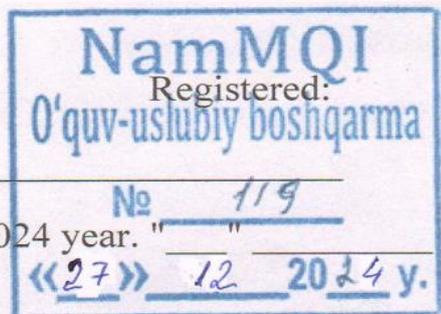
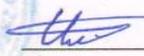


THE MINISTRY OF HIGH EDUCATION, SCIENCE AND INNOVATIVE

NAMANGAN ENGINEERING AND CONSTRUCTION INSTITUTE



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**THE SUBJECT OF OPERATING MATERIALS USED IN
VEHICLES**

for practical exercises

METHODICAL GUIDE

NAMANGAN - 2024

This methodological guide describes the methodology for conducting practical exercises in the main sections of the discipline "Operating Materials Used in Vehicles." The procedure for selecting a specific brand of fuel, oil, and lubricants from the range of operating materials for a specific type of vehicle is indicated, and calculations are performed during the practical training.

The methodological manual is intended for undergraduate students of higher educational institutions in the field of 60712500-Vehicle Engineering and is aimed at developing students' professional knowledge and practical skills in testing and determining the quality indicators of lubricants.

It was reviewed and recommended for use at the meeting of the Scientific and Methodological Council of the Namangan Engineering and Construction Institute dated [26-08 2024 \(Protocol of the meeting No. 1\)](#).

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Login

The methodological manual is intended for students studying the subject "Operating Materials Used in Vehicles" in the field of 60712500 - Vehicle Engineering (Automobile Transport).

The main goal of the subject "Operating Materials Used in Vehicles" is for students to acquire knowledge about the operational properties, quality, and rational use of fuels, lubricants, plastic lubricants, and special fluids in vehicles and other equipment.

This methodological guide provides methodological instructions for determining the suitability and performance characteristics of fuels, lubricants, and technical fluids for certain operating conditions of vehicles in order to determine the brand of the product, taking into account students' knowledge of subjects such as chemistry, automotive engineering, and internal combustion engines.

As a result of mastering the module, the student must possess the following competencies:

1. Understand the essence and social significance of your future profession, show constant interest in it.
2. Organize your own activities, choose exemplary methods and techniques for performing professional tasks, evaluate their effectiveness and quality.
3. Make decisions in standard and non-standard situations and accept responsibility for them
4. Effective performance of professional tasks, search and use of information necessary for professional and personal development.
5. The use of information and communication technologies in professional activities.
6. Working in a team and in a team, effective communication with colleagues, management, and consumers.
7. Accept responsibility for the work of team members (subordinates), the results of assignments.
8. Independently define the tasks of professional and personal development, engage in self-education, consciously plan, and improve skills
9. To act in the context of frequent technological changes in professional activity.

10. Organization and conduct of maintenance and repair work for vehicles on a computer.
11. Carrying out technical supervision during the storage, operation, maintenance, and repair of vehicles on a computer.

As a result of mastering the subject, the student must be able to:

- obtaining visco-temperature properties of petroleum products;
- construction of fractional fuel injection curves based on experimental data;
- determination of evaporation and ignition temperatures of diesel fuels and motor oils;
- assessment of the impact of gasoline, diesel fuel, oils, plastic lubricants and technical fluids on the durability of vehicles and their environmental safety based on lab labeling and analysis.

- As a result of mastering the subject, the student should know the following:

- the influence of temperature on the viscosity of petroleum products;
- the influence of temperature on the density of petroleum products;
- requirements for oils depending on climatic conditions;
- formulas for calculating the heat of combustion of the fuel-air mixture;
- ways to increase fuel efficiency of cars;
- promising methods for the development of automotive technology in order to increase fuel efficiency and environmental safety.

General instructions for practical exercises

The purpose of practical classes on the subject "Materials Used in Vehicles" is to teach students the basic methods of analyzing fuel and lubricants and technical fluids, as well as to assess the operational qualities (passport) of these products based on analyses.

Laboratory work on fuel and lubricants and technical fluids differs from other works in the characteristics of the analyzed products: their evaporation, fire hazard, and toxicity.

The successful completion of laboratory assignments is linked to the prior preparation of students for laboratory work, strict adherence to testing methods, and adherence to safety regulations and fire safety measures in the laboratory.

The workplace must have all the necessary equipment, supplies, and materials for the student to complete the assignment, and there should be no objects that distract their attention and hinder their work.

Installation of contaminated containers and appliances, poorly connected aggregates, and improperly prepared reagents lead to a violation of analytical results. The laboratory session can only be started after the entire assembly of the apparatus or instrument has been checked.

After the analysis is complete, the tools are removed and the workplace is organized. There should be no residues of petroleum products and waste at the workplace.

The urgency of conducting experiments and analyses not only violates the test result, but can also lead to accidents and equipment damage.

At the end of the analysis, the device is disassembled and the workplace is organized. There should be no traces of petroleum products or garbage at the workplace.

The laboratory session report should cover (perform) all assignments for completing the work:

- serial number and name of the case;
- the quality indicator under study and its dimensions;
- the essence of the test;
- a brief description of the test process with a printed sketch of the software;
- product name (sample numbers) and experimental data;
- Calculation of indicators and construction of their graph (if necessary);
evaluation of test results, including comparison with GOST standards;
- Evaluation of product behavior during vehicle operation.

PRACTICAL LESSON 1.

Calculation of fuel element composition

1.1 Calculation of fuel element composition

Fuel refers to combustible substances that release thermal energy during combustion. Depending on the physical state, fuel can be liquid, solid, and gaseous. Fuel contains both flammable and non-flammable components.

The combustible part includes various hydrocarbons and other compounds, such as carbon (C), hydrogen (H), oxygen (O), nitrogen (N), and sulfur (S).

The non-combustible part (ballast part) of liquid fuel is moisture and ash. Ash is the non-combustible residue formed after the combustion of the fuel. Mainly, mineral-mechanical impurities entering ash fuel from outside - dust, sand particles, etc.

Carbon C is the main combustible part of the fuel. The thermal value of the fuel increases with increasing carbon content. Various fuels contain between 50 and 97% carbon.

Hydrogen H is the second most important component of fuel, after carbon. Compared to carbon, the hydrogen content in the fuel is lower (up to 25%) and its combustion releases more than 4 times more heat.

Oxygen O, which is part of the fuel, does not burn and does not emit heat, so it is actually an internal ballast. Depending on the type of fuel, it contains 0.5...4.3% hydride, not exceeding 2.7% by the norm.

Nitrogen N is non-combustible and, like oxygen, is an internal ballast of the fuel. In liquid and solid fuels, its content is low and amounts to 0.5...1.5%.

Sulfur S is a very unwanted component of fuel that releases a certain amount of heat when it burns, as its combustion products - sulfur dioxide SO_2 and sulfur trioxide SO_3 - cause intense gas or liquid corrosion of metal surfaces. The sulfur content in solid fuel ranges from 0.5% to 8%, while in crude oil it ranges from 0.1% to 4%.

Ash A is a solid non-combustible component, the amount of which is determined after the fuel is fully burned. This is an unwanted and even harmful mixture, as its presence increases abrasive wear, complicates the operation of boiler installations, and so on. In fuel with a high ash content, the heat of combustion decreases and ignition decreases.

Humidity W is a very unwanted mixture of fuel, as part of the heat is used to evaporate it, resulting in a decrease in fuel heat and combustion temperature. In the presence of moisture, the operation of devices becomes more difficult (especially in winter), corrosion increases, and so on.

Mineral mixtures - ash and moisture - are divided into external and internal. The first enters fuel from the environment during extraction, transportation, or storage, while the second is contained in its chemical composition.

1.2. Heat of combustion of fuel

With the "ignition" of the combustible mixture in the engine, the chemical energy of the fuel is converted to heat, and then to mechanical energy. The amount of heat depends on the composition of this combustible mixture and the specific properties of the fuel.

The specific heat of combustion Q (kJ/kg or kJ/m³) is the amount of heat generated by the solid combustion of 1 kg of liquid or solid fuel or 1 m³ of gaseous fuel. This indicator can be determined by two methods: calculation and experiment.

It is important to know the elemental composition of the fuel using the calculation method. According to G.I. Hess's law, the heat of combustion of the fuel depends only on the initial and final combustion products and does not depend on the nature of intermediate reactions. Therefore, the heat of combustion of the fuel is equal to the heat of combustion of its constituent elements.

Since the fuel is not a mechanical mixture of various elements and is a complex chemical compound, its combustion releases slightly less heat. Some of it is used to break bonds between molecules. The fuel is converted into water vapor, which is formed as a result of the combustion of hydrogen, and a certain amount of heat is also used for this process. When 1 kg of hydrogen fuel is burned, 9 kg of water is formed. Therefore, it is possible to distinguish the highest specific heat of combustion Q_{up} and the lowest Q_{pas} .

The highest specific heat of combustion of fuel is released when 1 kg of liquid or 1 m³ of gaseous fuel is completely burned, if the resulting water vapor condenses.

The lowest specific heat of combustion of fuel is the heat released during the full combustion of 1 kg or 1 m³ of fuel, which is the heat spent on evaporating the moisture from the combustion of hydrogen and the moisture contained in the fuel. Therefore, if the

moisture in the products of combustion of fuel is in the form of liquid, the highest heat of combustion is low, if it is in the form of steam.

The relationship between the lower and upper temperatures is described by the equation:

$$Q_{\text{pas}} = Q_{\text{yuq}} - 2512,08 \cdot 9(H + W), \quad (1.1)$$

where 2512.08 is the amount of heat used to convert 1 kg of water into steam, kJ;

9H is the amount of water formed from the combustion of hydrogen, kg.

W is the amount of water contained in the fuel, kg.

In calculations, it is more convenient to take the amount of hydrogen and moisture in the fuel, not in weighted percentages, where:

$$Q_{\text{pas}} = Q_{\text{yuq}} - 25,1208 \cdot 9(H + W). \quad (1.2)$$

If the heat of combustion is calculated in kcal/kg, it is as follows:

$$Q_{\text{pas}} = Q_{\text{yuq}} - 6 \cdot 9(H + W). \quad (1.3)$$

The formulas proposed by D. I. Mendeleev are used to determine the specific heat of the element in terms of its composition. These formulas show that the heat of combustion of the fuel is equal to the total heat released during the combustion of its individual elements.

The highest specific heat of combustion of liquid or solid fuel, kJ/kg:

$$Q_{\text{yuq}} = 339C + 1256H - 109 \cdot (O - S), \text{ chunku } 1 \text{ kcal} = 4,1868 \text{ Dj}, \quad (1.4)$$

$$1 \text{ kkal} = 4,1868 \text{ kJ}, \text{ bundan } Q_{\text{yuq}} = 81C + 300H - 26 \cdot (O - S). \quad (1.5)$$

The lowest specific heat of combustion of liquid or solid fuel, respectively, is kJ/kg and kcal/kg:

$$Q_{\text{pas}} = 339C + 1256H - 109 \cdot (O - S) - 25W, \quad (1.6)$$

$$Q_{\text{pas}} = 81C + 246H - 26 \cdot (O - S) - 6W. \quad (1.7)$$

The formulas show the percentage of different elements and moisture content in the fuel. A calorimetric device is empirically used to determine the heat of combustion, the main elements of which are a bomb and a calorimeter.

The heat of combustion of low-viscosity fuel is determined by the formula, kcal/kg:

$$Q_{\text{pas}} = Q_{\text{yuq}} - 600 \cdot q, \quad (1.8)$$

where 600 is the vapor formation temperature, kcal/kg;

q is the amount of condensate accumulated, kg.

The average heat of lower combustion is:

gasoline - 44...44.5 MJ/kg;

- kerosene - 43.2 MJ/kg;
- diesel fuel - 42.6 MJ/kg;
- 41.16 MJ/kg of household fuel for the furnace;
- sulfur-containing fuel oil - 39.9 MJ/kg.

2.3. Determining the amount of air required for combustion

Burning is the chemical process of combining a combustible substance and an oxidizing agent. Burning is actually the oxidation of fuel with oxygen in the air. As a result of this process, a certain amount of thermal energy is released, and the temperature rises sharply.

The rate of oxidation reactions during combustion is very high and the released heat does not have time to dissipate. This specific property distinguishes combustion from many oxidation processes.

It is in a homogeneous combustion-fuel and oxidized gaseous state. The substances involved in heterogeneous combustion reactions are in various aggregate (e.g., solid and gaseous) and explosive states.

To evaluate the completeness of fuel combustion, we need to know the following:

- the theoretically necessary amount of air for fuel combustion;
- the actual amount of air required for complete fuel combustion;
- theoretical combustion temperature;

The composition of combustion products.

All these values are determined by calculation based on the elemental composition of the fuel.

Example: We have 1 kg of dry fuel, C g of carbon, H g of hydrogen, S g of sulfur, N g of nitrogen, O g of oxygen, and A g of ash. We write the combustion reactions of the combustible elements C, H, and S. that require oxygen to burn, and from the ratio of atomic masses, we determine the amount of oxygen required for a particular element to burn completely:



$$12 + 32 = 44;$$



$$4 + 32 = 36;$$



$$32 + 32 = 64.$$

It takes 32 kg of oxygen to burn 12 kg of carbon, and it takes 1 kg of carbon to burn:

$$32/12=8/3\approx 2,67 \text{ kg oxygen is needed.}$$

So, to burn 4 kg of hydrogen, we need 32 kg of oxygen, or 1 kg of hydrogen:

$$32/4 = 8 \text{ kg oxygen.}$$

It takes 32 kg of oxygen to burn 32 kg of sulfur, or 1 kg of sulfur to burn:

$$32/32 = 1 \text{ kg oxygen.}$$

Therefore, for 1 kg of fuel to burn completely (in mass percent), the following amount of oxygen (taking in account the oxygen in the fuel) is needed:

$$L_{O_2} = \frac{(2,67C + 8H + S - O_2)}{100}, \quad (1.12)$$

Here, it was assumed that the oxygen contained in the fuel was consumed for complete combustion. In fact, the engine does not provide pure oxygen for fuel combustion, but air contains 23.2% of the oxygen mass (the rest of the air, about 76.8%, is mainly nitrogen and does not participate in combustion). Then the theoretical amount of air required to burn 1 kg of fuel will be:

$$L_{h.n} = \frac{(2,67C + 8H + S - O_2)}{23,2}, \quad (1.13)$$

If the air content is expressed in units of volume, then the equation is divided by the air density in the normal state (temperature °C and pressure 101.3 kPa), which is 1.293. In this case, the theoretical amount of air (m³) is expressed as:

$$L_{h.n} = \frac{(2,67C + 8H + S - O_2)}{30}, \quad (1.14)$$

The ratio of the quantitative composition of substances that react with each other without residue is called a stoichiometric composition. In fact, it is difficult to achieve this. Due to the variability of operating conditions and engine operating modes, the actual fuel-air mixture composition entering the engine combustion chamber differs from the theoretically required. The sufficient or insufficient amount of air in the mixture is characterized by the coefficient of excess air. This coefficient is the ratio of the actual amount of air to the theoretical

$$\alpha = \frac{L_{h.h}}{L_{h.n}}, \quad (1.15)$$

The stoichiometric quantity and composition of the fuel mixture are called normal, normal if present, dense if present, and liquid if present. In a liquid mixture, the fuel burns completely and its chemical energy is completely released. Due to the lack of air in the thick mixtures, the fuel does not burn completely, therefore they are considered inefficient. At the same time, it burns faster and more evenly than liquid mixtures, releasing more thermal energy per unit time. Therefore, unsaturated liquid mixtures are economical, while thick.

The amount of excess air depends on the amount of fuel used, its combustion conditions, and the engine's design (Table 1.1).

Table 1.1. Air surplus coefficient values

Types of fuel	α
Gaseous fuel	1,05-1,20
Gasoline	1,05-1,15
Diesel fuel	1,20-1,40
Motor fuel	1,50-1,70
Coal (brown), peat, wood	1,50-2,00
Cox, anthracite	1,40-1,60

Determining the quality of combustion products. The quality of the products obtained from the combustion of fuel also characterizes the combustion process of fuel. For example, the complete absence of carbon monoxide CO in the combustion product indicates the complete combustion of fuel; The presence of CO and H₂ indicates incomplete combustion.

The composition of combustion products is determined using gas meters and other instruments. In this case, if the amount of carbon monoxide SO₂, oxygen O₂, and carbon monoxide SO is determined, then the amount of nitrogen is calculated analytically using the following formula:

$$N_2 = 100 - (CO_2 + O_2 + CO), \quad (1.16)$$

depending on the composition of the combustion product, the air surplus coefficient can be determined:

$$\text{in case of incomplete combustion- } \alpha = \left[1 - \frac{3,76 \cdot (O_2 - 0,5CO)}{N_2} \right]^{-1}; \quad (1.17)$$

$$\text{on full combustion of fuel- } \alpha = \left[1 - \frac{3,76 \cdot O_2}{N_2} \right]^{-1}; \quad (1.18)$$

where O₂, CO, H₂ are the percentage of oxygen, carbon monoxide, and nitrogen combustion products (calculated using the difference calculated by formula (1.2)).

Table 1.2. Heat of combustion of fuel and fuel-air mixture

Fuel type	Heat burning		Air theoretical
	Yonilg‘i	Yonilg‘i-havo aralashmasi	
Gasoline:			
- aviation gasoline	44380	2788	14,9
- Automotive gasoline	43961	2780	14,8
Kerosene	42915	2767	14,5
Diesel fuel	49705	2771	14,4
Ethyl alcohol (96%)	25958	2763	8,4
Benzene	39356	2771	13,2

1.4. Heat of the fuel-air mixture

In engines, a mixture of fuel and air burns. The amount of heat released depends on the heat of combustion and the amount of air in the mixture. When a gasoline mixture with air burns completely, 3430-3480 kJ/m³ or 2780-2890 kJ/kg of heat is released. However, in practice, the amount of heat released from the engine is much lower, as it is difficult to ensure the composition of the mixture and the stoichiometric composition of the mixture at all points of the combustion chamber.

Therefore, it should be taken into account that the power of the engine is influenced not by the heat of combustion of fuel, but by the heat of the combustible mixture. The heat of combustion of the combustible mixture can be determined as follows:

$$Q_{yon.ar} = \frac{Q_{pas}}{(1 + \alpha \cdot L_{h.n})}, \quad (1.19)$$

bu yerda Q_{pas} – yonilg‘ini past yonish issiqligi, kJ/kg;

α – havoning ortiqchalik koeffitsiyenti;

$L_{h.n}$ – 1 kg yonilg‘ini yoqish uchun zarur hisobiy havo miqdori, kg.

Havoning ortiqlik koeffitsienti oshishi bilan 1 kg yongan mahsulotning beradigan issiqlik miqdori kamayadi.

where - Q_{pas} low combustion heat of fuel, kJ/kg;

α - air surplus coefficient;

$L_{h,n}$ is the calculated amount of air required to burn 1 kg of fuel, kg.

As the air surplus coefficient increases, the amount of heat yielded by 1 kg of burned product decreases.

1.5. Problem

1.5.1. Problem solving example

Problem 1. When burning 1 kg of fuel, 10300 kcal of heat and 1.3 kg of water vapor are obtained. Determine the maximum amount of heat produced as a result of combustion, Q_{yuq} (in kJ), and the amount of hydrogen in the fuel.

Solution. From formula (2.8) we know:

$$Q_{pas} = Q_{yuq} - 600 \cdot q, \text{ formuladan kelib chiqib, berilgan } Q_{pas}=10300\text{kcal/kg}, q=1,3$$

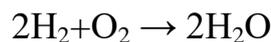
kg da

$$Q_{yuq} = 10300 + 600 \cdot 1,3 = 11080 \text{ kkal/kg},$$

or

$$Q_{yuq} = 11080 \cdot 4,1868 = 46389,7 \text{ kJ/kg}.$$

Write the hydrogen combustion reaction (2.10) and plug in the molecular weight:



$$4 + 32 \rightarrow 36$$

Thus, when 4 kg of hydrogen is burned, it attaches to 32 kg of oxygen and forms 36 kg of water, while when 1 kg of hydrogen is burned, it forms 9 kg of water. 1.3 kg of water vapor was released when the tested fuel was burned.

We construct a proportion and determine how much hydrogen is burned (x)

$$1 \text{ kg} - 9 \text{ kg};$$

$$x \text{ kg} - 1,3 \text{ kg};$$

$$x = \frac{1,3 \cdot 1}{9} = 0,144 \text{ kg}$$

According to the condition of this task, 1 kg of fuel was burned, and the 0.144 kg of hydrogen contained in it burned, which is 14.4%.

The answer: $Q_{yuq} = 46389.7 \text{ kJ/kg}$; the amount of burnt hydrogen was 0.144 kg.

1.5.2 Self-solving problems

Problem 2.1. If the air surplus coefficient is $\alpha = 1.12$, how much combustion product will be formed when burning 5 kg of C_9H_{20} fuel?

Problem 2.2. If the air surplus coefficient is $\alpha = 1.08$, how much air is needed to burn 20 kg of C_8H_{18} fuel in the engine?

PRACTICAL LESSON #2.

Gasoline calculation by elemental composition

2.1. General information

Gasoline is used as fuel for a forced-ignition internal combustion engine.

Gasoline is a complex mixture of light aromatic, naphthenic, kerosene hydrocarbons and their derivatives with an average molecular weight of about 100 and a boiling point of 35...5 to 9...10 carbon atoms. 200 °C.

Gasoline is a light flammable colorless or slightly yellow liquid. The majority of gasoline is obtained by refining oil (direct distillation, thermal and catalytic cracking) or petroleum gases. Gasoline is a light volatile liquid with a burning point of minus 20...40°C and a hardening point of minus 60°C. The kinematic viscosity of gasoline is twice as low as that of water.

2.2. Assignment

2.2.1. Problem solving example

Problem. Gasoline with the following composition: C=85,6 %, H=14,2 %, S=0,1 %, O=0,1 %, dvigatelda yondi va undan chiqqan gazlar tarkibi: CO₂=11,5%, O₂=3,2%, CO = 1,0%. $Q_{yon.aral}$ ni aniqlang.

Solution: Determine gasoline Q_{pas} using the Mendeleev formula: $Q_{pas} = 81C + 246H - 26 \cdot (O - S)$, (3.1)

$Q_{pas} = 81 \cdot 85,6 + 246 \cdot 14,2 - 26 \cdot (0,1 - 0,1) = 10426,8$ kkal/kg, yoki $10426,8 \cdot 4,1868 = 43654,9$ kj/kg.

Let's determine the air surplus coefficient. The amount of nitrogen (N₂) in the exhaust gas is determined by formula (2.18):

$$N_2 = 100 - (CO_2 + O_2 + CO) = 84,3 \%$$

Since the exhaust gas contains oxygen and carbon monoxide, we can use formula

(2.16) to calculate:

$$\alpha = \frac{1}{1 - \frac{3,76 \cdot (3,2 - 0,5 \cdot 1,0)}{84,3}} = 1,137,$$

$Q_{yon.aral}$. Let's find (2.19)

$$Q_{yon.aral} = \frac{Q_{yon.pas}}{1 + \alpha \cdot L_n},$$

For this, we find L_n using formula (2.13):

$$L_n = \frac{2,67 \cdot 85,6 + 8 \cdot 14,2 + 0,1 + 0,1}{23,2} = 14,75 \text{ kg/kg},$$

$$L_n = \frac{104268}{1 + 1,136 \cdot 14,6} = 587,23 \text{ kkal/kg} = 2458,61 \text{ kJ/kg}$$

$$Q_{\text{гор. смеси}} = 2458,61 \text{ кДж/кг}$$

2.2.2. Problems for independent solution

Problem 2.1. Determine the heat of combustion of gasoline and its normal working mixture of the following composition: C = 85,5 %; H = 13,5 %; S = 0,6 %; O = 0,4 %.

Problem 2.2. Density $\rho_4^{20} = 0,740$ 5 liters C_8H_{16} determine the heat of combustion of a normal hydrocarbon $Q_{\text{yon.aral}}$ mixture.

Problem 3.3. Determine the heat of combustion of a normal mixture of 10 liters of gasoline containing C_7H_{16} with a specific weight of 0.736.

PRACTICAL LESSON 3.

Diesel fuel composition calculation

3.1. General information

Diesel fuel is an oil fraction, the basis of which is hydrocarbons with a boiling point of 200 to 350°C. Diesel fuel is a more transparent, viscous liquid than gasoline. Its color depends on the resins in its composition and ranges from yellow to light brown.

Problem 3.2.

3.2.1. Problem solving problem

Problem. C = 85,2 %, H = 13,7 %, S = 0,74 %, W = 0,1 %, determine the actual amount of air expended on the combustion of 15 kg of oxygen-containing diesel fuel in $L_{h,h}$ kg and m^3 .

Composition of exhaust gases: $CO_2=11,2$ %, $O_2 =4,6$ %, $CO=0,3\%$, $SO_2=0,5$ %.

Solution: Determine the amount of oxygen in diesel fuel:

$$O = 100 - (C + H + S + W) \quad (3.1)$$

$$O = 100 - (85,2+13,7+0,74+0,1) = 0,26 \text{ \%}.$$

We calculate the calculated amount of air required for the complete combustion of 1

kg of diesel fuel in $L_{h,h}$ kg and m^3 (2.14): $L_{h,h} = \frac{2,67 \cdot 85,2 + 8 \cdot 13,7 + 0,75 - 0,26}{23,2} = 14,55$

air consumption is in m^3 : $14,55 / 1,293 = 11,24 m^3$.

Let's determine the air surplus coefficient α . The combustion products contain sulfur oxides (SO_2). We can add them to the amount of carbon dioxide (three atomic gases).

Determine the amount of nitrogen (N_2) in the exhaust gases:

$$N_2 = 100 - (CO_2 + SO_2 + O_2 + CO), \quad (3.2)$$

$$N_2 = 100 - (11,2 + 0,5 + 4,6 + 0,3) = 83,4 \text{ \%}.$$

Since the exhaust gases contain oxygen and carbon monoxide, we can use formula

(2.16) to calculate:

$$\alpha = \frac{1}{1 - \frac{3,76 \cdot (4,6 - 0,5 \cdot 0,3)}{83,4}} = 1,16$$

From formula (2.15) we determine L_h :

$$L_h = L_n \cdot \alpha, \quad (4.3); \quad L_h = 1,16 \cdot 14,55 = 16,88 \text{ kg/kg}$$

$$L_h = 1,16 \cdot 11,24 = 13,04 \text{ m}^3/\text{kg}.$$

It takes 15 times as much air to burn 15 kg of fuel.

Answer: $L_h = 16.88 \text{ kg/kg}$; $L_h = 13.04 \text{ m}^3/\text{kg}$,

3. 2.2. Problems for independent solution

Problem 3.1. If the exhaust gas analysis $\text{CO}_2 = 15,2 \%$; $\text{O}_2 = 3,4 \%$; $\text{CO} = 2,1 \%$ in the presence of $\text{C} = 83,1 \%$; $\text{H} = 13,6 \%$; $\text{O} = 2,0 \%$; $\text{S} = 1,3 \%$ How much air is needed to burn 18 kg of diesel fuel?

Problem 3.2. If the analysis of combustion products $\text{CO}_2 = 10,5 \%$, $\text{O}_2 = 5,1 \%$, $\text{CO} = 0,4 \%$, $\text{SO}_2 = 0,85 \%$ in the presence of $\text{C} = 85,4 \%$, $\text{H} = 13,2 \%$, $\text{S} = 0,8 \%$, $\text{O} = 0,6 \%$, $\rho_{420} = 0,825$ Determine the amount of air used to burn 20 liters of diesel fuel.

Problem 3.3. $\text{C}_{16}\text{H}_{34}$ va $\text{C}_{10}\text{H}_7\text{CH}_3$ diesel fuel, consisting of an equal mixture of hydrocarbons, burned in the engine with an air surplus coefficient of 1.3. Determine the heats of combustion Q_y , Q_{pas} , L_h , and cetane.

PRACTICAL LESSON No. 4.

Calculation of the composition of types and thermal value of gas fuels

4.1. Types of gas fuels and thermal value (value)

All gaseous fuels are divided into two types - natural and artificial.

Natural gases include light hydrocarbons captured during oil extraction and natural gases from clean gas fields.

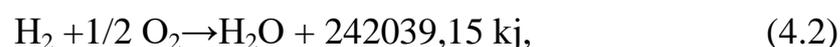
Artificial gases are obtained by processing solid and liquid fuels. The combustible component includes combustible gases - carbon monoxide (CO), hydrogen (H_2), methane (CH_4), propane (CH_8), butane (CH_{10}) and others. Gaseous hydrocarbons with a carbon number greater than one (heavier than methane), but less than five (pentane-liquid), are usually designated by the general formula S_nH_m and are called heavy hydrocarbons.

The ballast of gaseous fuel is non-combustible gases: water vapor (H_2O), nitrogen (H_2), carbon dioxide (CO_2), oxygen (O_2), sulfur dioxide (SO_2) and others.

The thermal value of the combustible components of gaseous fuel is different:



When 1 m³ of CO is burned, 12751.05 kJ/m³ of heat is released:



1 m³ when hydrogen is burned, 10805.32 kJ/m³ of heat is released: $\text{CH}_4 + 2\text{O}_2 \rightarrow \text{CO}_2 + \text{H}_2\text{O} + 796831,77 \text{ kJ}$, (4.3)

1 m³ CH₄ during combustion, 35572.84 kJ/m³ of heat is released.

Even more oxygen is needed to burn heavier gaseous hydrocarbons: $\text{C}_2\text{H}_4 + 3\text{O}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O} + 1309281,27 \text{ кДж}$, (4.4)

1 m³ C₂H₄ 58896.48 kJ/m³ of heat is released during combustion

As can be seen from the above data, the combustion of methane and heavy hydrocarbons releases much higher heat than the combustion of carbon monoxide and hydrogen.

If the composition of gaseous fuel is known, then its combustion heat can be calculated using the following formulas:

$$Q_{yuz}^{gur.gaz} = 30,4 \cdot (CO + H_2) + 95,05 \cdot CH_4 + 152,4 \cdot C_n H_m, \text{ kkal/m}^3 \quad (4.5)$$

$$Q_{pas}^{gur.gaz} = 30,4 \cdot CO + 25,8 \cdot H_2 + 85,6 \cdot CH_4 + 143 \cdot C_n H_m, \text{ kkal/m}^3 \quad (4.6)$$

yoki

$$Q_{pas}^{gur.gaz} = 127,51 \cdot CO + 108,05 \cdot H_2 + 355,73 \cdot CH_4 = 588,96 \text{ kJ/m}^3, \text{ kkal/m}^3 \quad (4.7)$$

Gaseous fuel is conventionally divided into 3 groups based on the heat of combustion:

- high-calorie gases with a combustion heat of more than 20,000 kJ/m³ (these gases include various natural gases obtained from gas fields, petroleum gases obtained from oil wells together with oil, or passing gases, as well as various cracking gases obtained during oil refining and other gases);

- gases with an average calorific value, with a combustion heat of up to 10000-20000 kJ/m³ (cox, illuminating gases, etc.);

- low-calorie gases with a combustion heat of up to 10000 kJ/m³ (generator, domna, mixed, ore gases, etc.);

4.2. The amount of air required for the combustion of gaseous fuel

The amount of air theoretically needed to burn gaseous fuel can be determined by the specific volume composition (%) of the gas:

$$L_n^{gaz} = \frac{0,5 \cdot (CO + H_2) \cdot C_m \cdot H_n - O_2}{21} \text{ m}^3/\text{m}^3, \quad (4.8)$$

here L_n^{gaz} – theoretically required amount of air, m³/m³;

CO, H₂, C_nH_m, O₂ – gas composition by volume, %;

21 – volume of oxygen in the air %.

4.3. Problem

4.3.1. Problem solving example

Problem. How much heat will be released when 8 m³ of gas with a composition of CH₄ = 92%, CH_m = 2.0%, H₂ = 2.0%, CO₂ = 3.5%, H₂ = 0.5% is burned? Which gas burned on the burner?

The solution is the heat of combustion of 1 m³ of gas according to formula (5.6):

$$Q_{pas}^{qr.gaz} = 30,4 \cdot CO + 25,8 \cdot H_2 + 85,6 \cdot CH_4 + 143 \cdot C_n H_m, \text{ kkal/m}^3$$

$$Q_{pas}^{qr.gaz} = 25,8 \cdot 2 + 85,8 \cdot 92,0 + 143 \cdot 2 = 8212,82 \text{ kkal/m}^3$$

Multiply the amount of heat received by the gas flow rate:

$$8212,92 \cdot 8 = 65702,4 \text{ kkal/m}^3$$

The answer: by composition, we can say that it is natural gas.

$$Q_{pas}^{qr.gaz} = 65702,4 \text{ kkal/m}^3.$$

4.3.2 Self-solving problems

Problem 4.1. Gaseous fuel has the following composition: propane C₃H₈=94%, butane C₄H₁₀=2.0%, ethylene C₂H₄=2.0%, the rest are non-combustible components. Determine the name of the gas, the amount of air required for the gas to burn completely, and the heat of its combustion.

Problem 4.2. The gaseous fuel has the following composition:

$$CO = 32 \% ; H_2 = 13 \% ; CH_4 = 1,2 \% ; CO_2 = 5,0\% ; O_2 = 2,0\% ; N_2 = 46,2\% .$$

Determine the name of the gas, its heat of combustion, and the amount of air required to completely burn 1 cubic meter of gas.

Problem 4.3. How much heat will be released when 5m³ of the following gas burns:

CH₄ = 90 %; C_nH_m = 3,0 %; H₂ = 2,0 %; O₂ = 1,5 %; CO = 2,5 %. Which gas burned on the burner? What is the amount of air required for the gas to burn completely?

PRACTICAL LESSON No. 5.

Calculation by elemental composition of solid fuel

5.1 Fuel Composition

Natural types of solid fuel include fossil coal, peat, wood, and agricultural waste, while artificial fuels include coke, semicoke, various briquettes, and coal. Solid fuel contains a large amount of ballast, which sharply reduces its thermal value. The moisture (W) contained in the fuel is in the form of external and internal water, or hygroscopic

water. The sum of the outer and inner water gives the total or working humidity of the fuel and is calculated by the formula:

$$W^p = W^{BH} + \frac{W^i \cdot (100 - W^{BH})}{100}, \quad (5.1)$$

bu yerda W^{BH} и W^i – tashqi va ichki namlik tarkibi, %.

where W^{BH} and W^i are the content of external and internal moisture, %.

It operates on solid fuel burned in boilers, furnaces, and other installations, which contain moisture, mineral impurities, and organic matter. This state of the aggregate is called the working mass:

$$C^p + H^p + S^p + O^p + N^p + A^p + W^p = 100 \%. \quad (5.2)$$

Such a mass cannot be analyzed, as the fuel in the room quickly loses external moisture and therefore changes its composition (becoming air-dry). Air-dry fuel can be ground, a medium sample can be prepared, and various studies can be conducted. Such a mass of fuel is called the laboratory mass:

$$C^l + H^l + S^l + O^l + N^l + A^l + W^l = 100 \%. \quad (5.3)$$

If the fuel is artificially dried to completely remove its hygroscopic moisture, then the mass of the fuel is obtained, which is called completely dry:

$$C^c + H^c + S^c + O^c + N^c + A^c = 100 \%. \quad (5.4)$$

The flammable mass is water and non-ash fuel:

$$C^r + H^r + S^r + O^r + N^r = 100 \%. \quad (5.5)$$

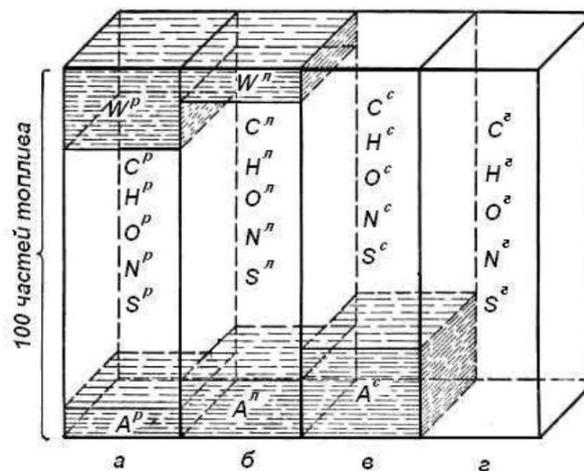


Figure 5.1. Fuel aggregate states: a - working mass; b - air-dry mass (laboratory); c - completely dry mass; g - flammable mass

Recalculation of the working mass of fuel. Figure 5.1 shows that the difference between the composition and properties of the laboratory mass and the working mass

depends on different amounts of water, as the laboratory mass contains only internal moisture, while the working mass contains both internal and external moisture. Knowing this, we can make a proportion:

B^{I} 100 percent of the fuel – W^{I} , B^{P} and contains 100 percent of the fuel in – W^{P} .

From

$$B^{\text{P}} = \frac{B^{\text{I}} \cdot (100 - W^{\text{P}})}{100 - W^{\text{I}}},$$

Recalculation of the mass of completely dry fuel. According to Figure 5.1, we compare completely dry and air-dry fuel. Absolute dry fuel has no water at all, while air-dry fuel has internal, hygroscopic moisture. Therefore, completely dry fuel contains more organic matter. Let's make a proportion:

V_{I} is present in 100 parts of the fuel - W_{I} , and V_{C} is present in 100 parts of **the fuel, of which:**

$$B^{\text{C}} = \frac{B^{\text{I}} \cdot 100}{100 - W^{\text{I}}}, \quad (5.7)$$

Recalculation based on the mass of combustible fuel. The combustible mass is completely devoid of ballast, there is no water or ash in it; therefore, the greater the change in composition and properties in the fuel, the greater the ballast. The laboratory sample contains internal moisture and ash. Let's compare the states of these two aggregates and make a proportion:

W_{I} is present in 100 parts of the fuel - W_{I} is A_{I} , and in V_{G} it is present in 100 parts of the fuel.

$$B^{\text{G}} = \frac{B^{\text{I}} \cdot 100}{100 - W^{\text{I}} - A^{\text{I}}}, \quad (5.8)$$

We can perform any recalculation using the obtained formulas or their derivatives; it should be remembered that under the symbol B stands for any possible fuel constant.

Ash detection. According to the standard, ash is designated by the symbol A, and the index at the level of A indicates how much ash is calculated per mass of fuel.

For example:

A_{I} is the ash content contained in air-dry fuel. The percentage of ash found in air-dry fuel must be recalculated to completely dry and running fuel, since the amount of ash varies depending on how much moisture is in the fuel. These calculations are carried out according to the following formulas:

$$A^C = \frac{A^a \cdot 100}{100 - W^a}, \quad (5.9)$$

$$A^P = \frac{A^C \cdot (100 - W^P)}{100}, \quad (5.10)$$

where W^l and W^r are the amount of hygroscopic and working moisture in the fuel (taken from the first definition).

5.2 Conditional Fuel

All fuels have unequal combustion heat, as they differ in composition, physical and chemical properties. The standard for comparing different types of fuels is "conditional fuel," where the lowest combustion heat for liquid and solid fuels is 29307 kJ/kg, while for gaseous fuels it is 29307 kJ/m³.

Caloric (Ekal) and technical (Etsh) equivalents are used for calculations (e.g. for switching one type of fuel to another):

$$\mathcal{E}_{kal} = \frac{Q_n}{29307}, \quad (5.11)$$

$$\mathcal{E}_{mex} = \frac{Q_n \cdot \eta_n}{29307}, \quad (5.12)$$

where Q_n is the lowest heat of combustion of the fuel, the lowest heat of combustion of the fuel;

η_n is the average efficiency of the boiler (used to calculate various types of fuels used in boilers).

The values of calorie equivalents for the main types of fuel are given in Table 5.1.

Table 5.1. Number of calorie equivalents

Fuel	Heat burning	Calorie equivalent
Charcoal	29307	1,00
Gasoline	45216	1,57
Diesel	42704	1,45
Natural gas	35586	1,21

PRACTICAL LESSON #6.

Calculation of the influence of oil properties on engines and transmissions

6.1 Purpose and requirements for motor oils

Oils used in lubricating systems of internal combustion engines are called motor oils. The primary purpose of engine oils is to reduce the wear of engine parts by creating a strong oil film on the surface of friction components. Moreover, motor oils must ensure the compaction of the gaps in the parts of the cylinder-piston group, heat dissipation and removal of wear products from the friction zones, protection of the working surfaces of the engine parts from corrosion, and also facilitate the starting of engines at low temperatures.

Motor oils should prevent the formation of precipitates of all types in engine parts when operating in different modes, exhibit high antioxidant resistance during operation, as well as during long-term storage. Moreover, motor oils must ensure minimal engine consumption during operation and maximum service life until replacement without compromising the reliability of the engine, possess good viscosity-temperature characteristics, and have high washing-crushing capacity.

6.2. Purpose and properties of transmission oils

Transmission oils are oils that serve to lubricate gearboxes, distribution boxes, differentials, steering mechanisms, gear transmissions - cylindrical, conical, chervy, hypoid, etc.

Transmission oils must possess good wear resistance and anti-pitting properties, a viscosity-temperature curve with a gradual downward descending characteristic, low-temperature hardening, good thermal and thermooxidative stability, and high storage stability, minimal impact on rubber-technical sealants, their non-destructibility, good anti-corrosion properties, and the absence of mechanical impurities and.

The main property of transmission oils is their antiwear and anti-clogging properties. Oils with these properties possess high lubricating properties, resulting in a strong film on the friction surfaces of the gear teeth to prevent micro-levels from welding and scratching.

This ability is determined by the presence of the highest content of surfactants in the residual petroleum products from which the transmission oils are obtained. In addition, special additives containing chlorine, phosphorus, sulfur, and zinc compounds are added to

oils to enhance their anticonvulsant properties. These substances form oxide films at high pressures and high temperatures, which protect the metal from capture at contact points.

6.3. Problem

6.3.1 Problem solving example

Problem. The specific gravity of the oil is 0.918, the kinematic viscosity is $v_{50} = 112$ cSt, and $v_{100} = 15.4$ cSt. Determine the viscosity of the oil at 0°C and 20°C (using Appendix B).

The solution: The calculation is performed according to the nomogram shown in Figure B.1b in Annex B. On the right vertical ordinate, we find a temperature of 50°C ; on the opposite side, we find a kinematic viscosity of 112 cSt, connecting these two points with a straight line from the temperature scale to the viscosity scale. Similarly, we find the following points: the temperature is 100°C and the corresponding viscosity value is 15.4 cSt. We connect these points with a straight line. Let's denote the point of intersection of the two constructed lines (in the nomogram, the lines are represented by continuous lines). To do this, we find the desired temperature on the temperature scale and translate the line through the intersection point of the two lines into the viscosity scale, where we read the answer (on the nomogram, the lines are drawn with straight lines).

Reply: $v_{20} = 800$ sSt; $v_0 = 9000$ sSt.

6.2.2 Examples of independent problem solving

Problem 6.1. The M-14 oil has a $v_{50} = 78$ sSt. Determine its viscosity (-10°C) and 0°C .

Problem 6.2. There are two oils with the same viscosity of 7.9 cSt at 100°C . At 50°C , the viscosity of the first oil is 65, while the second is 40 cSt. Which oils are more suitable for winter use, and what viscosity index do they have?

Problem 6.3. Determine the brand of the oil when the following information is accurate: $v_{100} = 10 \dots 11$ cSt, viscosity index 120, alkaline number 5 mg KOH/g, ash content 0.9%, hardening temperature -38°C .

PRACTICAL LESSON #7.

Determining water hardness

7.1. Calculation of water application area and key quality indicators.

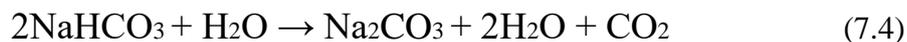
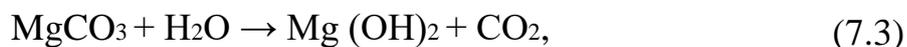
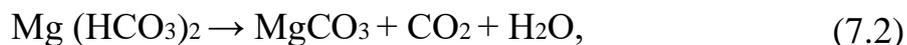
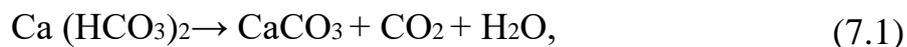
The water is intended for use in heating installations, does not cause corrosion of metals, does not foam, and most importantly, does not cause corrosion at the bottom of boilers and in the engine cooling system. When using hard water, debris is formed on the radiators, on the engine's water drums, and on the cylinder heads. The bulk does not conduct heat well, therefore the engine's cooling conditions deteriorate, the parts overheat, and the engine's normal operation is disrupted. The performance of cars and other water-cooled mechanisms decreases, fuel and oil costs increase, and the wear of parts increases.

Water used to power boilers and engine cooling should not contain mechanical volatile impurities, and even if they are not very noticeable, dissolved salts, the amount of calcium and magnesium, the alkaline metals that determine the hardness of the water, should be minimal. The hardness is divided into carbonate, which depends on the presence of calcium bicarbonates $\text{Ca}(\text{HCO}_3)_2$ and magnesium $\text{Mg}(\text{HCO}_3)_2$ in the water, and chloride, sulfur (sulfide), and silicon salts of calcium and magnesium in the water. The sum of calcium and magnesium gives the total hardness of water. Typically, the hardness of natural waters is expressed in milligram equivalent per liter, i.e., in mg-eq/l.

Water with a concentration of up to 3.0 mg-eq/L is considered soft, water with a concentration of 3.0 to 6 mg-eq/L is considered moderately hard, and water with a concentration greater than 6 mg-eq/L is considered hard.

7.2. Carbon hardness determination

To determine the hardness of a carbonate more accurately, we need to know the alkalinity of water. To do this, 100 ml of test water is poured into a flask with a volume of 250 ml, the water level is marked on the flask with a wax pencil. The flask is sealed by a root plug with a reverse-acting refrigerator and boiled for 30 minutes. When water is boiled, the bicarbonates break down according to the following reactions:



If some of the water evaporates during boiling, distilled water is poured to the specified mark. After boiling, the resulting precipitate is filtered through a dense "blue ribbon" paper filter, and the precipitate is washed with distilled water. 3-4 drops of methyl orange are added to the solution and neutralized with a solution of hydrochloric acid of 1/10 N until the yellow color changes to orange. The amount of acid administered for titration is accurately recorded in the byurette. If we subtract the amount of acid sent to neutralize unsaturated salts (sodium salts, if available, organic acid salts) from the total amount of n acid sent to determine alkalinity, then the difference gives the carbonyl hardness:

$$J_{kar} = n - m, \quad (7.5)$$

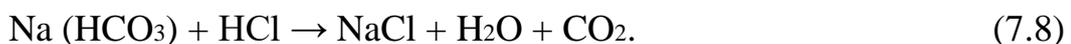
here J_{kar} – carbonate hardness, *mg-ekv/l*;

n – The total volume of acid used to determine alkalinity., *ml*;

m – the volume of acid for titration, *ml*.

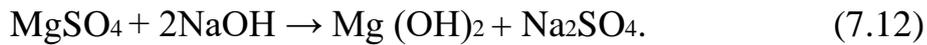
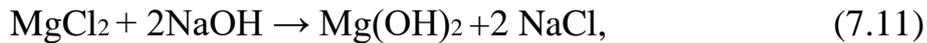
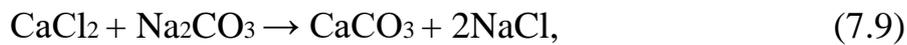
7.2. Determining the total hardness of water

The easiest way to determine the total hardness of water is to precipitate it with a mixture of salt hydroxides. The alkaline mixture Na_2CO_3 is prepared with non-equal and clearly de-normal volumes of soda and caustic sodium NaOH . Determination is carried out as follows: 100 ml of the tested water is neutralized with a solution of HCl in the presence of methyl orange 1/10 N until orange (orange) color is formed, i.e., the alkalinity of the water is determined once again. During neutralization, bicarbonates transition to chloride compounds through the following.



After transferring the salts to chloride compounds, the flask with water is boiled in an open electric furnace for 3-5 minutes until carbon dioxide is removed from the water. 20 ml of an alkaline mixture is poured into the boiling solution in a pipette and boiled for another 3-5 minutes. With an alkaline mixture, the salts are precipitated, and the salts must be reboiled to become a complete precipitate.

After adding the mixture, the color of the solution should be yellow, indicating that part of the mixture has gone to precipitate the salts, and part remains in a free state, i.e., the mixture is taken in excess. The salt precipitation reactions are as follows:



The flask with the obtained precipitate is cooled with pure water, and the solution is poured into a measuring flask with a volume of 200 ml. The sediment residue is washed in a measuring flask with distilled water and its volume is reduced to exactly 200 ml. The product inside the measuring flask is thoroughly mixed and the precipitate is filtered. A 100 ml solution can be filtered in the measuring cylinder.

The filtered solution is poured into a clean and dry conical flask and neutralized with 1/10 N of hydrochloric acid. In this case, the salt is free, unreacted (excess), the alkaline mixture is neutralized with hydrochloric acid, which is carefully added until the acid turns orange. The total hardness of water is calculated using the formula:

$$J_{um} = \pi - 2b, \quad (7.13)$$

here π – The volume of the alkaline mixture of solid salts obtained for precipitation., *ml*;

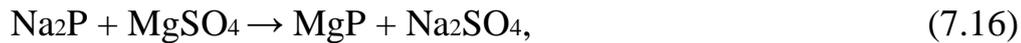
b – the amount of hydrochloric acid used to neutralize the excess mixture, *ml*.

The coefficient before the letter may be different, depending on how much of the total part of the solution contained in the measuring flask is taken for titration.

7.4. Water softening

The easiest way to soften water is to boil it first. To soften water, hardness salts are often precipitated using various chemical reagents, such as soda, lime, sodium hydroxide, etc. However, the most common and convenient method is the use of permutite and glauconite filters.

Permutite is an artificially prepared mineral, while glauconite is natural, consisting of Na, Al, and Si salts. The active element is sodium, so they are conventionally labeled Na₂P. If water is passed through such filters, an inverse reaction will occur. Calcium and magnesium are trapped in water by minerals, while sodium is trapped in water. As a result of such treatment, the amount of Ca and Mg in water decreases sharply, while Na increases. Softening reactions are listed below:



The quality of softening depends on the initial hardness of the water, the height of the filtered mineral layer of water, its activity, and the filtration rate.

A volume of 250-300 ml of water was passed through the permutite layer, and the filtrate was passed through the mineral once more. Take 100 ml of softened water and check its alkalinity. The remaining water is filtered through the mineral twice more and again checked for alkalinity. Complete removal of hardness salts can be achieved by filtration through permutite.

This method is widely used in practice, as it is very easy to restore the activity of the mineral, for which it is sufficient to wash it with a ten percent solution of NaCl table salt. Restoration is carried out according to the following reaction:



After being washed with table salt, clean water is passed through the mineral, and the filter is ready to work again.

7.5. Problems

7.5.1. Problem solving example:

Determine the total carbonate and non-carbonate hardness of water if 1 liter of water contains $\text{Ca}(\text{HCO}_3)_2 - 0,169 \text{ g}$, $\text{CaSO}_4 - 0,040 \text{ g}$ va $\text{MgCl}_2 - 0,022 \text{ g}$ If:

Given: $\text{Ca}(\text{HCO}_3)_2 - 0,169 \text{ g}$;

$\text{CaSO}_4 - 0,040 \text{ g}$;

$\text{MgCl}_2 - 0,022 \text{ g}$.

The solution: The hardness of water is called the total number of Ca and Mg ions in 1 liter of water, the unit of measurement is mg-eq/l (1 mg-eq corresponds to the content of 20.04 mg/l Ca^{2+} or 12.16 mg/l Mg^{2+}).

Determine the mg-eq in the salt contained in the water. To do this, we find the molecular weights of the salts in the water:

a) $\text{Ca}(\text{NCO}_3)_2$ The molecular weight of the salt is:

$$M = 40 + 2 + 24 + 96 = 162,$$

b) CaSO₄ The molecular weight of the salt:

$$M = 40 + 32 + 64 = 136,$$

v) MgCl₂ The molecular weight of the salt:

$$M = 24 + 71 = 95.$$

Since they are salts of dibasic acids, we can divide the molecular weight by 2 to find the equivalent:

$$162/2 = 81; 132/2 = 68; 95/2 = 47,5$$

2. Let's find the carbonyl hardness.

The hardness of the carbonate depends on the content of Ca (HSO₃)₂ in the water, its content is 0.169 g/l or 169 mg/l. For this salt, the equivalent is 81, which means that the hardness of the carbonate is equal to:

$$J_{kar} = \frac{169}{81} = 2,086 \text{ mg-ekv/l},$$

3. We find the non-carbonate hardness, which is determined by the salts of CaCO₄ and MgCl₂, containing:

$$0,040 \text{ g/l va } 0,022 \text{ g/l}.$$

CaSO₄ equivalent to 68, and consequently, hardness:

$$40/68 = 0,588 \text{ mg-ekv/l}.$$

MgCl₂ equivalent to 47.5, from which it follows that the hardness is:

$$22/47,5 = 0,463 \text{ mg-ekv/l}.$$

Carbonless hardness:

$$J_{kar.s} = 0,588 + 0,463 = 1,051 \text{ mg-ekv/l},$$

4. Let's find the total stiffness:

$$J_{um} = J_{kar} + J_{kar.s},$$

here J_{kar} - carbonate hardness;

$J_{kar.s}$ - non-carbonate hardness,

$$J_{um} = 2,086 + 1,051 = 3,137 \text{ mg-ekv/l}.$$

Conclusion: medium hard water. The total hardness is 3.137 mg-eq/L; carbonate hardness is 2.086 mg-eq/L; non-carbonate hardness is 1.051 mg-eq/L.

7.5.2. Self-solving problems

Problem 1. The following salts are dissolved in water:

NaHCO_3 – 0,062 g/l,

KHCO_3 – 0,072 g/l,

$\text{Ca}(\text{HCO}_3)_2$ – 0,120 g/l,

MgSO_4 – 0,130 g/l.

Determine the alkalinity and total hardness of water.

Problem 2. One liter of water contains the following salts:

$\text{Mg}(\text{HCO}_3)_2$ – 0,187 g;

$\text{Ca}(\text{HCO}_3)_2$ – 0,098 g;

MgSO_4 – 0,072 g;

CaCl_2 – 0,102 g.

Determine the total hardness of the water.

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