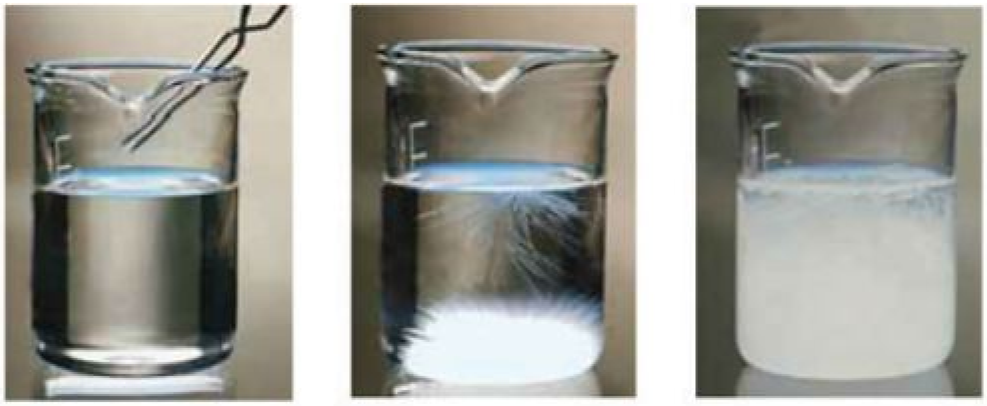
Solutions of copper compounds may be toxic - wash your hands thoroughly.



Crystals of copper sulfate

Supersaturated solutions

A supersaturated solution is a solution that contains more dissolved solute in a given amount of solvent. For example, 161 g of sodium acetate (CH3COONa) can be dissolved in 100 g of water at 90oC. When this saturated solution is carefully cooled to 20oC, at this temperature the solubility of sodium acetate is 123 g/100 g of water, but all the solute still may remain in the solution. The cooled solution contains more solute than it normally would. Such a solution is unstable, and the excess dissolved solute (161 g - 123 g = 38 g) may crystallize by the addition of a seed crystal of the solute to the supersaturated solution.



When a small seed crystal of sodium acetate is added to this supersaturated solution, the excess salt quickly crystallizes

When a small seed crystal of sodium acetate is added to this supersaturated solution, the excess salt quickly crystallizes.

Honey is an example of a supersaturated solution

Heating of solutions

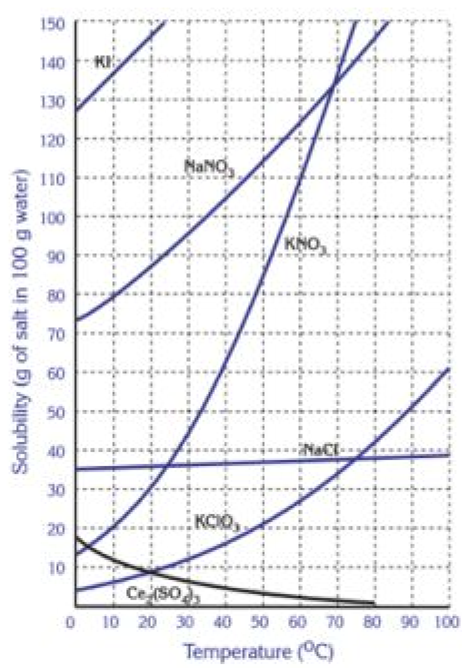
Factors affecting solubility

The solubilities of substances do not depend only on the amount of solute or solvent. Temperature and pressure are also factors that affect solubility. As for mixing, even if it seems to increase solubility, it has no effect. Stirring only speeds up dissolution. Solubility varies with temperature. The solubilities of solids usually increase as the temperature rises. For example, sugar dissolves more in hot coffee than in cold coffee.

This table shows the effect of temperature on the solubility of sugar:

Temperature, °C	0	10	20	25	30	40	45	50
Solubility of sugar, g/100g of water	179	190	204	211	219	238	248	260

But gases, unlike solids, are more soluble in liquids at lower temperatures. As pressure increases, the solubilities of solids and liquids do not change much, but the solubilities of gases increase.



The solubilities of most solids increase as temperature increases

Terminology

- affecting factors – әсер етуші факторлар / влиющие факторы;
- to grow crystals – кристалл өсіру /выращивать кристаллы;
- to decide – шешім қабылдау /решать;
- pharmacy – дәріхана / аптека;
- gardening store – бау-бақша дүкені/ магазин для садоводства;
- to desire – қалау / желать;
- patience – сабыр / терпение;
- to select – таңдау / выбрать;
- hang up – іліп қою / повесить;
- supersaturated – аса қаныққан / перенасыщенный;
- cooling – суыту / охлаждение;
- to remain – қалдыру / оставаться;
- seed crystal – кристалл өсіндісі / семя кристалла;
- to depend – байланысты болу/ зависеть;
- to rise – өсу / повышать;
- stirring – араластыру / перемешивание;
- thread – жіп / нить.

10.3 CALCULATIONS OF SOLUBILITY AND MASS PERCENTAGE OF SUBSTANCES

How can we calculate the mass of salt in a solution?

You will:

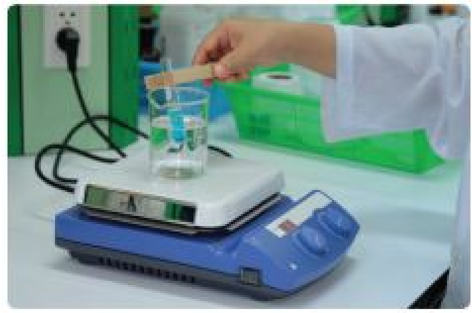
- calculate solubility of substances in 100 g of water by using evapouration method;
- calculate mass percentage of salts in solution.

Obtaining soluble substances

Soluble substances can be obtained by evaporating water from the mixture. This method is used widely in the industry.

- Fill the 100 ml of 250 ml of a beaker with distilled water then put 35 g of sodium chloride salt into the beaker.
- Stir the salt until the salt dissolves.
- Place the evaporating dish in the middle of the wire gauze, then heat it. Observe the recrystallization of the salt (mass of salt must be 35 g).

Colourful salt solutions



Water bath: heating of solution

Example 1

The solubility of potassium iodide is 136 g / 100 g of water at 10°C. How many grams of water is needed to dissolve 200 g of potassium iodide at the same temperature?

Solution

This question can be calculated by using a simple proportion.

If 136 g of KI dissolve in 100 g of water

200 g of KI dissolve in X g of water

X = 200 • 100 / 136 = 147 g

147 g of water is needed to dissolve 200 g of potassium iodide at 10°C.

Percent concentration

One common way of describing a solution's composition is mass percentage, known as weight percentage or percentage by weight. Mass percentage expresses the mass of solute present in a given mass of solution. To calculate mass percentage, we must divide. The mass of solute by the mass of the solution & multiply by 100%:

$$\text{Mass percentage} = \frac{\text{mass of solute}}{\text{mass of solution}} \cdot 100\%$$

For example, let us prepare a solution by adding 20 g of table salt, NaCl, to 80 g of water. In this solution the mass of solute (table salt) is 20 g and the mass of solution (table salt and water) is 100 g (20 + 80 = 100g). The mass percent is,

$$\omega\,(\text{salt}) = \frac{20g}{20g+80g} \cdot 100\% = 20\%$$

Example 2

How many grams of glucose (C6H12O6) must be dissolved in water to prepare 400 g of 15% solution by mass?

Solution

The mass percentage and the mass of the required solution are known. The mass of solute can be found by the following equation:

$$\text{Mass percent} = \frac{\text{mass(solute)}}{\text{mass(solution)}} \cdot 100\%$$

$$15\% = \frac{\text{mass (glucose)}}{400\ g} \cdot 100\% \qquad \text{mass (glucose)} = \frac{400 \cdot 15\%}{100\%} = 60\ g$$

Practice work

№ 4. The effect of temperature on the solubility of solid substances

Mostly of solid substances are more soluble in hot water than in cold water. This experiment shows solubility of substances at different temperatures.

Materials:

potassium chloride KCl, distilled water, heating bath or burner, thermometer, stirring rod.

Procedure:

1. Prepare a beaker with 100 g of cold water (5-10oC).
2. Dissolve 45-50 g of potassium chloride in it. Observe the dissolution process.
3. Heat the beaker and stir the solution.
4. Check the temperature at which the salt will totally dissolve.

Observation and questions:

1. Compare approximately amount of dissolved salt with the solubility table.
2. How many grams of potassium chloride wil be dissolved in 1 L of water at 50oC? (d(water)=1 g/ml)
3. Why are salts more soluble in hot water, than in cold water?

The solubility table of KCl

temperature , °C	mass, g
0	29
10	32
20	36
30	40
40	42.5
50	45
60	47.5
70	50
80	52
90	54
100	56

Literacy

1. A solution is prepared by mixing 350 g of water and 50 g of sugar. What is the percent concentration of sugar by mass in the solution?
2. How many grams of CuSO4 must be dissolved in water to prepare 600 g of 25% solution by mass?
3. How many grams of potassium iodide can be dissolved in 400 g of water at 10°C? (The solubility of KI at 10°C is given in the example 1)

Terminology

- mass percentage – массалық үлес / массовая доля;
- parameters – параметрлер (масса, көлем) / параметры;
- widely – кеңінен / широко;
- to stir – араластыру / перемешать;
- wire gauze – сым торша / проволочные сетки;

- recrystallization – қайта кристалдану / перекристаллизация;
- proportion – қатынас / пропорция;
- to multiply – көбейту / умножать.
- solubility – ерігіштік /растворимость.

10.4 MOLAR CONCENTRATION

What is the molarity of solution?

You will:

- calculate molar concentration (molarity) in a solution;
- prepare solutions with given mass percentage and molar concentration.

Molar concentration (Molarity)

Molarity is the most common concentration unit. It is used in calculations with a volume of solutions. Molarity can be defi ned as the mole number of solute dissolved per one litre of solution. The symbol for molarity is CM.

$$Molarity = \frac{mole\ number}{volume\ of\ solution} = \frac{mol}{L} \qquad C_M = \frac{n}{V}$$

The unit of molarity is mol/L or M (read as molar). A sodium hydroxide solution that contains 1 mole of NaOH per litre of solution has a concentration of 1 molar, which is often shortened 1 M. A more concentrated, 3 M sodium hydroxide solution contains 3 moles of NaOH per litre of solution.

Example

A water sample was taken from the Balkhash lake contains 5.2 g of sodium chloride (NaCl) in one litre of solution. Find the molarity of sodium chloride in the sample.


The lake Balkhash, Kazakhstan

Solution

First, we must calculate the mole number of NaCl (solute).

The molar mass of sodium chloride is Mr (NaCl) = 23 + 35.5 = 58.5 g/mol.

Thus, the mole number of sodium chloride becomes

$n = m/M = 5.2/58.5 = 0.089$ mol

Now, the molarity of solution can be calculated:

$CM = n/V = 0.089/1 = 0.089 \approx 0.09M$

The molar concentration of sodium chloride is approx.0.09 M.

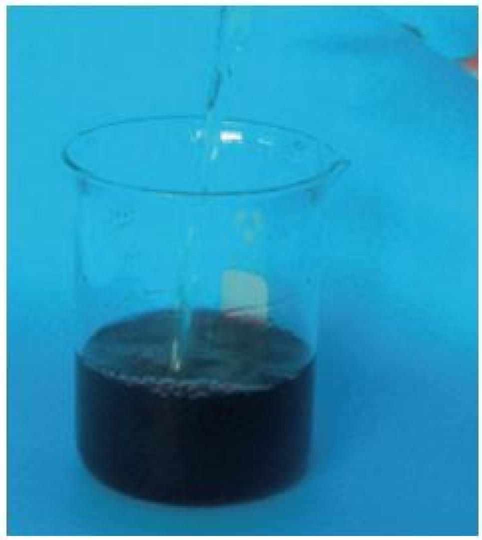
Literacy

A 29.8 g sample of potassium chloride KCl is dissolved in enough water to obtain 100 ml of solution. What is the molar concentration of the resulting solution?

Preparation of solutions

1. Take some amount of a salt.
2. Then, weigh it and record the mass of this salt.
3. Then, place the salt into a flask.
4. Dissolve this salt in some amount of water and weigh the solution on a balance.
5. Record the result in the data table.

A concentrated fruit juice solution



Dilution process by adding water

A dulite fruit juice solution

Practice work

№ 5. Preparation of solutions with given a mass percentage and molar concentration

Materials:

iron (III) chloride FeCl3, sodium chloride NaCl, distilled water, conical flask (250 ml), scales.

Variant I

1. Put 50 g of iron (III) chloride FeCl3 into a flask.
2. Add 150 g of disstilled water.
3. Weigh the resulting solution.
4. Calculate mass percentage of obtained solution.

Variant II

1. Put 40 g of sodium chloride NaCl into a flask.
2. Add 160 ml of distilled water.
3. Weigh the resulting solution.
4. Calculate mass percentage of obtained solution.

Reflection

Reflection for the 3rd quarter

The most difficult topic for me was ....

The easiest topic for me was ....

Rate yourself on 10-point scale

1. I can help others ....
2. I need more practice ....
3. I need extra lessons ....

Terminology

- molar concentration – молярлық концентрация / молярная концентрация;
- mass percentage – массалық үлес / массовая доля;
- molarity – молярлық / молярность;
- volumetric – көлемдік / объемная;
- scale – таразы / весы;
- necessary – қажетті / необходимое;
- stoichiometry – стехиометрия / стехиометрия;
- shortened – қысқартылып / сокращенный;
- sample – үлгі / навеска;
- distilled water – дистильденген су / дистиллированная вода.

Problems: Solutions

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

a) The solute in a solution is always solid.
b) Solutions are the homogeneous mixtures.
c) Main components of the solution are solvent and solute.
d) Water is universal solvent.
e) Chalk $CaCO_3$ is soluble in water.
f) Most of the salts are soluble in water.

2. Complete the statements below. The missing words can be found in the word list below. There may be more words in the list than necessary.

Word list

solubility molarity solvent and solute unsaturated solution temperature solvent

a) Main components of a solution are ....
b) An .... is when there is too little solute in the solvent.
c) .... is a measure of how much solute can dissolve in a solvent at a given temperature.
d) .... is a substance that dissolves another substance.
e) The unit of .... is mol/L.
f) .... is the main affecting factor of solubility.

3. For each of the following solutions, identify the solvent and the solute:

a) Water and salt
b) 100 ml of alcohol and 30 ml of water
c) 30 g of sugar and 100 ml of hot water.

4. When there is ice on the roads in winter, salt is added to the ice. Explain why it is done.

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

6. Explain how temperature affects the solubility of carbon dioxide gas in soft drinks.

7. Explain why chemical compounds tend to dissolve more quickly a in hot solvent than in cold solvent.

8. How can you make a supersaturated solution from a saturated solution?

9. How can you make an unsaturated solution from a saturated solution?

10. The solubility of table salt, NaCl is 37g/100g in water at 20oC. How many grams of table salt can be dissolved in 350 g of water at the same temperature?

11. In two different test tubes, there are two solids, sodium bicarbonate (baking soda) and sugar. How can you identify them?

12. The solubility of KCl is 40g/100g of water at 30oC. A solution is prepared by dissolving 65 g of KCl in 200 g of water at 30oC.

Is the prepared solution saturated?

If not, how many grams of KCl must be added to make the solution saturated?

13. The solubility of sugar is 204 g /100 g of water at 20oC. How many grams of sugar can be dissolved in 75 g of water at the same temperature?

a) 75 g
b) 200 g
c) 153 g
d) 45 g
e) 88 g

14. Which one of the following substances is not a solution?

a) sweet water
b) salt water
c) honey
d) water vapour
e) human blood

15. Which one of the following statements is wrong for solutions?

a) They are impure substances
b) They are homogeneous mixtures
c) They have 2 components, solvent and solute
d) In salt water, salt is the solute
e) The solubility of substances is not affected by temperature.

16. Which of the given dissolve(s) in water?

I. Wood
II. Sugar
III. Alcohol

a) Only I
b) Only II
c) I and II
d) II, III
e) Only III

17. Which one of the following is more soluble in water?

a) ethyl alcohol
b) carbon dioxide
c)oil
d) table salt
e) sugar

CHAPTER 11: INORGANIC COMPOUNDS

11.1 Oxides

How is acid rain formed?

You will:

- know and understand classification and properties of oxides.

Classifications of oxides.

Compounds of oxygen with other elements are called oxides. So, there are only 2 kinds of atoms in oxides. $CO2$, NO, CaO, $H2O$ and $Fe2O3$ are some examples of oxides.

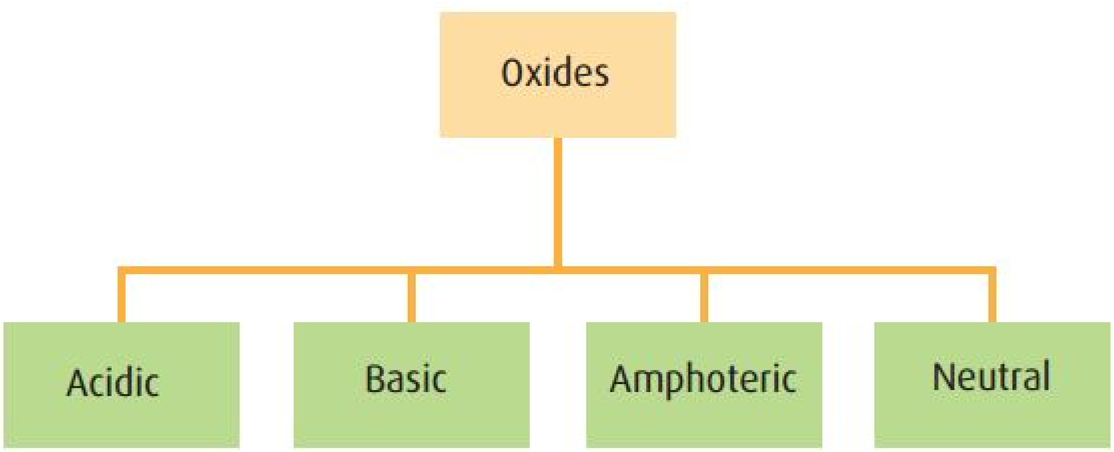
Oxides are widely spread in nature. Water is an oxide of hydrogen. Silicon dioxide, $SiO2$, is the main component of sand. Carbon dioxide, $CO2$, is expelled by humans, animals and plants during respiration. Sulfur dioxide $SO2$ and nitrogen oxides (NO, $NO2$) are dangerous gases that pollute our atmosphere.

No life without water

Sand is the most abundant substance

CO_2 extinguishes fire

Oxides can be classified into four different groups: basic, acidic, amphoteric and neutral.



Basic oxides

Most of the metal oxides are basic oxides. MgO, Na2O and Li2O are some examples of them. They react with water to produce bases:

Basic oxide + Water → Base

$Na_2O(s) + H_2O(l) \rightarrow 2NaOH(aq)$

$CaO(s) + H_2O(l) \rightarrow Ca(OH)_2(aq)$

$CaO(s) + H_2O(l) \rightarrow CaSO_4(aq) + H_2SO_4(aq)$

Basic oxides react with acidic oxides to produce salts:

$Li_2O(s) + CO_2(g) > Li_2CO_3(s)$

Acidic oxides

Acidic oxides react with water to form acids. Most of acidic oxides are oxides of nonmetals. SO_2, P_2O_5, NO_2 are examples of acidic oxides. They react with water in that way:

Air pollution from vehicle exhaust pipe on road (NO_2, CO_2)

Match burning (SO_2, P_2O_5)

Acidic oxide + Water → Acid

$SO_2(g) + H_2O(l) \rightarrow H_2SO_3(aq)$

$P_2O_5(s) + 3H_2O(l) \rightarrow 2H_3PO_4(aq)$

Acidic oxides react with bases to produce salts and water:

$$CO_2(g) + 2KOH(aq) \rightarrow K_2CO_3(aq) + H_2O(l)$$

Acidic oxides react with basic oxides to produce salts:

$$SO_3(g) + MgO(s) \rightarrow MgSO_4(s)$$

Amphoteric oxides

Al, Zn, Sn, Pb, Cr, Be are amphoteric metals. The following oxides of these metals are also amphoteric: Al_2O_3, ZnO, SnO, PbO, Cr_2O_3, BeO. They react with both acids and bases to produce salts and water:

$$Al_2O_3(s) + 6HCl(aq) \rightarrow 2AlCl_3(aq) + 3H_2O(l)$$

$$ZnO(s) + 2NaOH(aq) \rightarrow Na_2ZnO_2(aq) + H_2O(l)$$

Neutral oxides

Neutral oxides NO, N_2O, CO are compounds which show neither basic nor acidic properties. They do not react with acids and bases.

Facts

Dinitrogen oxide is a colourless, nonflammable gas, with a pleasant, slightly sweet odour, taste. N_2O is used in surgery and dentistry for its anesthetic effects.

Lab work

№ 6. Properties of oxides

Introduction

Oxides react with water to produce bases or acids. In this experiment we will produce base.

Materials:

Calcium oxide CaO, water, beaker (250 ml), stirring rod, litmus paper.

Procedure:

- Pour 100 ml of water into a 250 ml beaker. Check water with litmus paper.
- Add 3-4 g of calcium oxide to the beaker and mix.
- Check result solution with litmus paper.

Observation & questions:

1. Write equation of chemical reaction.
2. Try to explain colour change of litmus paper indicator after the reaction.

Terminology

- oxides – оксидтер / оксиды;
- spread – таралған / распределенный;
- sand – құм / песок;
- pollution – ластану / загрязнение;
- basic – негіздік / основной;
- acidic – қышқылдық / кислотный;
- amphoteric – екідайлы, амфотерлі / амфотерный;
- bases – негіздер (сілтілер) / основания (щелочи);
- acids – қышқылдар / кислоты;
- neither – ешқайсы / ни один из них.

11.2 ACIDS

What are the benefits of acids?

You will:

- know and understand classification and properties of acids.

Classification of acids

Acids are one of the most important classes of compounds in chemistry. They are so common that we face them every day. The sourness of lemonade, fizzy drinks and specific taste of vinegar all come from acids. Car batteries use sulfuric acid, and many cleaning materials contain hydrochloric acid. We eat lemons containing citric acid and drink coke containing carbonic and phosphoric acids.

Acids have a sour taste. Most acids are soluble in water. At normal conditions, many acids are liquid (HNO3, H2SO4), while some of them are solid (H2SiO3 , H3PO4). Some volatile acids (HCl, HNO3) have a characteristic odour.

Acids are corrosive substances. Sulfuric acid, nitric acid and hydrochloric acid (H2SO4, HNO3, HCl) are the most dangerous. They can corrode paper, wood, organic tissue.

Acids are often shown as HA, where H is hydrogen and A is the anion. So they are composed of H+ cations and A-anions.

Acids can be classified according to strength: strong and weak.

Strong	Weak
H_2SO_4	H_2CO_3
HNO_3	HNO_2
HCl	H_3PO_4
	CH_3COOH

According to the number of H+ ions, acids are classified as monoprotic, diprotic and triprotic.

Monoprotic	Diprotic	Triprotic
• HCl	• H_2SO_4	• H_3PO_4
• HNO_3	• H_2CO_3	
• HBr	• H_2SiO_3	

All fruits contain acids

Chemical properties of acids

Acids are chemically active substances, so they can react with many other chemicals. Several acids ionize when added to water. Therefore, because of produced ions solutions of acids conduct electricity:

$$HNO_3 \leftrightarrow H^+(aq) + NO_3^-(aq)$$

$$H_2SO_4 \leftrightarrow 2H^+(aq) + SO_4^{2-}(aq)$$

Acid solutions change colours of indicators (litmus paper to red, methyl orange to red, phenolphthalein become colourless). Acids react with bases to give salt and water. Such reactions are called neutralisation reactions.

Acid + Base □ Salt + Water

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

Acids react and give displacement reactions with the metals that are more reactive than hydrogen:

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

$$2HCl + 2Li(s) \rightarrow 2LiCl(aq) + H_2(g)$$

Acids react with basic oxides:

$$CaO(s) + H_2SO_4(aq) \rightarrow CaSO_4(aq) + H_2O(l)$$

$$2HCl(aq) + MgO(s) \rightarrow MgCl_2(aq) + H_2O(l)$$

Literacy

1. Tell three characteristic property of acids.
2. Explain the effect of acids on methyl orange and litmus paper.

3. Metals react with acids to give hydrogen gas and salts. Write the equations for the reactions of iron and lithium with sulfuric acid.
4. Which one of the fruits is the most acidic?
5. Carry out the following transformations:
6. $C \rightarrow CO_2 \rightarrow H_2CO_3 \rightarrow K_2CO_3$
7. $S \rightarrow SO_2 \rightarrow SO_3 \rightarrow H_2SO_4 \rightarrow MgSO_4$

Facts

Gastric juice is a digestive fluid, formed in the stomach. It is composed of hydrochloric acid (HCl) potassium chloride (KCl), sodium chloride (NaCl) and different bacteria and enzymes.

Science in context

Acids which are used in daily life:

- H_2SO_4 – in car batteries;
- H_2SiO_3 - silicone glue;
- H_3PO_4 – against plant diseases, fungicide;
- CH_3COOH (vinegar) – food preparation.

Car battery

Sulfuric acid is one of the most important industrial chemical

Silicone glue

Lab work

№ 7. Properties of acids

Acids change the colours of indicators. They are corrosive. They react with metals, bases and some of the salts.

Materials:

1M sulfuric acid (H2SO4) solution, methylorange indicator, piece of chalk (CaCO3), aluminium (Al) pieces.

Procedure:

1. Pour 20 ml of sulfuric acid solution into the beaker. Add a few drops of indicator. Observe colour change of solution.
2. Add 2-3 pieces of aluminium metal to the sulfuric acid solution.

3. Repeat procedure with adding 5 g of chalk into solution of sulfuric acid. Write your observations.

Observation & questions:

1. Write reactions of chalk and aluminium with sulfuric acid.
2. What is the colour of indicator before and after reaction?

Terminology

- benefit – пайда / выгода;
- acid – қышқыл / кислота;
- sour – қышқыл / кислый;
- fizzy drink – газды сусын / газовый напиток;
- specifi c taste – өзіне тән дәм / специфический вкус;
- vinegar – сірке суы / уксус;
- corrosive – күйдіргіш / разъедающий;
- irritant – тітіркендіргіш / раздражитель;
- silicon glue – силиконды желім / силиконовый клей;
- fungicide – фунгицид / фунгицид;
- neutralisation – бейтараптану / нейтрализация.

11.3 Bases

Why does soap feel slippery?

You will:

- know and understand classification and properties of bases.

Classification of bases

Bases are substances known as the “opposite” of acids.

Like acids, bases must be used carefully, especially the strong ones, because they are corrosive and can damage skin and destroy the texture of substances.

Bases have a bitter taste. They give a slippery feeling.

Bases consist of metal cations and hydroxide anions, OH^-.

Cleaning materials generally contain bases. Ammonia NH_3 solutions are used widely as household cleaners and detergents. Sodium hydroxide $NaOH$ and potassium hydroxide KOH are used in the production of soap. In medicine, some bases are used to prepare antacid tablets.

Water soluble bases are called alkalis and they give OH^- ions when they are dissolved in water. Most alkalis are in a solid state.

Antacid tablets

Solid soap

Cleaning materials

Bases can be classified according to strength as strong and weak.

Strong	Weak
$NaOH$	$Fe(OH)_2$
KOH	$Cu(OH)_2$
$LiOH$	$Mg(OH)_2$
$Ba(OH)_2$	$NH_3 \cdot H_2O$
$Ca(OH)_2$	$Ni(OH)_2$

Chemical properties of bases

The chemical properties of bases change according to their water solubilities. Alkalis are soluble in water, so they change the colour of indicators (litmus paper to blue, methylorange to yellow, phenolphthalein to pink).

The bases most common reactions of are with acids. Bases react with acids to give salts and water (neutralisation reaction).

Base + Acid --> Salt + Water

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

$$NH_3(g) + HNO_3(aq) \longrightarrow NH_4NO_3(aq)$$

Water insoluble bases decompose by heating to give metal oxides and water:

$$Fe(OH)_2(s) \longrightarrow FeO(s) + H_2O(l)$$

Bases react with acidic oxides to give salts or salts and water:

$$NaOH(aq) + CO_2(g) \longrightarrow NaHCO_3(aq)$$

$$2NaOH(aq) + CO_2(g) \longrightarrow Na_2CO_3(aq) + H_2O(l)$$

Literacy

1. What are the differences between alkalis and other bases?
2. Write the equations for the ionisation of NaOH, $Ba(OH)_2$ and $Ca(OH)_2$.
3. How do bases affect litmus paper and phenolphthalein indicators?
4. Calculate the mass of salt that can be obtained from the reaction of 80g of sodium hydroxide with an excess amount of nitric acid.
5. A base contains 29.17% metal, 66.67% oxygen and 4.16% hydrogen by mass. Find this metal.
6. Why do soluble bases (alkalis) change the colour of indicators while insoluble ones do not? Explain.

Facts

Swimming pool pH is generally kept at a level that is slightly basic, from 7.2 to 7.8. This range of pH is more natural to the human body and helps to keep the pool water clean through chlorination.

Science in context

Uses some bases

- Sodium hydroxide NaOH is used widely in industry, for example in the production of many chemicals, silk, soap, paper, textiles, dyes and detergents.
- Potassium hydroxide KOH is used in industry to produce soft soap and fertilisers.
- Magnesium hydroxide Mg(OH)2 is used in a production of antacid tablets.

While calcium hydroxide Ca(OH)2 (white powder) is used in the production of cement.

Ammonia is used for production of fertilizers. Man is fertilizing a soil

Lab work

№ 8. Properties of bases

Materials:

1M sodium hydroxide NaOH solution and 1M hydrochloric acid HCl solution, solution of phenolphthalein indicator, beakers.

Procedure:

1. Pour 30-40 ml of sodium hydroxide solution into the beaker. Add a few drops of indicator. Observe colour change of solution.
2. Add 30-40 ml of hydrochloric acid solution to the sodium hydroxide solution. Observe colour change of solution.
3. Repeat procedure starting with hydrochloric acid solution, adding indicator and base. Observe colour changes of solution.

Observation & questions:

1. Write reaction of NaOH with HCl acid.
2. Explain colour changes of solutions.
3. What is the colour of litmus paper in these solutions?

Terminology

- bases – негіздер / основания;
- slippery – тайғанақ / скользкий;

- opposite – қарама-қарсы / противоположный;
- bitter taste – ащы дәм / горький вкус;
- detergent – жуғыш ұнтақ / моющее средство;
- soap – сабын / мыло;
- antacid tablets – жоғары қышқылдыққа қарсы дәрі / таблетки от повышенной кислотности;
- alkalis – сілті / щелочь;
- silk – жібек / шелк;
- cement – цемент / цемент;
- dye – бояу / краска;
- fertilizer - тыңайтқыш / удобрение;
- litmus – лакмус / лакмус;
- hydroxide - гидроксид / гидроксид.

11.4 SALTS

Why can't we drink sea water?

You will:

- know and apply the preparation methods of salts;
- know and understand classification and properties of salts.

Salts and preparation methods

Salts are crystalline solids. They have ionic structure and their melting and boiling points are high. Salts have different colours, for example, white (sodium carbonate), green (copper (II) chloride), violet (cobalt (II) chloride), yellow (lead (II) iodide), black (mercury (II) sulfide), etc.

Colourful salts

Worker at salt extraction

Copper sulfate crystal

Silver nitrate $AgNO_3$ is used as an antiseptic

White alum stone $KAl(SO_4)_2 \cdot 12H_2O$ is used in a paper industry

1. When acidic oxide (or acid) reacts with a basic oxide (or a base) the product is always salt (or salt and water):

CaO(s) + SO2(g) --> CaSO3(s)

Ca(OH)2(aq) + H2SO4(aq) --> CaSO4(aq) + 2H2O(l)

2. Basic oxides react with acids to produce salts and water:

BaO(s) + 2HCl(aq)-- > BaCl2(aq) + H2O(l)

3. Acidic oxides also react with bases to produce salts and water:

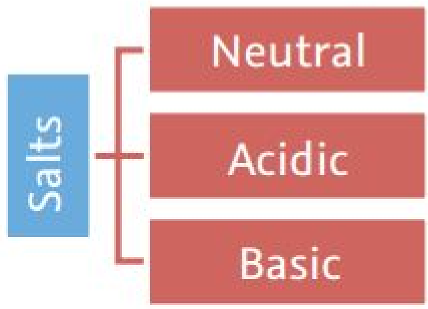
CO2(g) + KOH(aq) --> K2CO3(aq) + H2O(l)

4. Active metals and middle active metals react with acids to give salts and hydrogen gas:

$$Fe(s) + H_2SO_4(aq) \longrightarrow FeSO_4(aq) + H_2(g)$$

Classification of salts

When salts are dissolved in water, they can show neutral, acidic or basic properties.



Neutral salts.

These are formed by the reactions of strong acids and strong bases. Aqueous solutions of neutral salts do not show acidic or basic properties.

Strong acids	Strong bases	Neutral salts + water
HCl	$NaOH$	$NaCl + H_2O$
H_2SO_4	$Ca(OH)_2$	$CaSO_4 + H_2O$
HBr	KOH	$KBr + H_2O$

Acidic salts.

Acidic salts are formed by the reaction of strong acids with weak bases. They have acidic properties. Some salts that contain H^+ in their structure, like $NaHSO_4$, are also acidic because when they ionise in water, they give H+ ions to the media.

Strong acids	Weak bases	Acidic salts + water
HCl	$Fe(OH)_2$	$FeCl_2 + H_2O$
H_2SO_4	$NaOH$	$NaHSO_4 + H_2O$
HBr	$Mg(OH)_2$	$MgBr_2 + H_2O$

Basic salts.

Basic salts are produced from the reactions of weak acids with strong bases. They have basic properties. Salts that produce OH-ions in water, such as MgOHCl, are also basic.

Weak acids	Strong bases	Basic salts + water
H_2SO_3	$NaOH$	$Na_2SO_3 + H_2O$
H_2CO_3	$Ca(OH)_2$	$CaCO_3 + H_2O$
HCl	$Mg(OH)_2$	$MgOHCl + H_2O$

Chemical properties of salts

1. Iron metal can displace copper metal from its salt solution, so one more active metal can displace another one from its salt:

Fe(s) + CuSO4(aq) --> FeSO4(aq) + Cu(s)

2. A water-soluble salt can react with another water-soluble salt, at least one of the products should be insoluble in water:

AgNO3(aq) + KCl(aq) --> AgCl(s) + KNO3(aq)

3. Salts react with acids to give weak acids:

$$Na_2CO_3(aq) + 2HNO_3(aq) \rightarrow 2NaNO_3(aq) + H_2CO_3(aq)$$

4. Acidic salts react with bases to give insoluble bases:

$$FeBr_2(aq) + 2NaOH(aq) \rightarrow Fe(OH)_2(s) + 2NaBr(aq)$$

Literacy

1. Which salt is used for baking cookies?
2. What types of salts do you use at home?
3. Calculate the mass of salt that is produced from the reaction of 96 g of magnesium with an excess hydrochloric acid.
4. Classify the following salts as either acidic, basic or neutral: $NaCl$, Na_2SO_3, $BaOHCl$, $MgSO_4$, NH_4Br, Na_2CO_3 and $LiHSO_4$.
5. Write chemical equations to show how the products can be obtained from the reactants:

   a. Sodium chloride → Sodium nitrate
   b. Aluminium nitrate → Aluminium hydroxide.

Terminology

- violet – күлгін / фиолетовый;
- insoluble bases – ерімейтін негіздер / нерастворимые основания;
- soluble salts – еритін тұздар / растворимые соли;
- strong acid – күшті қышқыл / сильная кислота;
- weak base – әлсіз негіз / слабое основание;
- preparation – алу / получение;
- different colour – түрлі түсті / разные цвета;
- to extraction – бөліп алу / извлечение;
- ionize – иондану / ионизация.

11.5 GENETIC RELATIONSHIP BETWEEN INORGANIC COMPOUNDS

What is the relation between salts, acids and bases?

You will:

- classify inorganic compounds by its composition and properties;
- explore in practice the genetic relationship between inorganic compounds.

From our last topics, you have learned about chemical properties of oxides, acids, bases and salts. Oxides can be produced if metals or nonmetals react with oxygen. Acids can be produced when acidic oxides react with water. Water reacts with basic oxides to produce bases. And salts can be produced from reactions of acids with bases, acidic oxides with bases, basic oxides with acids, etc. The genetic relationship between inorganic compounds is given below:

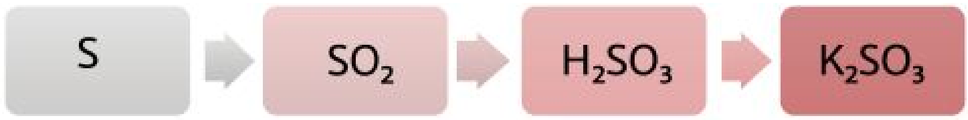
For example, genetic series of potassium K metal:

2K(s) + O2(g) --> 2K2O(s)

K2O(s) + H2O(l) --> 2KOH(aq)

2KOH(aq) + H2SO3(aq) --> K2SO3(aq) + 2H2O(l)

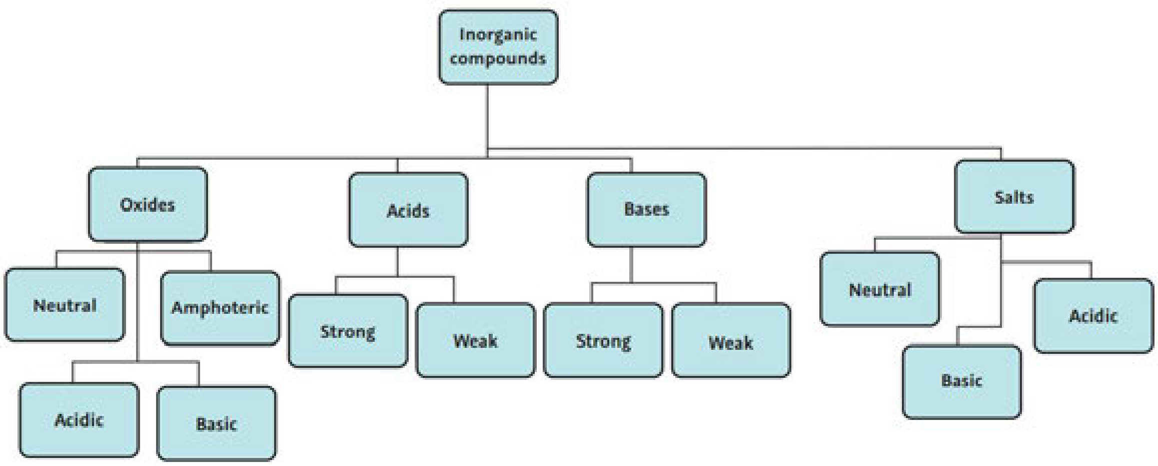
Genetic series of sulfur S nonmetal:



S(s) + O2(g) --> SO2(g)

SO2(g) + H2O(l) > H2SO3(aq)

H2SO3(aq) + 2KOH(aq) --> K2SO3(aq) + H2O(l)



Classification of inorganic compounds

Literacy

1. What are the main types of inorganic compounds? Give two examples for each type.
2. Write balanced equations for the following chemical schemes:
   - Mg → MgO → Mg(OH)2 → MgCl2
   - C → CO2 → H2CO3 → Na2CO3

   - $Li \rightarrow Li_2O \rightarrow LiOH \rightarrow LiNO_3$
3. Classify the following salts as acidic, basic or neutral:
   - $NaBr$, K_2SO_4, $KHCO_3$, $Mg(NO_3)_2$, FeS, $FeCO_3$, $ZnSO_3$, $MgOHBr$, $Ca(HCO_3)_2$, KI, $Al_2(SO_4)_3$.
4. Classify the following oxides: K_2O, CaO, NO_2, P_2O_5, H_2O, SO_2, ZnO, SiO_2, SO_3, N_2O, TiO_2.
5. Write the equations for the reactions of the following oxides with water: SO_2, N_2O_5, K_2O, CaO.
6. Explain the formation of acidic, basic and neutral salts. Give two examples of each.

Facts

Acid rain

Acid rain is the rain or any other form of precipitation that is usually acidic. It has harmful effects on plants, aquatic animals and buildings. Acid rain is mostly caused by human emissions of sulfur and nitrogen oxides which react in the atmosphere to produce acids.

Science in context

Caustic electrolysis factory is located in Pavlodar. This factory produces sodium hydroxide $NaOH$, sodium hypochlorite $NaClO$, hydrochloric acid HCl and chlorine gas Cl_2 from sodium chloride NaCl. NaOH is used as pipe cleaner and NaClO as a bleaching agent.

Lab work

№ 9. Preparation and properties of salts

When solutions of 2 soluble compounds (salt + salt, or salt + base) are mixed, a solid can form.

Materials:

1M sodium carbonate Na2CO3 and 1M calcium hydroxide Ca(OH)2 solutions, conical flask, filter paper.

Procedure:

1. Mix 30 ml of sodium carbonate solution and 30 ml of calcium hydroxide solution in a flask.
2. Filter the mixture by using filter paper.
3. Collect calcium carbonate from filter paper, dry and weigh it.

Observation & questions:

1. Write an equation for this reaction.
2. What is the colour of calcium carbonate?
3. What is the expected theoretical mass of calcium carbonate? Compare it with mass of precipitate obtained in experiment.

Terminology

- genetic relationship – генетикалық байланыс / генетическая связь;

- genetic series – генетикалық қатар / генетический ряд;
- factory – зауыт / завод;
- classifi cation – жіктелу /классификация;
- inorganic compounds – бейорганикалық қосылыстар / неорганические соединения.

Problems: Inorganic compounds

1. What are the main types of inorganic compounds? Give two examples for each.

2. Give 3 common properties of bases.

3. What are the differences between strong and weak acids? Give three examples of each group.

4. Match the following compounds:

   Acid, Base, Oxide, Salt
   1. H_2SO_4
   2. H_2O
   3. H_3PO_4
   4. $NaOH$
   5. $CaCO_3$
   6. K_2O
   7. $LiOH$
   8. KH_2PO_4

5. Complete and balance the reactions below:

   a) $NaOH(aq) + HNO_3(aq) \rightarrow$
   b) $Ca(OH)_2(aq) + H_2SO_4(aq) \rightarrow$

6. What is a neutralisation reaction? Give two examples of such reaction.

7. Write differences between acids and bases.

8. Write products of the reactions of the following oxides:

$Na_2O + SO_2$
$Na_2O + P_2O_5$
$CaO + SO_2$
$CaO + P_2O_5$

9. For the solution of a strong acid

I. It has a sour taste
II. It contains more OH^- ions than H^+ ions
III. When it reacts with Ca, H_2 is produced.

Which of the above is (are) always correct?

a) I only
b) II only
c) I and III
d) II and III
e) I, II and III

10. Which of these reactions do occur to produce salt(s)?

I. $CO_2(g) + H_2O(l) \rightarrow$
II. $CaO(s) + HCl(aq) \rightarrow$
III. $MgO(s) + H_2O(l) \rightarrow$

a) I and II
b) II only
c) II and III
d) I, II and III
e) I only

11. Two of the reactions of element X is given below. Which element can be X?

$X + H_2SO_4(aq) \rightarrow XSO_4(aq) + H_2(g)$
$XO + H_2(g) \rightarrow X + H_2O(l)$

a) S
b) Fe
c) Na
d) Al
e) Li

12. Which option gives the correct classification of these oxides?

I. Na_2O II. NO III. Al_2O_3

a) Basic Acidic Amphoteric
b) Acidic Basic Basic
c) Amphoteric Basic Neutral
d) Neutral Acidic Basic
e) Basic Neutral Amphoteric

13. Complete and balance the reactions below:

a) $Na_2CO_3(aq) + HBr(aq) \rightarrow$
b) $CuSO_4(aq) + Al(s) \rightarrow$

14. Write preparation reactions of $CuSO_4$, KCl, Na_2CO_3 salts.

15. Suggest the usage of following salts in daily life:

- sodium bicarbonate $NaHCO_3$
- Copper sulfate $CuSO_4 \cdot 5H_2O$
- Potassium permanganate $KMnO_4$
- Sodium chloride NaCl
- Ammonium nitrate NH_4NO_3

CHAPTER 12: Carbon and its compounds

12.1 CARBON

Why is graphite not as hard as diamond?

You will:

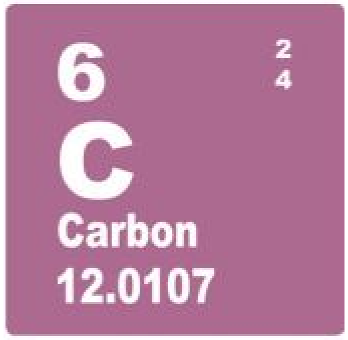
- know forms and minerals, ores of carbon in nature;
- know the difference between forms of carbon;
- how carbon is used in the nanocarbon materials.

General properties

Carbon is one of the most well-known elements in the world. Carbon, the lightest member of the group number 14 (IV), is a nonmetal. In the group, atomic radius and metallic properties increase from top to bottom.

Carbon has an atomic number of 6 and its electron arrangement is 2) 4). It means that carbon has got 4 valence electrons and able to make four bonds with other elements. Carbon has three natural isotopes. Their abundances are given below:

12C : 98.9%, 13C : 1.1% and 14C : trace amounts. 12C and 13C are stable isotopes of carbon whereas the 14C isotope is radioactive.

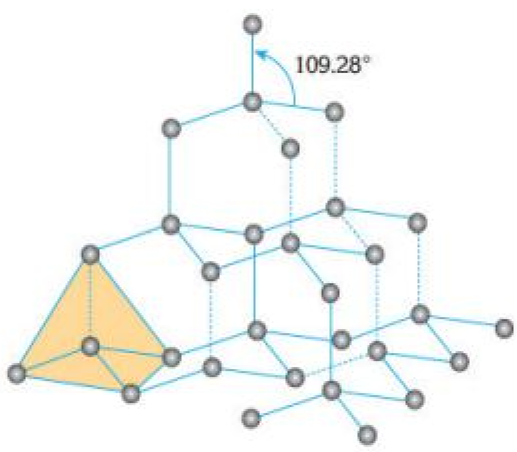


Carbon element

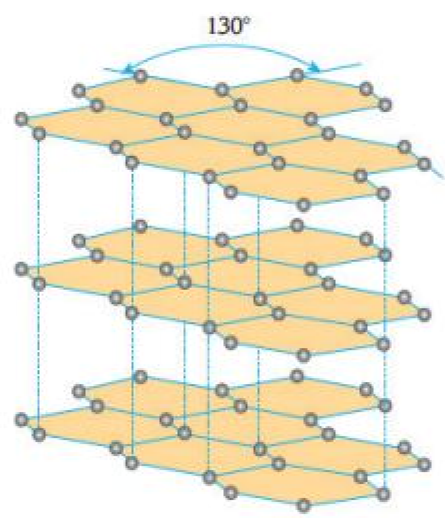

Carbon is essential for living organisms

There is a big number of carbon compounds. Carbon is the basic element of living organisms. In our daily life, it is found as petroleum and its products. For that reason, carbon chemistry has become a special branch of chemistry called organic chemistry. However, in this chapter, we will study only the inorganic compounds of carbon.

Carbon has two allotropes of major importance in daily life. They are graphite and diamond.



Structure of diamond



Structure of graphite

DIAMOND

- the hardest substance in nature
- nonconductor
- used as an abrasive
- transparent

GRAPHITE

- soft
- good conductor
- used as a lubricant
- dark grey, black

Graphite

The different types of bonds between the atoms of carbon cause the differences in physical properties of these two allotropes. Graphite is a soft, dark grey or black solid with a shiny metalic colour. It is an excellent conductor of electricity, so it is used as electrodes in dry cells. In pencils, a graphite and clay mixture is used. Graphite crystals have a layered structure formed by hexagonal carbon cycles. These layers slide over each other easily because they are bonded to each other with weak bonds shown in a figure above. Because of this, graphite conducts heat and electricity. In comparison to diamond, carbon has lower melting and boiling points.

Diamond

Diamond is formed naturally by the transformation of graphite exposed to high underground pressure over millions of years. Pure diamond is a transparent solid.

Each carbon atom in the structure of diamond is bonded with strong bonds to 4 neighbour carbon atoms in the shape of a tetrahedron. For these reasons, diamond is the hardest natural mineral and has a high melting point (3500oC) and boiling point (4850oC). It does not conduct electricity and tends to change into graphite which is more stable.

Artificial diamond is obtained by changing the crystalline structure of graphite under high pressure and temperature. Such a diamond does not have any value as jewellery. Because of its hardness, it is used to cut hard materials in the industry. In addition to these allotropes, carbon is found naturally in the forms of coal, coke, charcoal and soot, but they are not in crystalline forms. They are amorphous solids with wide surfaces.

There are also two more allotropic forms of carbon. They are amorphous carbon and fullerene, which molecule is look like a soccer-ball.

Facts

Carborundum (SiC) is a compound of silicon and carbon which is nearly as hard as diamond.

Activity

1. There are four different nanocarbon materials. They are fullerenes, carbon nanotubes, graphene, nanodiamonds. Your group can choose any topic from the mentioned list. You are expected to prepare a poster about the uses of chosen

material. The information about these nanocarbon materials can be taken from the internet or your teacher.

2. Search what is diamond and graphite molecule look like. Try to make its model using paper.

Literacy

Study how is the age of archaeological artefacts being determined. Which method is often used to fi nd the age?

Terminology

- carbon - көміртек / углерод;
- transparent - мөлдір / прозрачный;
- nanocarbon - нанокөміртек / наноуглерод;
- organic - органикалық / органическая;
- diamond - алмаз / алмаз;
- graphite - графит / графит;
- to comparison - салыстыру / сравнение;
- underground - жерасты / подземный;
- charcoal - ағаш көмірі / древесный уголь;
- artifacts - көне бұйымдар / артефакты.

12.2 PHYSICAL AND CHEMICAL PROPERTIES OF CARBON

What is the difference between active carbon and graphite?

You will:

- know physical and chemical properties of carbon.

Physical properties

Carbon has a crystalline lattice structure. There are strong covalent bonds between its atoms. Because of these strong bonds, carbon has the highest melting and boiling points in the group 14. Melting and boiling points of carbon are 35270 C and 40270 C. Density is 2.3 g/cm3.

Natural wood charcoal

Charcoal fire

Metal carbides are the hardest and most brittle of the drill bit materials

Chemical properties

Carbon is a nonmetal. It has an atomic number of 6. It takes oxidation states between -4 and +4.

1. Graphite burns easily, but burning diamond is very hard. The burning product of carbon at low temperature and excess amount of oxygen is carbon dioxide (combustion). Carbon monoxide is the product of combustion at high temperature and limited amount of oxygen.

$$C(s) + O_2(g) \rightarrow CO_2(g)$$

$$2C(s) + O_2(g) \rightarrow 2CO(g)$$

2. Carbon forms carbides by reacting with elements or their oxides at high temperatures:

$$2C(s) + Ca(s) \rightarrow CaC_2(s)$$

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

3. Carbon reacts with water steam at very high temperature to give “water gas” (a mixture of CO and H_2 gases):

$$C(s) + H_2O(g) + heat \rightarrow CO(g) + H_2(g)$$

4. Reduction of metals at about 6000C:

$$2PbO(s) + C(s) \rightarrow 2Pb(s) + CO_2(g)$$

5. Oxidation reaction:

$$C(s) + 4HNO_3(aq) \rightarrow CO_2(g) + 4NO_2(g) + 2H_2O(l)$$

Literacy

1. Complete the following equations and balance them:

   a. $C + O_2(excess) \rightarrow$
   b. $C + O_2(limited) \rightarrow$
   c. $C + Al \rightarrow$
   d. $C + FeO \rightarrow$
   e. $ZnO + C \rightarrow$
   f. $Fe_3O_4 + C \rightarrow$

2. What is the mass of a 1 L mixture of CO - CO Facts 2 at STP if the volume percentage of CO is 30%?

3. Write the common compounds of carbon.

4. What is the oxidation state of carbon in each of the following compounds?

   CO, Al_4C_3, CO_2, CS_2, H_2CO_3, $NaHCO_3$.

5. 24 g of carbon is reacted with sand SiO2. How many litres of CO gas can be obtained?

Facts

Diamond is used in jewellery and in cutting systems to cut hard substances such as steel.

Science in context

Active carbon is used in gas masks to absorb pollutants and poisonous gases in the air. It can absorb substances in liquid or gas solutions. Other uses of active carbons a distillation of water, bleaching of sugar solutions, and in ventilation systems to control the odour of the medium. In daily life, active carbon is also used in printers and photocopy machines as a toner.

Gas mask

Photocopy machine

Practice work

№ 6. Chemical and physical properties of carbon

Materials:

active carbon (10 tablets), water, 2 beakers (250 ml), dyes, batteries 9 V, crocodile clips wires, carbon graphite rods.

Variant I

1. Write reactions of carbon with oxygen, chlorine and calcium.

2. Take graphite rod. Connect it to the battery by using crocodile clips wires. Graphite conduct electricity. Why?

Variant II

1. Write reactions of carbon with water, fl uorine and sodium.

2. Take 2 beakers. Pour 100 ml of water into the beakers. Dissolve some dye in the fi rst beaker. Then mix active carbon with dye solution. After 10 minute dye solution will loses its colour. Why?

Terminology

- active carbon - белсендірілген көмір / активированный уголь;
- lattice - тор / решетка;
- “water-gas” - "синтез газ" / "водяной газ";
- to drill - бұрғылау / бурить;

- ventilation - желдету / вентиляция;
- photocopy machine – көшіру аппараты / копировальный аппарат;
- resistance - қарсылық / сопротивление;
- cutting - кесу / резка.

12.3 OXIDES OF CARBON

Carbon monoxide and carbon dioxide are made up of the same atoms but why is one very toxic while the other one is not?

You will:

- know how carbon oxides form;
- prepare carbon dioxide and study its properties;
- know the carbon cycle.

Carbon has two oxides: carbon monoxide and carbon dioxide.

Carbon monoxide, CO

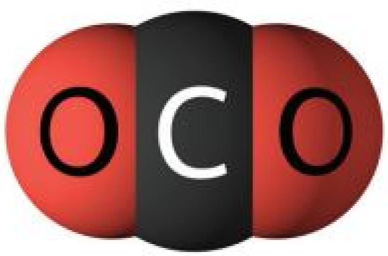
Carbon monoxide is found in the atmosphere in trace amounts. It is a colourless, odourless and poisonous gas that is lighter than air. It is slightly soluble in water.

The exhausts of motor cars and the combustion of fuels cause an increase in the concentration of carbon monoxide in the air.

Combustion fumes of car exhaust pipe

Carbon dioxide, CO2

Carbon dioxide is found in the atmosphere at around 0.04% by volume. It is a colourless, odourless and nonpoisonous gas. It is approximately 1.5 times heavier than air. CO2 is quite soluble in water. It solidifies at -78oC to form dry ice.



CO_2 molecule

Dry ice in water

Preparation

1. CO2 is produced when limestone is heated to make quicklime:

CaCO3(s) --> CaO(s) + CO2(g)

2. Reactions of carbonate salts with acids:

$$CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$$

3. In a coal fire, the main reaction is:

$$C(s) + O_2(g) \rightarrow CO_2(g)$$

But at high temperature and limited amount of oxygen, the burning product is carbon monoxide:

$$2C(s) + O_2(g) \rightarrow 2CO(g)$$

Chemical properties

1. Carbon dioxide is an acidic oxide. When it is dissolved in water, it forms carbonic acid, which is unstable:

$$CO_2(g) + H_2O(l) \leftrightarrow H_2CO_3(aq)$$

2. It reacts with basic oxides and bases:

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

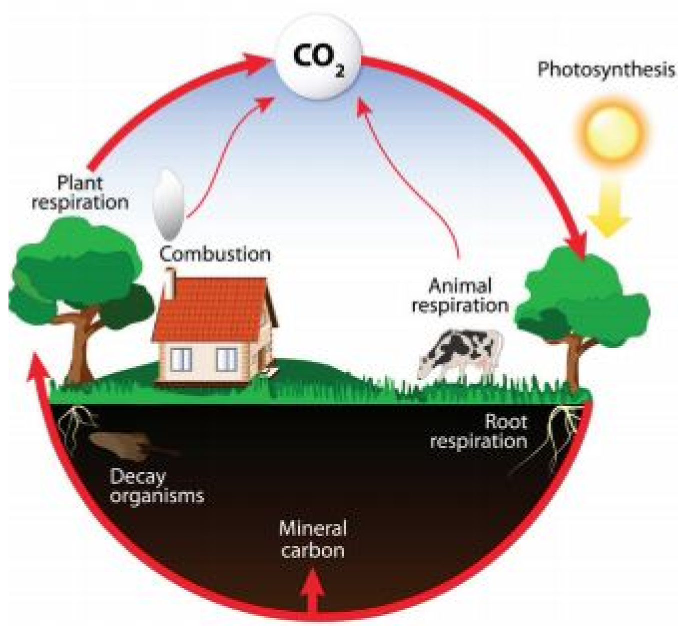
$$CO_2(g) + 2NaOH(aq) \rightarrow Na_2CO_3(aq) + H_2O(l)$$

We can detect the existence of carbon dioxide with limewater, $Ca(OH)_2$. When carbon dioxide is passed into a solution of limewater, colourless limewater solution gives a milky white precipitate of calcium carbonate:

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

Carbon cycle

Carbon dioxide is a vital part of the carbon cycle. The carbon cycle shows how carbon is moved from place to place around the earth. Look at the cycle below.



Carbon cycle

Facts

Carbon monoxide is a poisonous gas, causing death in atmospheric concentrations as low as 0.5%. If carbon monoxide is inhaled, it combines in the lungs with the haemoglobin and changes it into carboxyhaemoglobin that cannot carry oxygen. If excess CO is inhaled, it may cause death. In cases of CO poisoning, medical experts advise that the patient should is removed to fresh air as quickly as possible.

Carbon monoxide is extremely poisonous

Practice work

№ 7. Preparation and properties of carbon dioxide gas

Materials:

calcium carbonate (or chalk), sodium bicarbonate $NaHCO_3$, hydrochloric acid, acetic acid (vinegar), test tubes, calcium hydroxide solution (limewater).

Variant I

1. By using calcium carbonate (chalk) and hydrochloric acid, you will produce CO_2 gas.

2. Write reactions of CO_2 with water and with lime water $Ca(OH)_2$.

Variant II

1. By using sodium bicarbonate $NaHCO_3$ and acetic acid (vinegar), you will produce CO_2 gas.

2. Calculate the relative density of CO_2 by air. How many times is CO_2 heavier than air?

Literacy

1. How to detect CO_2 in laboratory?

2. Do electric cars produce carbon monoxide?
3. Write all reactions for each step of given schema:
    1. $C \rightarrow CO_2 \rightarrow CaCO_3 \rightarrow CO_2$
4. There are 24 grams of carbon in the structure of 88 grams of unknown carbon oxide. What is the simplest formula of this compound?
5. If 2.8 g of CO and O_2 are mixed and reacted to give CO_2. How many grams of CO_2 can be produced?

Terminology

- trace amount - өте аз / малое количество;
- exhaust - пайдаланылған газ / выхлопные газы;
- poisonous - улы / ядовитые;
- fume - түтін / дым;
- pipe - құбыр / труба;
- chimney - мұржа / дымовая труба;
- to inhale - жұту / вдыхать;
- vital - өмірлік маңызды / жизненно важно;
- to advise - кеңес беру / советовать;
- dry ice - құрғақ мұз / сухой лед;
- limestone - әктас / известняк;
- quicklime - сөндірілмеген әк / негашеная известь;
- to detect - анықтау / обнаруживать;
- limewater - сөндірілген әк / гашеная известь.

Problems: Carbon

1. Fill in the gaps for the carbon:

   a) Allotropes of carbon are _______ , _______ , ______ and __________.
   b) Oxidation states of carbon _______________.
   c) All allotropes are found in __________ state at 25oC.

2. Compare the properties of diamond and graphite.

3. Why does graphite conduct electricity whereas diamond doesn't? Explain.

4. Write electron configuration of carbon.

5. Where can be carbon found in nature?

6. Write the common compounds of carbon.

7. CO or CO2? Identify them:

   a) CaCO3 --> CaO + ...
   b) C + O2(limit) --> ......
   c) Used in photosynthesis process ....
   d) Toxic gas: ....
   e) .... reacts with water to give carbonic acid
   f) Good reducing agent
   g) Chemical formula of "dry ice"........

8. Which events in daily life cause the formation of CO2?

9. Which one of the following is not carbon allotrope?

a) Graphite
b) Diamond
c) Ozone
d) Carbon nanotubes
e) Fullerene

10. Which one(s) of the following is/are correct?

I. Carbon is a nonmetal.
II. Diamond is very soft mineral.
III. CO is toxic gas.

a) I only
b) II only
c) I and II
d) I and III
e) I, II and III

11. What is the correct way to show the configuration of valence electrons of carbon?

a) 2s22p2
b) 2s22p3
c) 3s23p2
d) 2s22p4
e) 2s22p1

12. What is the colour of carbon element (coke)?

a) Red
b) Black
c) White
d) Green
e) Blue

13. Which one of the following is incorrect?

a) Diamond is more expensive than graphite
b) Carbon is used as a fuel
c) Printers use carbon compounds
d) Carbon burns in oxygen
e) Carbonic acid is very strong acid

14. Which of the following names is/are incorrect?

I. CO(g) - Carbon monoxide
II. CO2(g) - Carbon dioxide
III. CO2(s) - Dry ice

a) I and II
b) III and IV
c) I, II and III
d) I, II and IV
e) None of them

CHAPTER 13: WATER IS A BASIS OF LIFE

13.1 UNIQUE PROPERTIES OF WATER

Why is only 10% of an iceberg above the surface of the water?

You will:

- know that boiling point can show the purity of water;
- know unique properties of water and importance for the life.

Water is the most common and essential oxide found in nature. The water is the only substance naturally present on the Earth in all three states: solid (near the north and south poles and in glaciers), liquid and gas (water vapour in the atmosphere).

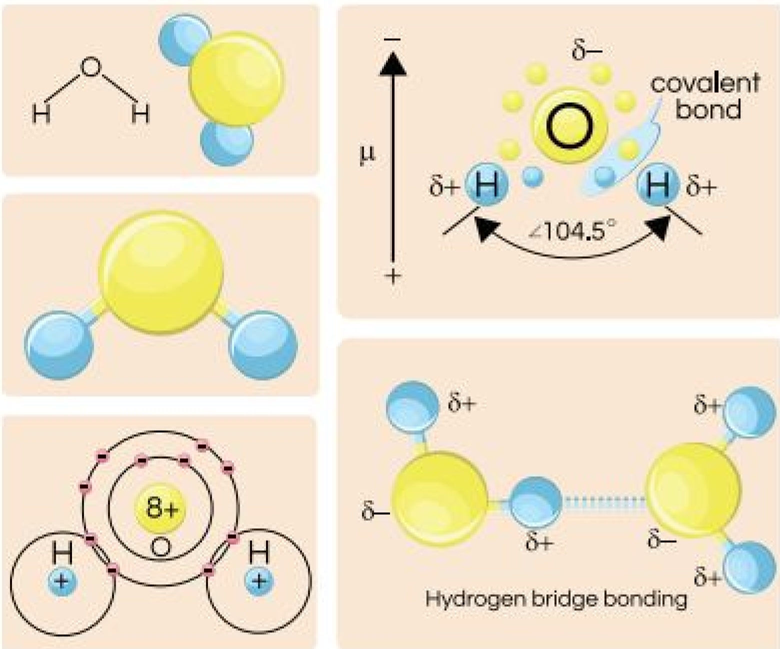
About 75% of the Earth's surface is covered with water in which many other compounds (such as salt) are dissolved.

Water is essential for all living organisms. It makes up 60% of trees, 70% of the body of an elephant, 95% of a tomato and about 99% of a jellyfish.

Our own body contains more water than any other substance: about 60-70% of our body is made up of water.

Water is needed to dissolve chemicals in our cells and to carry chemicals around our body. Water takes part almost in all metabolic reactions, and our blood is about 90% water.

Underwater life



Representations of the water molecule, charges, bonds

Properties of water

Pure water is colourless, odourless and tasteless liquid. It boils at 100oC and freezes at 0oC under 1 atmosphere pressure (at sea level). Water boils at a lower temperature as you rise to the mountain (lower pressure) and boils at a higher temperature if you go down under sea level (higher pressure).

The boiling point of water also depends on the purity of the water. Water which contains soluble substances like salt, sugar boils at a higher temperature. For example, salty water boils at about 102oC. Remember, pure water boils at 100oC. The density of water is the highest at 4oC: 1 g/cm3. So its density decreases and volume increases when it freezes. Water is the only substance whose density is lower when it freezes. This property of water makes life possible in seas and lakes in winter.

The water molecule is made up of two atoms of hydrogen and one atom of oxygen. Oxygen is more electronegative than hydrogen so that oxygen attracts electrons of hydrogen atoms. This causes a charge imbalance in water molecules and makes them polar.

Therefore, water can dissolve polar substances. Due to its high dissolving capacity, it is often called the universal solvent.

Due to their polarity, water molecules attract each other. Positively charged hydrogen of one molecule of water bonds with the negatively charged oxygen of another molecule of water. This attraction is an example of hydrogen bond. Hydrogen bond is one of the reasons for a relatively high boiling point of water. If there were no hydrogen bond the water would be in a gaseous state and there would be no life!

Facts

Nearly 97% of the world's water is salty or otherwise undrinkable. Another 2% is locked in ice caps and glaciers. That leaves just 1% for all of humanity's needs - all its agricultural, residential, manufacturing, community, and personal needs.

Watering of plants

Facts

By decreasing temperature of frozen water, there will be some miraculous changes. After you reach a temperature of -120oC water becomes super viscous!

And when you reach -135oC water turns to the glassy solid with noncrystallic structure! The Earth's mantle contains for about 10 times more water than all oceans!

Activity

Determination of boiling point of water

Materials:

distilled water, porcelain chips, round-bottom fl ask (250 ml), thermometer, double bored rubber cork, glass tube, stands and clamps.

Procedure:

1. Pour 150 ml of water into the fl ask.

2. Add 2-3 small pieces of chips.

3. Close the fl ask with a rubber cork and clamp it with the stand.

4. Insert a thermometer into one bore and glass tube into another. Note: Keep the bulb of the thermometer 4-5 cm above the surface of the water.

5. Heat the water till the temperature becomes constant, and the water remains boiling. Note the constant temperature (boiling point).

Observation:

1. When water boils, there is a change in _____________ state.

2. Boiling point of water: _______________. Discuss and explain.

Activity

Work in groups.

The specifi c heat capacity of water is the amount of heat needed to raise the temperature of 1 g of water by the 1 degree Celsius (10C). Heat capacity of water is almost 10 times higher than capacity of iron! This fact makes life on the Earth possible. How do you think why? Why there are great temperature changes in a desert regions? Why there are great temperature changes on the Mars planet? (There on Mars can be +200C in the daytime and -1000C in the night).

Literacy

1. Where does tap water come from?
2. What is mass percentage of oxygen in water molecule?

3. There are about 1.4 • 1018 L of water on the Earth. 97% of all water is salty and only 3% is fresh. Calculate the volume of fresh water.
4. How many grams of sugar should be dissolved in 200 g of water to prepare 20% sugar solution?
5. How many atoms in 36 gram of water?
6. 0.9 g of compound X contains 3.01 • 1022 molecules. What is the molecular mass of compound X.

Terminology

- unique – бірегей / уникальный;
- purity – тазалық / чистота;
- to float – жүзу / плавать;
- to boil – қайнау / кипеть;
- to freeze – қату / замерзать;
- to rise – көтерілу / расти;
- to depend – тәуелді болу/ зависеть;
- miraculous – таңғажайып / чудесный;
- superviscous – аса тұтқыр / супервязкий;
- attraction – тартылу / притяжение;
- residential – тұрғын / жилой;
- community – ұйым / сообщество;
- porcelain – фарфор / фарфор.

13.2 WATER CYCLE

How is water purified in nature?

You will:

- know the water cycle;
- know how water is polluted and why it is dangerous;
- know water purification methods.

Facts

Approximately 520,000 cubic kilometers of water evapourates within a year from the Earth's surface.

Ocean water

The Water Cycle

Water on the Earth is always changing. Its repeating changes make a cycle. This process involves water from oceans, rivers, plants and even you.

The water cycle explains how water evaporates from the surface of the earth, rises into the atmosphere, cools and turns into rain or snow in clouds, and falls again to the surface as precipitation.

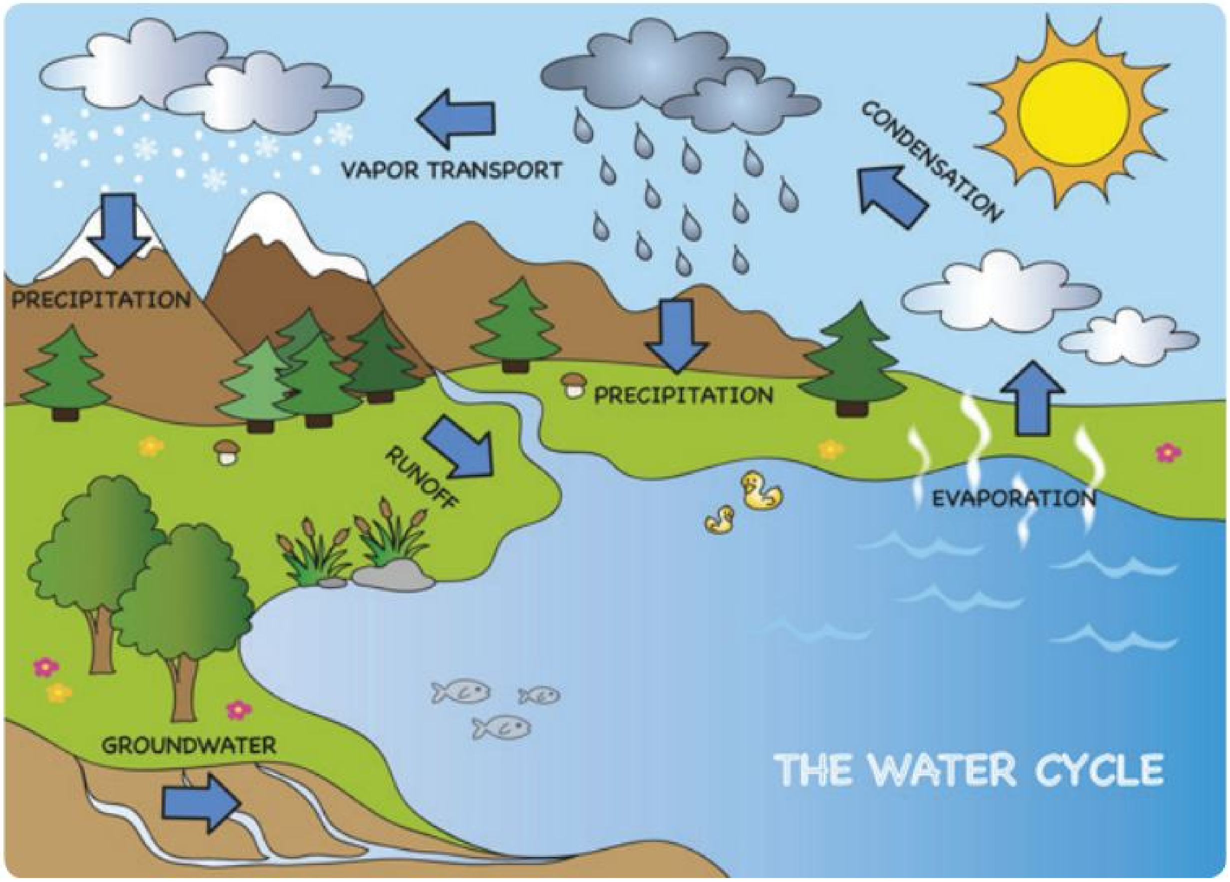
The water cycle involves the exchange of energy, which leads to temperature changes. For instance, when water evaporates, it takes up energy from its surroundings and cools the environment. When it condenses, it releases energy and warms the environment. These heat exchanges influence climate.

1. Water evaporates from oceans, lakes and rivers.

2. Formed water vapour condenses in the upper regions of the atmosphere.

3. Vapour further condenses into larger drops which fall as rain, snow.

4. These rain or snow water slowly passes through the soil back to rivers, lakes and oceans.



Water pollution

Water pollution can be defined in many ways. Usually, it means one or more substances in water cause problems for normal use of it. Pollution of water can affect the health of all the plants, animals, and humans.

There are many different types of water pollution sources. Examples are sewage, wastewater, agriculture, radioactive waste, oil pollution, plastics, etc.

As you can understand water pollution is always caused by damage done to an ocean, river, lake, or another water source.

Luckily, the damages from water pollutions are often reversible but not all of them.

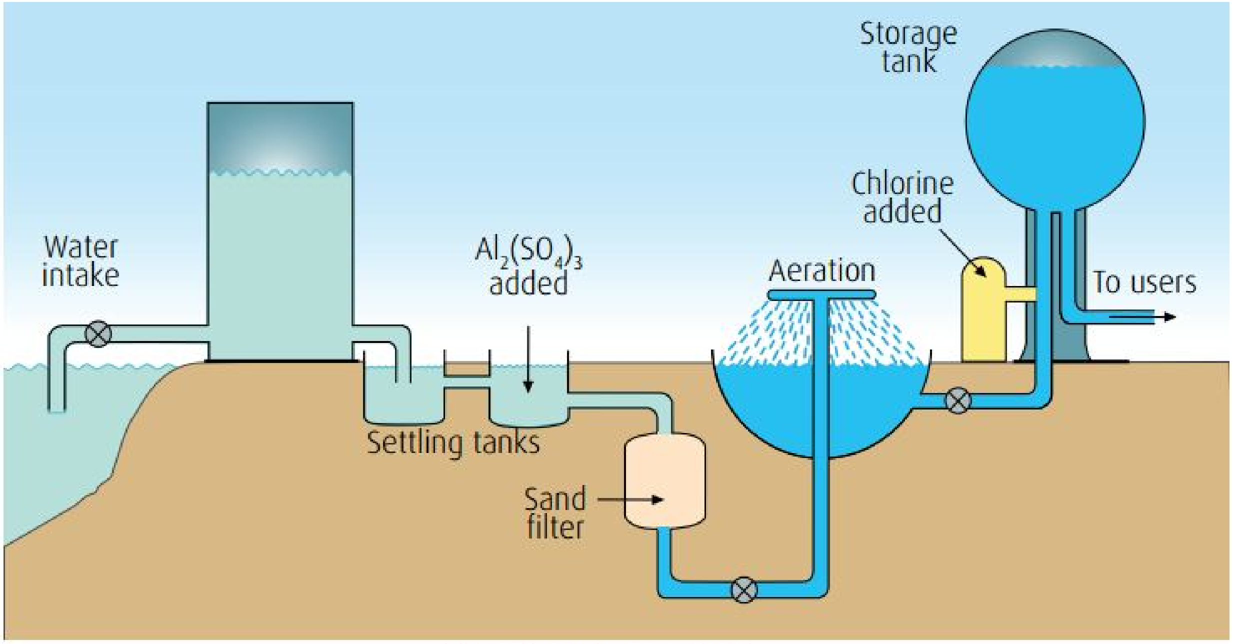
Bodies of the dead fish in a wastewater

Illustration of water and air pollution

Water purification

Water purification is a process of removing impurities from raw water to make it pure enough for human uses. Many pollutants are dangerous, and they need to be removed.

During the purification process bacteria, viruses and chemical pollutants (including toxic metals such as lead, copper, etc.) are removed. The water's smell, taste and appearance are improved.



Steps in water purification


Flow of wastewater from plant

Steps in water purification:

1. Preliminary filtration in settling tanks.

2. Precipitation of soluble impurities by the addition of aluminum sulfate.
3. Filtration of precipitates through a sand filter.
4. Elimination of dissolved organic substances by oxidation with oxygen in the air (aeration).
5. Destruction of bacteria with ozone or chlorination.
6. Storing of pure water in a tank (storage tank).

Activity

Intermolecular forces and surface tension

In any liquid substance, molecules will be attracted to each other due to the presence of intermolecular forces. These forces are known as surface tension. Surface tension makes molecules of liquid behave like an elastic sheet.

Materials:

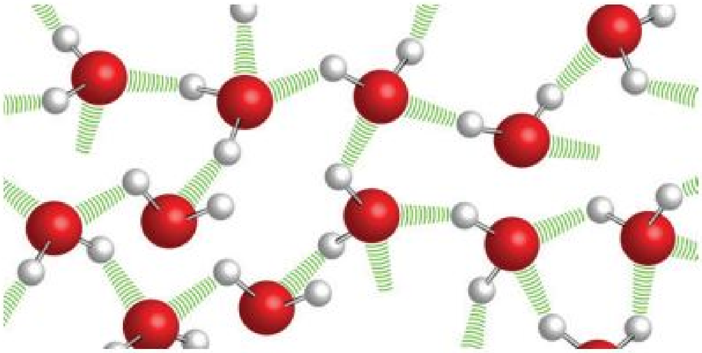
pure water, pipette, coin (10 tenges), vegetable oil.

Procedure:

1. Fill a pipette with water.
2. Hold pipette about 3 cm above the coin and add drops of water to the surface of the coin.
3. Record the number of drops of water (repeat steps 2-4 more times and record your results).
4. Repeat the experiment for vegetable oil.

Observation & questions:

1. Which liquid has stronger molecular forces?
2. Why can some insects walk on the surface of water?



Terminology

- purification - тазарту / очистка ;
- instance - мысал / пример;
- influence - әсер / влияние;
- sewage - ағын сулар / сточные воды;
- wastewater - кір сулар / сточные воды;
- damage - залал (зиян) / вред ;
- chlorination - хлорлау / хлорирование;
- aeration - желдету / аэрация;
- water intake - су алу / забор воды;
- storage tank - су сақтайтын
- қойма / резервуар для хранения;
- surface tension - беттік керілу / поверхностное натяжение;
- to condense - сұйық түрге айналу / конденсироваться;
- settling - тұну / отстаивание;
- involve - енгізу / включать.

13.3 HARDNESS OF WATER

Why do distilled and filtered water taste more sweet than tap water?

You will:

- know that water can be hard;
- learn the ways of softening hard water.

Water containing high amounts of Ca2+ and Mg2+ ions is called hard water. The anions that are usually present in these cations are Cl-, SO42-, and HCO3 . Water containing minimal concentrations of Ca2+ and Mg2+ is called soft water.

Mineral drink. Some people prefer a taste of hard water drinks

Scale in old pipe after years of using

Scum in the old copper kettle

Most natural water is hard. The use of hard water for household purposes and in the industry gives several problems. That is why metal ions which cause water hardness must be removed before the water is used. That process is called water-softening.

Water softening methods depend on the type of hardness. The hardness of water classified as temporary hard water and permanently hard water.

Types of water

Type	Temporary hardness (Carbonate hardness)	Permanent hardness (Non-carbonate hardness)
Anions	HCO_3^-	Cl^- and SO_4^{2-}
Softening methods	a) boiling b) addition of base	addition of washing soda
Chemical reaction	a) $Ca^{2+}_{(aq)} + 2HCO^-_{3\,(aq)} \rightarrow$ $\rightarrow CaCO_{3(s)} + CO_{2(g)} + H_2O_{(l)} \rightarrow$ b) $Ca(HCO_3)_{2(aq)} + Ca(OH)_{2(aq)} \rightarrow$ $\rightarrow 2CaCO_{3(s)} + 2H_2O_{(l)}$	$CaSO_{4(aq)} + Na_2CO_{3(aq)} \rightarrow$ $\rightarrow CaCO_{3(s)} + Na_2SO_{4(aq)}$

Softening of hard water

Temporary hard water contains dissolved Ca(HCO3)2, Mg(HCO3)2 salts and can be softened by boiling for a few minutes. When hard water is heated, Ca2+ ions precipitate as CaCO3.

Ca2+(aq) + 2HCO3-(aq) --> CaCO3(s) + CO2(g) + H2O(l)

The other method is to add a base solution.

Ca(HCO3)2(aq) + Ca(OH)2(aq) --> 2CaCO3(s) + 2H2O(l)

Permanently hard water contains dissolved CaCl2, CaSO4, MgCl2, MgSO4 salts and cannot be softened by boiling. Permanent hardness can be removed by adding washing soda, Na2CO3. In this method, Ca2+ and Mg2+ ions are precipitated as their carbonates.

CaSO4(aq) + Na2CO3(aq) --> CaCO3(s) + Na2SO4(aq)

Pros and cons of hard water

Disadvantages of hard water	Advantages of hard water
Difficult to form lather with soap	Some people prefer the taste
Scum forms in a reaction which wastes soap	Calcium in the water is good for children's teeth and bones
Scale (a hard crust) forms inside kettles. This wastes energy when you boil your kettle	Helps to reduce heart disease
Hot water pipes «fur up» on the inside. The scale formed can block up pipes completely	Hard water does not dissolve some heavy metals like lead and as a result of this it does not lead to lead poisoning

Literacy

1. Give definitions of soft and hard water?
2. What are the advantages and disadvantages of hard water?

Facts

Sometimes people confuse hard water with heavy water. Heavy water is composed of deuterium atoms that are actually hydrogen isotopes. The chemical formula of that type of water is 2H2O or D2O. Heavy water has the same chemical properties with ordinary water. People can drink that water. But today it is known that if 25% of water is replaced by heavy water it causes sterility and 50% of D2O causes death in rats.

Lab work

№ 10. Determination of hard and soft water

Materials:

distilled water, tap water, carbonated mineral drink, liquid soap, 3 test tubes with corks.

Procedure:

1. Pour 10 ml of distilled water into the first test tube, 10 ml of tap water into the second test tube, 10 ml of carbonated drink into the third test tube.
2. Add one drop of liquid soap to each of the test tubes. Shake test tubes.

Observation & questions:

1. Which one of the test tubes forms a large amount of lather? Why?
2. Arrange test tubes in order of increasing hardness of water. Explain why.


Reflection

Reflection for the 4th quarter

The most difficult topic for me was ....

The easiest topic for me was ....

Rate yourself on 10-points scale

1. I can help others ....

2. I need more practice ....
3. I need extra lessons ....

Terminology

- hardness - кермектік / жесткость;
- softening - жұмсарту / смягчение;
- temporary - уақытша / временный;
- permanent - тұрақты / постоянный;
- lather of soap - сабын көбігі / мыльная пена;
- to confuse - шатастыру / путаться;
- ordinary - қарапайым / обычный;
- pros and cons - артықшылықтары мен кемшіліктері / плюсы и минусы.

Problems: Water

1. Which two elements make up water?

2. At what temperature does water boil?

3. At what temperature does water freeze?

4. What is the water in the solid state is called?

5. How much of the water on the Earth is available to drink?

6. How much of our body is made up of water?

7. What falls to the ground when clouds become too heavy?

8. How many molecules are there in a 0.05 mol sample of water?

9. What mass of water vapour occupies a volume of 112 L at STP?

10. Find the density of ice with a mass of 59.4 g and a

11. What is the percentage by mass of solution made by dissolving 50 g of salt in 300 g of water?

12. How many litres of hydrogen gas can be produced from 7.2 g of calcium according to the equation?

$$Ca(s) + 2H_2O(l) \rightarrow Ca(OH)_2(aq) + H_2(g)$$

13. Find the mass of water required to produce 68.6g of phosphoric acid.

P2O5(s) + 3H2O(l) --> 2H3PO4(aq)

14. Calculate the mass of hydrogen gas which reacted with oxygen to produce 6.02 *1022 molecules of H2O.

H2(g) + O2(g) --> H2O(l)

15. Find the mass percentages of water in the following compounds:

a) Na2CO3 • 10H2O
b) CuSO4 • 5H2O
c) Na2SO4 • 7H2O
d) Al2O3 • 10H2O

ANSWERS

Chemical reactions

1) M(CaO) =56 g/mol
M(Na2S) =78 g/mol
M(SiO2) = 60 g/mol
M(KI) = 166 g/mol
M(OF2) = 54 g/mol
M(NaHCO3) = 84 g/mol
M(Li2SO4) = 110 g/mol
M(H2CO3) = 62 g/mol
M(CH3COOH) = 60 g/mol

2) a. 15 atoms
b. 21 atoms
c. 5 atoms
d. 105 atoms 90 atoms

8) 27.59%

9) 55.81%

10) MnO2

11) D

12) B

13) B

Activity of Metals

5) I C
II E
III A
IV B
V D
VI F

8) A

9) C

10) B

Mole

4) a. 40 g/mol
b. 117.5 g/mol
c. 44 g/mol
d. 194 g/mol
e. 100 g/mol
f. 96 g/mol
g. 98 g/mol

5) a. 63 g
b. 870 g
c. 88.2

6) a. 2.15*1024
b. 3.31*1023
c. 3.13*1024

7) 5.02*1024

8) 14 g/mol

9) 56 g/mol

10) 52 g/mol

11) 12.04*1023

12) a. 5 moles
b. 1.505*1024
c. 4.515*1024

Calculations in Chemical Reations

1) 11.2 L

2) 7.1 mol

3) 77.9 g

4) 4.5*10-5 mol

5) 2.35

6) 22

7) A(x) = 12 g/mol

8) n(CO2) = 0.35 mol
n(H2O) = 0.35 mol

9) n(A2S3) = 0.06 mol
n(S) = 0.18 mol

10) 17.92 L

11) 3.98 g

12) 67.2 L

Thermochemistry

3) a. endothermic
   b. exothermic
   c. exothermic
   d. endothermic

Hydrogen and Oxygen

7) 65.3%

8) D

9) 0.0625 mol

12) D

13) E

15) D

16) E

Periodic table of the chemical elements

9) 14 electrons

11) 3rd period and group 3

13) 4th period and group 2

16) 3rd period and group 16

Chemical bonds

5) O > S > P > H > Mg > Na

9) C

10) D

11) D

Solutions

10) 129.5 g

12) it is not saturated 15 g

13) C

17) A

Inorganic compounds

4) 1B 2D 3H 4A 5C 6F 7E 8G

5) $NaNO_3(aq) + H_2O(l)$ $CaSO_4(aq) + 2H_20(l)$

9) C

10) B

12) E

13) $2NaBr(aq) + CO_2(g) + H_2O(l)$
$Al_2(SO_4)_3(aq) + Cu(s)$

Carbon

1) a. graphite, diamond, fullerene, amorphous carbon

9) C

10) D

11) A

12) B

13) E

14) E

Water

8) 3.01*1022

9) 90 g

10) 0.98 g/ml

11) 14.3%

12) 4.032 L

13) 0.2 g

15) a. 62.9%
b. 36%
c. 47%
d. 63.8%

GLOSSARY

A

acid - 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. activity series - a series of elements that have similar properties

affecting factors - a fact or situation that influences the result of something alkali metal - any of the elements of group 1 in the periodic table alkaline earth metal - the heaviest members of group 2 in the periodic table

amphoteric - having both acidic and basic characteristics.

anion - an ion that is negatively charged. atom - the individual structure which constitutes the basic unit of any chemical element.

atomic mass unit - a unit of mass used to express relative atomic masses Avogadro's number - the number of atoms or molecules in one mole of a substance

B

base - a compound that reacts with a protonic acid to give water (and a salt).

boiling - the transition of a substance from the liquid to the gaseous phase

C

cation - a positively charged atom or group of atoms
chemical bond - the strong attractive force that holds together atoms in molecules and crystalline salts.

chemical reaction - a change in which a substance (or substances) is changed into one or more new substances
combination reaction - a chemical reaction in which two reactions combine to form a single product.

combustion - the burning of gas, liquid, or solid, in which the fuel is oxidized, evolving heat and often light.

compound - a substance whose molecules consist of unlike atoms and whose constituents cannot be separated by physical means.

corrosion - oxidation of a metal in the presence of air and moisture.

covalent bond - a bond in which each atom of a bound pair contributes one electron to form a pair of electrons crystal - a three-dimensional solid formed by regular repetition of the packing of atoms, ions, or molecules

D

decomposition - the breakdown of a complex compound into two or more simple compounds. detergent - an organic compound or compounds composed of molecules containing both hydrophilic (polar) and hydrophobic (nonpolar) portions.

dilution - the process of reducing the concentration of a solute in solution

displacement - a chemical reaction in which an atom or molecule displaces and sets free an element of a compound dissolution - dissolving of a material

distilled water - water that has been freed of dissolved or suspended solids and organisms by distillation.

double displacement reaction - a chemical reaction between compounds in which the elements in the reactants recombine to form two different compounds

dry ice - carbon dioxide in the solid form

E

electron - a negatively charged subatomic particle of an atom or ion that is outside of the nucleus. electron configuration - a distribution of the electrons of an atom over orbitals.

electron dot representation - a structural formula in which electrons are represented by dots; two dots between atoms represent a covalent bond.

electronegativity - ability of an atom or group of atoms to attract electrons to itself

endothermic reaction - to a chemical reaction which absorbs heat

energy - the capacity for vigorous activity

energy level - definitely fixed energy that a molecule, atom, electron, or nucleus can have exothermic reaction - a reaction that produces heat and give it to the surroundings

F

fertilizer - a natural or chemical substance that is spread on the land or given to plants

G

greenhouse effect - an increase in the amount of carbon dioxide and other gases in the atmosphere

H

hard water - water that contains certain salts, such as those of calcium or magnesium

heat - the degree of hotness; temperature

I

inorganic compound - a compound that does not contain hydrocarbon groups

intermolecular - existing or occurring between molecules.

ion - an electrically charged atom or group of atoms

ionic bond - a type of chemical bonding in which one or more electrons are transferred completely from one atom to another

isotope - different forms of a single element that have the same number of protons but have different numbers of neutrons

K

"king's water" - a mixture of concentrated nitric acid and concentrated hydrochloric acid in the ratio 1:3 respectively

M

mass - a measure of the amount of matter in an object, usually measured in grams or kilograms metallic bond - the bonding in metals

metalloid - an element that has both metallic and nonmetallic properties, arsenic, silicon, or boron

molar concentration (molarity) - the number of moles of solute dissolved in 1 litre of solution molar volume - the volume occupied by one mole of a gas, liquid, or solid.

mole -an amount of substance that contains as many items such as ions, molecules, etc., as the number of atoms in exactly 12 grams of carbon.

N

Nanochemistry - the study of the synthesis and analysis of materials in the nanoscale range

neutralisation - the process of making a solution neutral by adding a base to an acid solution neutron - an atomic particle found in the nuclei of atoms that is similar to a proton in mass but has no electric charge.

noble gas - all the elements of the periodic group 18

O

observation - the act of observing something or someone

ore - rock or soil from which metal can be obtained

oxidation - a chemical reaction in which a compound loses electrons, that is in which the positive valence is increased oxide - binary chemical compound in which oxygen is combined with a metal or nonmetal.

P

petroleum - an oily, thick, flammable, usually dark-coloured liquid;

poisonous - harmful; destructive;

product - a substance obtained from another substance through a chemical change;

proton - a positively charged elementary particle of an atom.

R

reagent - a substance that, because of the reactions it causes, is used in analysis and synthesis;

recrystallization - to crystallize again;

relative atomic mass - the average weight of an atom of an element;

rust - a reddish-brown substance that forms on the surface of iron.

S

salt - an ionic compound made up of a cation and an anion

saturated solution - a solution in which no more solute will dissolve

solubility - a quality a substance has of being able to dissolve in another substance solute - any dissolved substance in a solution

solution - any liquid mixture of two or more substances that is homogeneous

solvent - any liquid that dissolves another solute and forms a homogeneous solution

standard temperature and pressure (STP) - the temperature of 0oc and pressure of 1 atmosphere

stoichiometry - the calculation of the quantities of reactants and products involved in a chemical reaction

substance - all forms of matter that have the same chemical and physical properties supersaturated solution - one that contains a higher than-saturation concentration of solute

T

tarnish - to dull the luster of (a metallic surface), especially by oxidation

temporary hardness - hardness of water due to the presence of magnesium and calcium hydrocarbonates

thermochemistry - the branch of chemistry dealing with the relationship between chemical action and heat.

V

valence electrons - an electron of an atom, located in the outermost shell of the atom.

W

water cycle - the process by which water is transpired and evapourated from the land and water water pollution - the addition of harmful chemicals to natural water.

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CHEMISTRY

Grade 8

Authors:
Dauren Kaliyev
Almas Ordabayev
Nurbolat Zhumagulov
Abylay Samatov
Ali Tor

Edited by:
Aidyn Tussyubzhanov
Temirlan Khassen
Kanat Baikenov

Designed by:
Yelnar Beimish

Cover design:
Darkhan Berdibayev