ЗМІСТ

General and Inorganic Chemistry: textbook

Про книгу

The textbook briefly reviews the basic concepts and laws of chemistry, the structure of substances, their properties, the energy and kinetics of chemical reactions. On the basis of this material, the properties of solutions and regularities of the processes occurring in them are presented. The textbook describes the properties of chemical elements, their simple and complex substances, the biological role and application in medicine. The textbook is intended for students of higher pharmaceutical education establishments and pharmaceutical faculties of higher medical education establishments.

GENERAL AND INORGANIC CHEMISTRY

TEXTBOOK

Edited by V.O. KALIBABCHUK

RECOMMENDED
by the Academic Council of Bogomolets
National Medical University as a textbook
for students of higher medical education
establishments

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The textbook briefly reviews the basic concepts and laws of chemistry, the structure of substances, their properties, the energy and kinetics of chemical reactions. On the basis of this material, the properties of solutions and regularities of the processes occurring in them are presented. The textbook describes the properties of chemical elements, their simple and complex substances, the biological role and application in medicine.

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PREFACE

The level of professional training for a master's degree in pharmaceutical science depends on the quality of the student's basic knowledge. General and inorganic chemistry is one of the fundamental sciences of the system of higher pharmaceutical education and the basis for studying other types of chemistry such as analytical, organic, physical, colloid, pharmaceutical, biological, toxicological chemistry, as well as pharmacognosy, medicament technology etc.

This book includes the core topics of general and inorganic chemistry according to the achievements of current chemical science. The book consists of two parts – general chemistry (9 chapters) and chemistry of the elements (14 chapters). Throughout the book, every attempt has been made to explain the following questions in a clear, cohesive, brief and scientifically grammatical way: atomic and molecular theory and structure of atoms; periodic law and the periodic table of chemical elements in the light of the quantum mechanical model of the atom; current understanding of chemical bonding; coordination compounds; main classes of inorganic compounds; concepts of chemical thermodynamics and chemical kinetics; chemical equilibrium of the homogeneous and heterogeneous systems; solutions; physical properties, chemical properties, preparation and uses of the elements of IA, IIA, VIB, VIIB, VIIIB, IB, IIB, IIIA, IVA, VA, VIA, VIIA groups. The book is intended for the training of students at higher pharmaceutical education institutions and pharmaceutical faculties of higher medical education institutions. That is why among the different questions considered in the book the most important are the following: the biological role and medical application of some inorganic compounds; the mechanism of biological potentials; the mechanism of buffer systems action in the human body; the biological role of osmosis and osmotic pressure etc.

The material presented in the book is basic for acquiring the most important skills for the quantitative and qualitative prediction of the behaviour of chemical reactions, determination of the mechanism of interaction inorganic compounds that are used in pharmaceutical practice, and their biotransformation in the human body.

The authors have tried to expand the range of English-language books in inorganic chemistry for higher pharmaceutical education institutions and pharmaceutical faculties of higher medical education institutions of Ukraine by writing this book.

The book was prepared according to the model programme on inorganic chemistry for foreign students of higher pharmaceutical education institutions and pharmaceutical faculties of higher medical education institutions. The teaching experience in general and inorganic chemistry at the pharmaceutical faculties of Bohomolets National Medical University and Danylo Halytsky Lviv National Medical University was used in this book.

The book includes numerous tables, which give additional information for studying the major disciplines for a master's degree in pharmaceutical science and will be of great use to learn skills of predicting the properties and reactive ability of inorganic compounds, which are used in pharmacy and medicine.

Each chapter ends with control questions and tasks, questions and exercises for self-learning. To answer these questions the students will require a knowledge of the textbook material as well as an understanding of the causal relations between chemical compounds and phenomena.

Part One
GENERAL CHEMISTRY

Chapter 1. Fundamentals of atomic and molecular theory. Basic laws of chemistry

1.1. Basic concepts and quantities of atomic and molecular theory

The term *atom* was used already by ancient Greek philosophers Leucippus and Democritus (5^{th}–4^{th} centuries B.C.). According to Democritus, the term *atom* should be translated as "indivisible" and regarded as the limit of separation of substance, i. e. the smallest indivisible particle of substance.

In chemical science the concept of the atom was introduced in the 18^{th} century by J. Dalton and M. V. Lomonosov.

According to modern theories, the **atom** is an electrically neutral particle of substance consisting of a positively charged nucleus and negatively charged electrons moving around the nucleus. The nucleus of an atom is formed of protons and neutrons. The **proton** is a subatomic particle which has a positive charge, whose quantity is equal to $1.6 \cdot 10^{-19}$ C. The **neutron** is a subatomic particle which has no electric charge. The masses of the proton and the neutron are almost identical. The composition of the nucleus determines its electronic structure. The **electron** is a subatomic particle having a negative charge, whose quantity is equal to $1.6 \cdot 10^{-19}$ C. The mass of the electron is 1839 times smaller than the mass of the proton and the neutron. The relative charge of particles the proton, the electron, the nucleus, the ion) is the ratio between their charge and the charge of subatomic particles (proton, electron) calculated taking into account the sign of the charge. The relative charge of the electron is −1, of the proton +1, of the carbon nucleus +6.

A **chemical element** is a kind of atoms with the same nuclear charge. Today there are 112 known chemical elements. Thus there are 112 known kinds of atoms, and the atoms of one kind have the same nuclear charge.

Chemical elements are denoted by symbols. For example, the chemical element hydrogen is indicated as H, oxygen as O, sulfur as S, ferrum as Fe, sodium as Na etc. An atom representing a given chemical element is also denoted by the same symbol.

The electronic structure of the atom is changed as a result of chemical interaction, which is accompanied by destruction and formation of chemical bonds. An electrically neutral atom due to chemical reactions can be transformed into a positively or negatively charged ion. This runs contrary to its original name as an indivisible and the smallest particle of substance.

Isotopes are variants of atoms of the same chemical element, which have different masses. The existence of isotopes is caused by the different number of neutrons in the nucleus of the same chemical element.

The total number of protons and neutrons in the nucleus of an atom determines its nucleon (mass) number A.

$$A = N + Z,$$

where N is the number of neutrons, Z is the number of protons.

Isotopes are denoted by the chemical element symbol with two indices on the left: the superscript shows the nucleon (mass) number, the subscript shows the number of protons. For example, ${}^{35}_{17}Cl$, ${}^{37}_{17}Cl$.

The **nuclide** is an atom (the nucleus of an atom), for which the number of protons and the nucleon number are indicated. For example, one may say “the atom (nucleus) of the isotope carbon-12 $\left({}^{12}_{6}C\right)$” and “the nuclide of carbon-12 $\left({}^{12}_{6}C\right)$”. Nuclides are atoms (nuclei) of the same chemical element with different nucleon (mass) numbers. Therefore isotopes are variants of nuclides of the same chemical element (types of atoms which have the same number of protons and different nucleon numbers due to the different number of neutrons).

In physics, the term *nuclides* is often used for atoms or nuclei, for which the number of protons and the nucleon number are specified while writing equations of nuclear reactions:

$${}^{4}_{2}He + {}^{9}_{4}Be = {}^{1}_{0}n + {}^{12}_{6}C.$$

Hence, ${}^{4}_{2}He$ is a nuclide, as well as ${}^{9}_{4}Be$ and ${}^{12}_{6}C$. It should be noted that such terms as *chemical element* and *isotope* denote abstract concepts, while chemical element atom and nuclide are particles of matter which may be either in the free state or parts of compounds.

The **atomic mass** (the relative atomic mass) $A_r(x)$ is the ratio of the mass of 1 atom of the chemical element to 1/12 of the mass of 1 atom of the isotope carbon-12:

$$A_r(x) = \frac{m(1\ atom\ x)}{\frac{1}{12}m\left(1\ atom\ of\ {}^{12}_{6}\mathrm{C}\right)}.$$

One should not confuse the physical quantity of the atomic mass (the relative atomic mass) $A_r(x)$ with the physical quantity of the mass m of the atom (1 atom X). For example, the mass of an atom of the isotope carbon-12 $\left(1\ atom\ of\ {}^{12}_{6}\mathrm{C}\right) = 1.992 \cdot 10^{-26}$ kg, and the atomic mass (the relative atomic mass) of the isotope carbon-12 $A_r\left({}^{12}_{6}\mathrm{C}\right) = 12$.

The atomic masses of the chemical elements listed on the Periodic table of chemical elements or on reference tables are the average values of the atomic masses of natural isotopes of the given chemical element.

Atoms can rarely be found in the free state. As a rule, they form bonds with each other or with other atoms of the chemical element, forming more complex particles − molecules of elementary or complex substances, in this case the electronic structure of atoms changes. For example, the electronic structure of atomic hydrogen in the free state (H) is different from the electronic structure of atomic hydrogen in the bound state (H_2, HCl, NaH).

A chemical element can exist in the form of elementary substances or as a part of complex substances.

Elementary substance is a form of existence of a chemical element in the free state. One should not confuse the concept of the “element in the free state” with the “atom of an element in the free state”. Elementary substances may consist of free atoms (He, Ne, Ar, Cr, Xe, Rn); of particles formed by two atoms (hydrogen, H_2; oxygen, O_2, nitrogen, N_2); of particles formed by three atoms (ozone, O_3) etc. At high temperatures oxygen (as well as other chemical elements) may be in the form of individual atoms. This elementary substance is called monoxygen or atomic oxygen. There are elementary substances, in which atoms form a crystal lattice by means of covalent bonds (diamond), or a metal lattice by means of delocalised electrons (copper, gold etc.).

Allotropy is a phenomenon of existence of a chemical element in the form of two or more simple substances, such as oxygen O_2 and ozone O_3. Carbon may exist as diamond, graphite, carbyne etc.

Atoms of the same chemical element or different chemical elements, when connected with each other, form molecules, ions, radicals and crystal systems (lattices).

The **molecule** is the smallest particle of matter capable of independent existence that retains the chemical properties of the substance. Molecules may contain two or more atoms. Often atoms of helium, argon, krypton, xenon and radon are called single-atom molecules, but these "molecules" have atomic electronic structure, not molecular. If molecules consist of more than 1000 atoms, they are called macromolecules. Molecules of elementary substances consist of atoms of the same chemical element, while those of complex substances contain atoms of different elements.

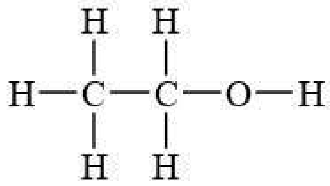
The **molecular mass** (relative molecular mass) $M_r(x)$ is equal to the ratio between the mass of a molecule of the substance and 1/12 of the mass of 1 atom of the isotope carbon-12 $\left({}^{12}_{6}C\right)$. To find the molecular mass of a substance it is necessary to know the molecular formula and atomic masses of the elements. For example, $M_r(H_2SO_4) = 2\ A_r(H) + 1\ A_r(S) + 4\ A_r(O) = 2 \cdot 1 + 32 + 4 \cdot 16 = 98$.

An **ion** is an atom or a group of atoms that has a surplus or shortage of electrons. A cation is an ion that has a shortage of electrons and carries a positive charge (Na^+, Ca^{2+}, NH_4^+). An anion is an ion that has excess electrons and is negatively charged (Cl^-, SO_4^{2-}, PO_4^{3-}). When writing formulas of a cation or an anion one should indicate their relative charges and signs of charges, "+" or "–" respectively.

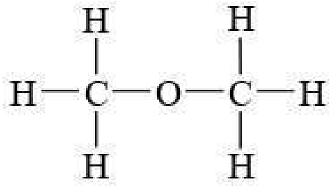
A **chemical radical** is an atom or a group of atoms with unpaired electrons ($\cdot CH_3$, $\cdot OH$, $\cdot NO$). Most radicals are characterised by highly reactive activity and therefore exist only during reactions.

The chemical formula indicates the atoms of which chemical elements and how many of them compose a substance. There are empirical (simplest), molecular, structural and other kinds of formulas of substances. The **empirical formula** expresses the simplest atomic composition of the compound, i. e. the structure of a conventional particle of this compound (a conventional molecule). The **molecular formula** shows the true number of atoms of each chemical element in the molecule (for substances with molecular structure). For example, the molecular formula of oxygen (dioxygen) is O_2, of iodine (diiodine) I_2, of ethane C_2H_6.

The **structural formula** is a molecular formula, in which the sequence of atom combination in a molecule is indicated. For example, the molecular formula C_2H_6O can be represented by two structural ones because they correspond to two different substances:



Ethanol



Dimethyl ether

Often, abbreviated variants of structural formulas are used, namely:

$$CH_3—CH_2—OH;\ CH_3—O—CH_3.$$

Isomers are substances, which have the same qualitative and quantitative composition of molecules that differ in their structure. Ethanol and dimethyl ether are isomers.

The chemical equation is a record of a chemical reaction by means of chemical formulas. In a chemical equation, the number of atoms of each chemical element before and after the reaction is the same:

$$2H_2 + O_2 \overset{T}{=} 2H_2O.$$

One should not confuse the chemical equation with the chemical transformation scheme, where formulas of parent substances and reaction products are combined by an arrow:

$$H_2 + O_2 \xrightarrow{T} H_2O;$$

$$Fe + Cl_2 \xrightarrow{T} FeCl_3.$$

In the organic chemistry course the behaviour of complex reactions is recorded by means of schemes in which the number of atoms of each chemical element before and after the reaction varies.

The mole is a basic unit of measurement that expresses the amount of a substance in the International System of Units (SI).

The **mole** is the amount of substance containing as many actual or conventional particles, as many atoms there are in 0.012 kg of the isotope carbon-12. For example, a molecule of CO_2 is an actual particle, while that of SiO_2 is a conventional particle, etc.

Using the mole as a unit of measuring amounts of a substance one should know what actual or conventional particles are under consideration. They can be real molecules (CO_2, N_2), conventional molecules (SiO_2, i. e. fragments of the polymer lattice), atoms, ions, ion associates, electrons, protons etc.

The **Avogadro constant** N_A is the number of actual or conventional particles in 1 mole of a substance. $N_A = 6.02 \cdot 10^{23}$ mol^{-1}.

The **molar mass** $M(x)$ is the mass of one mole of a substance. The units of measurement are as follows: kg/mol, g/mol. If the molar mass $M(x)$ is expressed in g/mol, it is numerically equal to the molecular mass $M_r(x)$ or the atomic mass $A_r(x)$ of the chemical element, respectively.

The amount of substance (denoted by the Latin letter $n(x)$ or Greek $\nu(x)$) is the quantity equal to the ratio between the mass of substance $m(x)$ and the molar mass of substance $M(x)$:

$$n(x) = \frac{m(x)}{M(x)}.$$

The units of measurement are mol, kmol, mmol.

The definitions of the Avogadro constant and the molar volume imply the following:

$$n(x) = \frac{N(x)}{N_A},$$

where $N(x)$ is the number of conventional or real particles of substance;

$$n(x) = \frac{V(x)}{V_m(x)},$$

where $V(x)$ is the volume of substance, $V_m(x)$ is the molar volume of a substance, i. e. the volume occupied by 1 mole of substance. The units of measurement are m^3/mol and l/mol.

It is worth mentioning that the mass and the amount of substance are different quantities. The mass of substance is measured in kilograms (grams), and the amount of substance is measured in moles, mmoles, kmoles. The connection between the mass of substance ($m(x)$), its amount ($n(x)$) and the molar mass $M(x)$ is calculated according to the formula:

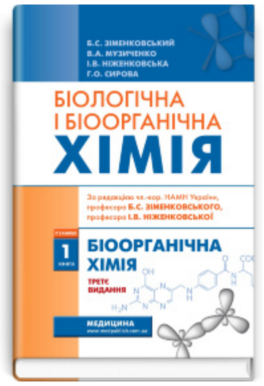
$$m(x) = n(x) \cdot M(x).$$

Control questions and tasks

1. Calculate the mass of an atom of oxygen.

2. Find the amount of substance and the number of molecules in 4.4 kg of carbon (IV) oxide.

Рекомендована література



Біологічна і біоорганічна хімія: у 2 книгах. Книга 1. Біоорганічна хімія: підручник

Перейти до категорії
Медичні природничі науки