Ministry of Health of the Republic of Belarus
Educational institution
"Gomel State Medical University"

Department of General and Bioorganic Chemistry

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METHODOLOGICAL MANUAL
for conducting the laboratory class
in the academic discipline "Medical chemistry"
for students
the first-year of the Faculty of International Students (FIS),
studying in the specialty 7-07-0911-01 "Medical business"

Topic 1: Chemistry and medicine. The doctrine of the chemical equivalent. Methods of expressing the composition of solutions

Time: 2 hours

Approved at the meeting of the Department
of General and Bioorganic Chemistry
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THE TRAINING AND EDUCATIONAL GOAL, TASKS, MOTIVATION TO STUDY THE TOPIC

Training purpose:

– formation of students' basic professional competence for solving diagnostic, research and other tasks of professional activity based on knowledge about the chemical equivalent and methods of expressing the composition of solutions;

– familiarization of students with the task of the workshop, its content and organization, as well as with the rules of work in the chemical laboratory and safety techniques, the formation of skills in working with measuring utensils; training in performing calculations and preparing a solution of a given concentration using individual substances or more concentrated solutions.

Educational goal:

– to develop your personal, spiritual potential;

– to form the qualities of a patriot and a citizen who is ready to actively participate in the economic, industrial, socio-cultural and social life of the country;

– learn to observe academic and labor discipline, the norms of medical ethics and deontology;

– to realize the social significance of their future professional activities.

Tasks:

As a result of the training session, the student should

know:

– the content, organization, goals and objectives of the workshop on medical chemistry;

– the rules of work in the chemical laboratory and safety rules;

– fire safety rules;

– the concept of the chemical equivalent and the equivalent molar mass;

– formulas for calculating the equivalence factors of simple and complex substances, the molar mass of the equivalent;

– definition of the Equivalent Law and its mathematical expression;

– the concept of solutions and ways of expressing the composition of solutions: percent by mass (mass percent, mass fraction); mole fraction (mole percent); molarity (molar concentration); molality; normality (molar concentration of the equivalent); titer.

– use the reference literature to solve the tasks set;

be able to:

– determine the equivalence factor of individual substances and substances involved in chemical reactions;

– calculate the equivalent molar mass of various substances;

– perform calculations to find the concentration of a solute in a certain volume or mass of a solution or solvent;

– perform calculations for the preparation of solutions of a given concentration;

possess:

– methods of preparation of solutions with a given concentration;

– skills in solving computational problems for expressing the composition of solutions: molarity, molality, normality of solute, titer, mass fraction of solute.

Motivation to study the topic:

The concept of chemical equivalent is widely used in chemistry to perform quantitative calculations. This is the basis of one of the laws of chemistry – the Equivalent Law. Chemical amounts of solutes are used to express the concentration of solutions.

A general practitioner should have knowledge of the basis of the modern theory of solutions, since the important biochemical processes in the tissues of living organisms are running in solutions, and most medicines are absorbed only in the dissolved state. In addition, the modern theory of electrolytes serves as a scientific basis for studying the electrolyte balance of the human body under normal and pathological conditions.

NECESSARY EQUIPMENT

1. Methodological manual for students on the topic "Chemistry and medicine. The doctrine of the chemical equivalent. Methods of expressing the composition of solutions".

2. Training tables:

a) Periodic Table of chemical elements by D.I. Mendeleev;

b) table of solubility of acids, bases and salts.

3. Reference materials of basic physico-chemical constants.

4. Chemical reagents and equipment necessary for laboratory work.

CONTROL QUESTIONS ON THE TOPIC OF THE CLASS

1. Chemistry and medicine.

2. The concept of a chemical equivalent. The equivalence factor.

3. Concentration units used for expressing the composition of solutions:

a) percent by mass (mass percent, mass fraction);

b) mole fraction (mole percent);

c) molarity (molar concentration);

d) molality;

e) normality (molar concentration of the equivalent);

f) titer.

COURSE OF THE CLASS

The theoretical part

1. CHEMISTRY AND MEDICINE

Medical chemistry is an academic discipline that includes knowledge of the basic concepts and laws of chemical thermodynamics, kinetics, physical chemistry of surface phenomena, dispersed systems and high-molecular compounds, types of chemical equilibria (protolytic, heterogeneous, ligand-exchange, redox) necessary for the subsequent study of biological chemistry, physiology, pharmacology.

In addition, the achievements of chemistry are used in various branches of medicine.

These are drugs with antimicrobial, anti-inflammatory activity, artificial organs, arteries, teeth, nerve sheaths, joints, etc.

For the purpose of diagnosis and prevention, methods of qualitative and quantitative analysis (analysis of biological fluids – saliva, blood, gastric juice, etc.) are widely used in medicine.

2. THE CONCEPT OF A CHEMICAL EQUIVALENT. THE EQUIVALENCE FACTOR

Chemical equivalent is a real or hypothetical particle of a substance that is equivalent (chemically identical) to one proton in acid-base reactions or one electron in redox reactions. A real particle is an atom, molecule or ion, a hypothetical particle is a part of a real particle (½ part, ⅓ part, etc.).

Let's consider the following reactions:

a) $H^+ + OH^- \rightarrow H_2O$;

b) $2H^+ + S^{2-} \rightarrow H_2S$;

c) $H_2 - 2e^- \rightarrow 2H^+$;

d) $Al^{3+} + 3e^- \rightarrow Al^0$.

In acid-base reactions (a, b) 1 H^+ is equivalent to 1 OH^-, ½ S^{2-}. In redox reactions, (c, d), ½ of the H_2 molecule, ⅓ of the Al^{3+} are equivalent to 1 electron. The listed particles are considered as chemical equivalents of the substances involved in these reactions.

From another point of view, **a chemical equivalent** is a real or hypothetical particle that is equivalent to 1 elementary charge in the particular ion-exchange or oxidation-reduction reaction [2, 3].

For example, in the reaction: $H_3PO_4 + OH^- \rightarrow H_2PO_4^- + H_2O$, the equivalent corresponds to one H_3PO_4 molecule, since it reacts with one OH^-.

And in the reaction: $H_3PO_4 + 2OH^- \rightarrow HPO_4^{2-} + 2H_2O$, the H_3PO_4 molecule reacts with two OH^-, thus the equivalent of phosphoric acid is equal to ½ of H_3PO_4 molecule.

The mass of one mole of a substance is defined as molar mass (M), g/mol.

For example: $M(H_2O)$ = 18 g/mol; M(HCl) = 36.5 g/mol; M(NaOH) = 40 g/mol.

The mass of one mole of chemical equivalent of a substance is defined as **equivalent molar mass (*M_e*)**, g/mol. The equivalent molar mass relates to the molar mass of a substance as follows: $\boldsymbol{M_e(X) = f_e(X) \times M(X)}$, where $f_e(X)$ – an equivalence factor.

The equivalence factor $\boldsymbol{f_e(X)}$ is the number which indicates what part of the real particle of substance X is equivalent to one hydrogen ion in the given acid-base reaction or to one electron in the redox reaction.

The equivalence factors for individual substances may be calculated according to following formulas:

a) *for acids:* $f_e = \dfrac{1}{a\ number\ of\ H\ atoms\ in\ a\ molecule}$;

For example: $f_e(HCl) = 1$; $f_e(H_2SO_4) = ½$, $f_e(H_3PO_4) = ⅓$

b) *for bases:* $f_e = \dfrac{1}{a\ number\ of\ OH-groups\ in\ a\ molecule}$;

For example: $f_e(NaOH) = 1$; $f_e(Ca(OH)_2) = ½$; $f_e(Al(OH)_3) = ⅓$

c) *for salts:* $f_e = \dfrac{1}{a\ number\ of\ Me\ atoms \times oxidation\ number\ of\ Me}$;

For example: $f_e(NaCl) = 1$; $f_e(Na_2SO_4) = ½$; $f_e(Ca_3(PO_4)_2) = ⅙$.

d) *for oxides:* $f_e = \dfrac{1}{a\ \text{number of atoms of element} \times \text{oxidation number of element}}$;

For example: f_e (K_2O) = ½; f_e (CrO) = ½; f_e (Cr_2O_3) = ⅙; f_e (CrO_3) = ⅙.

For substances involved in ion-exchange or oxidation-reduction reactions the equivalence factors can be calculated according to following formula:

$$f_e = \frac{1}{Z} \leq 1,$$

Z is the total charge of ions exchanging in 1 molecule (for ion-exchange reactions) or the number of electrons which 1 molecule (or ion) gains or losses (for redox reactions).

Z has always a positive value and the equivalence factor is less or equal to 1.

Let's consider the following reactions:

a) $H_2S + KOH \rightarrow KHS + H_2O$ — f_e (H_2S) = 1 ($Z = 1$)

b) $H_2S + 2KOH \rightarrow K_2S + 2H_2O$ — f_e (H_2S) = ½ ($Z = 2$)

c) $H_2S + 4Cl_2 + 4H_2O \rightarrow 8HCl + H_2SO_4$ — f_e (H_2S) = ⅛ ($Z = 8$)

$S^{-2} - 8e^- \rightarrow S^{+6}$

d) $2H_2S + SO_2 \rightarrow 3S + 2H_2O$ — f_e (H_2S) = ½ ($Z = 2$)

$S^{-2} - 2e^- \rightarrow S^0$

3. CONCENTRATION UNITS USED FOR EXPRESSING THE COMPOSITION OF SOLUTIONS

Concentration is a general term that represent the amount of solute contained in a given amount of solution (solvent). Various ways of expressing concentration are in use, each of which has advantages as well as limitations [1, 3, 4].

We will use the next types of solution concentration units to quantitatively describe the amounts of the solute(s) and the solvent:

a) percent by mass or **mass percent** or **mass fraction (*ω*)** is the mass of solute present in 100 g of solution:

$$\omega(X) = \frac{m(X)}{m(solution)} \times 100\,\%; \qquad X - solute$$

The percent by mass has no units because it is a ratio of two similar quantities.

b) mole fraction or **mole percent (*χ*)** is the ratio of the number of moles of a single component of a solution to the total number of moles present in the solution:

$$\chi(X) = \frac{n(X)}{n(X) + n(solvent)} \times 100\,\%;$$

The mole fraction has no units, since it too is a ratio of two similar quantities.

c) molality (C_m) is the number of moles of solute present in 1 kg of solvent:

$$C_m(X) = \frac{n(X)}{m(solvent)}, \quad [mol/kg];$$

d) molarity or **molar concentration (C_M)** is the number of moles of solute present in 1 liter of solution:

$$C_M(X) = \frac{n(X)}{V(solution)}, \quad [mol/l] \text{ or } [M];$$

e) normality or **molar concentration of the equivalent (C_N)** is the number moles equivalents of solute present in 1 liter of a solution:

$$C_N(X) = \frac{n_e(X)}{V(solution)}, \quad [mol/l] \text{ or } [N];$$

f) titer (T) is the mass of solute present in 1 milliliter of solution:

$$T(X) = \frac{m(X)}{V(solution)}, \quad [g/ml].$$

Formulas for the relationship of concentration units:

a) $C_M(X) = \frac{\omega(X), \% \times \rho(solution) \times 10}{M(X)}$; $\quad C_N(X) = \frac{\omega(X), \% \times \rho(solution) \times 10}{M_e(X)}$;

b) $C_M(X) = f_e \times C_N(X)$; $\quad C_N(X) = \frac{C_M(X)}{f_e(X)}$

c) $C_M(X) = \frac{T(X) \times 1000}{M(X)}$; $\quad C_N(X) = \frac{T(X) \times 1000}{M_e(X)}$.

The practical part

Safety instructions before laboratory work.

Laboratory work

Preparation of a less concentrated solution from a more concentrated solution

Task: to prepare 100 ml of 6 % by mass NaCl solution using more concentrated stock solution.

Carry out an experiment in the following sequence of operations:

1) determine a density of the initial (more concentrated) solution using a set of areometers (densitometers);
2) find percent by mass of NaCl in the solution using a reference book;
3) calculate a volume of the initial (more concentrated) solution required for the less concentrated solution preparing;
4) prepare the dilute solution and determine its density;
5) calculate an absolute (D) and a relative (D_o) errors of the experiment:

$$D = \rho^{(exp)} - \rho^{(table)} =$$

$$D_o = \frac{|D|}{\rho^{(table)}} \times 100\,\% =$$

Control over the assimilation of the topic

It is conducted in the form of an oral conversation with students.

METHODOLOGICAL RECOMMENDATIONS FOR THE ORGANIZATION AND PERFORMING OF INDEPENDENT WORK OF STUDENT (IWS)

The time allotted for independent work can be used by students for:

– preparation for laboratory classes;
– taking notes of educational literature;
– performing tasks for self-control of knowledge;
– preparation of thematic reports, abstracts, presentations.

The main methods of organizing independent work:

– studying topics and problems that are not covered in the classroom;
– writing an abstract and making a presentation;
– performing tasks for self-control of knowledge.

List of tasks of IWS:

1. Calculate the equivalence factor (f_e) and the equivalent molar mass (M_e) for individual substances:

a) HNO_3; c) $H_2C_2O_4$; e) K_2O; g) $Ba(OH)_2$;
b) NaOH; d) $Na_2B_4O_7 \times 10H_2O$; f) N_2O_5; h) H_3PO_4.

Answers:

a) $f_e = 1$; $M_e(HNO_3) = 63$ g/mol;
b) $f_e = 1$; $M_e(NaOH) = 40$ g/mol;
c) $f_e = ½$; $M_e(H_2C_2O_4) = 45$ g/mol;
d) $f_e = ½$; $M_e(Na_2B_4O_7 \times 10H_2O) = 191$ g/mol;
e) $f_e = ½$; $M_e(K_2O) = 47$ g/mol;
f) $f_e = 1/10$.; $M_e(N_2O_5) = 10.8$ g/mol;
g) $f_e = ½$; $M_e(Ba(OH)_2) = 85.5$ g/mol;
h) $f_e = ⅓$; $M_e(H_3PO_4) = 32.7$ g/mol.

2. Calculate the equivalence factor (f_e) and the equivalent molar mass (M_e) of substances involved in redox reactions:

a) $FeSO_4$ ($Fe^{2+} \rightarrow Fe^{3+}$); c) $KMnO_4$ ($Mn^{7+} \rightarrow Mn^{6+}$);
b) HNO_3 ($N^{5+} \rightarrow N^{4+}$); d) $KMnO_4$ ($Mn^{7+} \rightarrow Mn^{4+}$).

Answers:

a) $f_e = 1$; $M_e(FeSO_4) = 152$ g/mol;
b) $f_e = 1$; $M_e(HNO_3) = 63$ g/mol;
c) $f_e = 1$; $M_e(KMnO_4) = 158$ g/mol;
d) $f_e = ⅓$; $M_e(KMnO_4) = 52.7$ g/mol.

3. What volume of 38 % by mass hydrochloric acid solution (density of the solution is 1.19 g/ml) should be taken to prepare 1 liter of 2N solution? Calculate the titer of the prepared solution.

Answer: 161.4 ml; 7.3×10^{-2} g/ml

4. 1 liter of aqueous solution contains 577 g of H_2SO_4. The density of the solution is 1.335 g/ml. Calculate the mass fraction (%) of H_2SO_4 in solution, as well as the molarity, normality, molality and mole fractions of H_2SO_4 and H_2O.

Answer: 43.22 %; 5.88 mol/l; 11.76 mol/l; 7.57 mol/kg; 0.123; 0.877

5. Calculate the percent by mass of the solute in each of the following aqueous solutions: a) 5.5 g of NaBr in 78.2 g of solution; b) 31 g of KCl in 152 g of water.

Answer: 7 %; 17 %

6. A solution is prepared by mixing 62.6 ml of benzene (C_6H_6) with 80.3 ml of toluene (C_7H_8). Calculate the mole fractions of these two components. The densities are: benzene – 0.879 g/cm^3; toluene – 0.867 g/cm^3.

Answer: 48 %; 52 %

7. Calculate the molality of each of the following solutions:
a) 14.3 g of sucrose ($C_{12}H_{22}O_{11}$) in 676 g of water;
b) 7.2 mole of ethylene glycol ($C_2H_6O_2$) in 3546 g of water.

Answer: a) 0.061 mol/kg; b) 2.03 mol/kg

The control of the IWS is carried out in the form of:
– evaluation of an oral answer to a question, message, report or presentation;
– individual conversation.

LIST OF SOURCES USED

1. Medical chemistry : textbook for students of higher education establishments – med. univ., inst. and acad. / V.O. Kalibabchuk, V.I. Halynska, L.I. Hryshchenko et al. ; ed. by V.O. Kalibabchuk. – 6th ed., corr. – Kyiv : AUS Medicine Publishing, 2018. – P. 58-60.

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