MINISTRY OF SCIENCE AND HIGHER EDUCATION OF THE RUSSIAN FEDERATION

FEDERAL STATE BUDGETARY EDUCATIONAL INSTITUTION OF HIGHER EDUCATION

«DON STATE TECHNICAL UNIVERSITY»
(DSTU)

INTERNATIONAL ACADEMIC COMPETITION

FOR MASTER'S APPLICANTS «MASTERSIUM»

18.04.01 CHEMICAL TECHNOLOGY

PROGRAM **«ELECTROCHEMICAL PROCESSES AND TECHNOLOGIES FOR PROTECTION OF OIL AND GAS FACILITIES FROM CORROSION»**

METHODOLOGICAL RECOMMENDATIONS FOR PREPARATION FOR THE FINAL STAGE OF THE COMPETITION

Compiled by:

Ph.D. in Chemistry, Associate Professor, Vladimir Igorevich Mishurov

Ph.D. in Engineering, Associate Professor, Vasily Vasilyevich Demyan

Ph.D. in Chemistry, Associate Professor, Evgeniya Aleksandrovna Flick

(Members of the Methodological Commission)

Chairman of the Methodological Commission:

Doctor of Engineering, Professor, Irina Yuryevna Zhukova

FINAL STAGE

The nature and level of complexity of the Competition tasks are aimed at achieving the goals of the Competition: identification and support of individuals who have demonstrated outstanding abilities; stimulation of educational, cognitive and research activities of students; development of intellectual and creative abilities of students; creating the necessary conditions for forming a quality contingent of master's students focused on continuing an academic career; formation of a system of continuous interaction with gifted and talented youth; dissemination and popularization of scientific knowledge; attracting talented youth, including from foreign countries, to study in master's programs.

The tasks are differentiated by complexity and require different amounts of time for correct and complete solution. The tasks are aimed at identifying the intellectual potential, analytical abilities and creativity of thinking of the participants, etc.

The in-person stage of the Competition is conducted only in written form. Each participant of the Competition receives a task sheet containing **five** tasks. When performing the tasks, the following are required:
  1. An engineering calculator;
  2. Two blue or black pens.

When preparing for the Competition, the following topics should be reviewed.

LIST OF CONTENT ELEMENTS INCLUDED IN THE TASKS OF THE FINAL STAGE OF THE COMPETITION FOR THE 2025/2026 ACADEMIC YEAR

Topic 1. General Chemistry

Calculations based on thermochemical equations. Knowledge of the basic laws of thermodynamics.

Example question (problem).

The heats of combustion of ammonia NH_3 and gaseous hydrazine N_2H_4 are 317 and 534 kJ/mol, respectively. In both cases, the combustion products are nitrogen and water vapor. Determine the N–N bond energy in hydrazine if the N≡N bond energy is 945 kJ/mol. Assume that the N–H bond energy is the same in ammonia and hydrazine.

In your answer, provide all necessary reaction equations and calculation steps. Round to the nearest whole number.

№	Answer	Points:
1.	Formal equation for the hydrazine decomposition reaction: $$3N_2H_4 \rightarrow 4NH_3 + N_2$$	5
2.	Heat of reaction taking into account the combustion heat values, Q_comb.: Q_comb. = 3Q_comb.(N_2H_4)– 4Q_comb.(NH_3) – Q_comb.(N_2)= = $3 \cdot 534 - 4 \cdot 317 - 0 = 334$ kJ/mol 5	5
3.	Heat of reaction taking into account the bond energies, E, and the equality of the N–H bond energy in different substances: $Q = E(N \equiv N) - 3 \cdot E(N–N) = 945 - 3E(N–N)$ kJ/mol 5	5
4.	Comparing the heats of reaction calculated in different ways, we determine the unknown bond energy: $945 - 3 \cdot E(N–N) = 334$ E(N–N) = 203 kJ/mol 5	5
	TOTAL:	20

Topic 2. Electrochemistry

Basic concepts and theories of electrochemistry, theoretical foundations of the structure and behavior of electrolyte solutions, thermodynamic foundations of processes occurring at the electrode-electrolyte interface, kinetic theories of processes occurring at the electrode-electrolyte interface.

Example question (problem).
Calculate the required number of barrel plating tanks and the equipment load factor in a shop with an annual production $G\_c = 37500$ kg of small parts with a specific surface area $S\_sp = 15.6$ dm²/kg.

The barrels operate on a sulfuric acid electrolyte at a load I = 40 A and a simultaneous parts load G_load = 12 kg. The thickness of the zinc coating d = 7 μm. The density of zinc $\rho\_Zn = 7.14$ g/cm³, the electrochemical equivalent of zinc q_Zn = 1.22 g/(A·h). The current efficiency for zinc $B\_T = 98\%$; the increase in the zinc plating process time in barrels, taking into account mechanical wear of the coatings and insufficient uniformity of part tumbling, is 15% (K = 1.15). The zinc–plating cathode surface is 3% of the total surface area of the load parts ($K_1 = 1.03$).

Assume that the nominal annual operating time fund of the plating department equipment is in days – 305, in hours – 4154. The time for loading and unloading parts in the barrels is 5 minutes. Preparatory and final time per day is 0.5 hours. Equipment downtime for repairs is 4.5% of the nominal annual equipment operating time.

SOLUTION

№	Answer	Points:
1.	The actual annual fund of equipment operation, including downtime for repairs: $$T_z = 4154-0.045 \times 4154 = 3967$$	2
h2 2.	Preparatory and final time for the year: $$T_0 = 305 \times 0.5 = 153 \text{ h}$$	2
3.	Zinc-coated surface of a one-time drum loading (taking into account the contact surface): $$S_b Sb = G_w * S_{ud} * K_1 = 12*15.6*1.03 = 193 \text{ dm}^2$$	3
4.	Required duration of galvanizing: $$\tau_1 \tau 1 = K*(S_6)*d*p_{Zn} / (I*q\ Zn*_{Zn}In_t)) =$$ $$= 1{,}15 \cdot (19300 \cdot 0{,}0007 \cdot 7{,}14/(40 \cdot 1{,}22 \cdot 0{,}98))*60 = 139 \text{ min}$$	3
5.	Duration of the coating cycle (including time for loading and unloading parts): $$\tau_2 = 139+5 = 144 \text{ min}$$	2
6.	Annual capacity of one drum: $$G_b = G_z \times (T_z - T_0) / \tau_2 = 12 \cdot (3967-153) \cdot 60/144 = 19050 \text{ kg}$$	3
7.	Required number of drums in the workshop: $$n = G_c / G_b = 37500 / 19050 = 1.97; \text{ we assume } n = 2$$	3
8.	Equipment loading factor: $$K_3 Kz = 1.97 / 2 = 0.985$$	2
	TOTAL: 20	20

Topic 3. Organic chemistry

Fundamental sections of organic chemistry, mechanisms of chemical reactions.

Example of a question (task).

Write the reaction equations that can be used to perform the following transformations:

$$benzene + HNO3_3 \rightarrow \underline{\textbf{A}} +_2 3H2 \rightarrow \underline{\textbf{B}} + CH3_3COOH \rightarrow \underline{\textbf{C}}$$

Give names to the resulting compounds **_A, B, and C._**.

Compounds **_A_** and **_B_** are aromatic substances containing substituents of the first and second kind. Specify what kind of substituent is present in compound **_A_** and compound **_B._**.

How do substituents oftype I and II affect the aromatic ring?

Task analysis (if a detailed task analysis is required).

SOLUTION

№	Answer	Points:
1.	$C_6H_6 + + HNO_3 \rightarrow H_2O + C_6H_5NO_2$	3
2.	$C_6H_5NO_2 + 3H_2 \rightarrow H_2O + C_6H_5NH_2$	3
3.	$C_6H_5NH_2 + CH3COOH \rightarrow H_2O + C_6H_5NHC(O)CH_3$	3
4.	**_A_** - nitrobenzene, **_B_** - aminobenzene (aniline) **_C_** - N-acetylaniline	6
5.	Compound **_A_** contains a substituent of the second kind, and compound **_B_** contains a substituent of the first kind. Substituents of the first kind (activating) increase the electron density of the ring, facilitating electrophilic substitution in the ring and orienting the new substituent to the *ortho*-and *para*-positions of the ring; substituents of the second kind (deactivating) lower the electron density, complicating the substitution reaction in the ring and orienting the new substituent to the *meta*-position of the ring.	5
	TOTAL:	20

Topic 2. Processes and apparatuses of chemical technology

Basic concepts and regularities of technological processes, classification of chemical technology processes, standard methods for calculating heat and mass transfer processes in the design and operation of technological equipment of chemical production.

Example of a question (task).

Saturated steam condenses on the vertical surface of the heat exchanger wall (figure). The condensate film flows laminarly over the wall surface, continuously increasing in thickness due to the condensation of new portions of steam on the film surface. The film width (*y-coordinate*) is 1 m. The total wall height is H..

The differential of the heat flow from steam to the wall at a distance z from the beginning of the film is expressed by the linear equation:

$$dQ_t = \frac{\lambda}{\delta}(t_n - t_{st})dz\, b$$

where λ is the coefficient of thermal conductivity of condensate;

δ is the thickness of the condensate film at a distance z from the beginning of the film;

t_{st} – constant along the length of the film temperature of the machine;

t_n is the temperature of the outer surface of the film, equal to the vapor temperature;
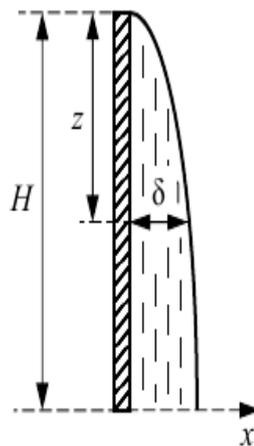
$b = 1$ m – width of the film (in the y coordinate).

Figure – Film condensation

The average flow rate of condensate is expressed by the equation:

$$\omega_{z\ average} = \frac{pg\delta^2}{3\mu}$$

The specific heat of vapor condensation is r (J / kg).

Determine the heat transfer coefficient from steam to the wall depending on the above parameters.

#	Response	Points:
1.	Boundary conditions for the equation: on the axis of the cylinder $$\left(\frac{dt}{dr}\right)_{r=0} = 0$$ on the surface $$\left(\frac{dt}{dr}\right)_{surf} pob = -\frac{\alpha}{\lambda}\left(t_{surf} - pob -_{average}\right)$$	2
cp 2 2.	We integrate the equation from the condition $$r\frac{dt}{dr} = -\frac{q_v}{\lambda}\cdot\frac{r^2}{2} + c$$ From the first equation it follows that $c = 0$	2
3.	Then, substituting equation two into equation three, we get: $$\left(\frac{dt}{dr}\right)_{surf} rep = -\frac{q_v \cdot r_{surf}}{rep\ 2\lambda} = -\frac{\alpha}{\lambda\ t}\left(t_{surf}rep - t_{av}\right)$$ $$t_t rep = t_{aver} + \frac{q_v \cdot r_{surf}}{rep\ 2\alpha}$$	4
4.	Power of the wire heater $$Q_t = I^2 R = 19^2 \cdot 4 = 1444\ W$$	2
5.	Heat flow from wire to air: $$q_v = \frac{Q_t}{\pi r_{surf}^{=2} L} = \frac{1444}{3{,}14 \cdot (10 - 3^{-3})^2 \cdot 12} = 3{,}832 \cdot 10^7\ \frac{W}{m^3}$$	5
	Surface temperature $$t_t pob = t_{av} + \frac{q_v \cdot r_{surf}}{pob\ 2\alpha} = 20 + \frac{3{,}832 \cdot 10^7 \cdot 10 - 3^{-3}}{2 \cdot 30}$$ $$= 658{,}7\ oS$$	5

		TOTAL:	20

Topic 5. Analytical chemistry. Quality control of petroleum products

A sample of engine oil was received by the laboratory for acid number determination. The lower the acid number, the better the oil's performance in the engine and the longer its remaining life. An increase in the acid number indicates oil oxidation caused by prolonged use and/or operating temperature.

For analysis in accordance with GOST 5985-2022, 10.0 g of the sample was collected. 6.85 ml of a 0.05 mol/dm³ alcoholic solution of potassium hydroxide were used for titration with Nitrazine Yellow.

The titer of the alcoholic solution of potassium hydroxide was determined using a hydrochloric acid solution prepared from 0.1 mol/dm³ of Fixanal: 21.10 ml of a 0.05 mol/dm³ alcoholic solution of potassium hydroxide were used for titration of 10.0 ml of a 0.1 mol/dm³ hydrochloric acid solution.

Determine the acid number (mg KOH/g).

Decide on the freshness of the motor oil.

Write a general equation for the chemical reaction for this determination method.

Calculate the error in titration with nitrosine yellow indicator (pT = 6.5) if X ml of titrant are used to titrate 10.0 ml of a 0.1000 M hydrochloric acid solution with a potassium hydroxide solution of the above concentration.

SOLUTION

№	Answer	Points:
1.	$$T(KOH) = \frac{V(HCl) \times 0.0036465 \times M_e(KOH)}{M_e(NCl) \times V(KOH)} \, 1000$$ $$T(KOH) = \frac{10 \times 0{,}0036465 \times 56{,}104}{36{,}465 \times 21{,}10} \, 1000 = 2{,}65896 \, \frac{mg}{cm^3}$$	4
2.	$$KF = \frac{V(KOH) \times T(KOH)}{m(samples)}$$	4

	$$KC = \frac{6.85 \times 2.65896}{10.0} = 1.82 \; mg \; KOH/g$$	
3.	KC = 1.82 mg KOH/g The acidity in the range of 1.5-3.0 mg KOH / g is minimal, the oil is fresh.	2
4.	RCN + KOH □RCOOK + H2O$_2$O or H$^+$ + OH$^-$ = H2O$_2$O	1
5.	$$= -\frac{(V_\text{к} + VK + VT_\text{т}) \times 10^{-rT}}{C_K \times V_K} \times 100\%$$ Since pT< pH$_\text{te}$, titration is completed before reaching the equivalence point. Therefore, the titration error is determined by the amount of non-titrated acid. $$= -\frac{(V_\text{к} + VK + VT_\text{т}) \times 10^{-rT}}{C_k \times V_k} \times 100\%$$ C$_\text{e}$(KOH) = T /M$_\text{e}$ =$\frac{265896.56.104}{56{,}104}$ 0.0474 mol / L According to the law of equivalents, $$V_{KOH} = \frac{C(HCl) \times V(HCl)}{C(KOH)} = \frac{10.0 \times 0.1000}{0.0474} = 21.1 \; ml$$ **X** = 21.1 ml $$= -\frac{(10 + 21{,}1) \times 10 - 6^{,5}}{10} \times 0{,}1000 \times 100\%$$ ⊗ H - 0, 0001%	9
	TOTAL:	20

Literature for preparation

1.   Minaevskaya, L. V. General chemistry. For engineering and technical directions of training and specialties : a textbook / L. V. Minaevskaya, N. A. Shchegolikhina. St.Petersburg: Lan Publ., 2020, 168 p. ISBN 978-5-8114-3837-2. - Text : electronic // Lan : electronic library system. - URL: https://e.lanbook.com/book/126907 (accessed: 20.12.2025). - Access mode: for authorized. users.

2.   Damaskin. B. B. Electrochemistry :a textbook / Damaskin. B. B, Petri O. A., and Tsirlina G. A. Electrochemistry :a textbook Tsirlina. -3rd ed., ispr. — St.Petersburg: Lan, 2022. - 672 p — - ISBN 978-5-8114-1878-7. - Text : electronic // Lan : electronic library system. - URL: https://e.lanbook.com/book/211859 (accessed: 09.11.2025).

3.   Processes and apparatuses of chemical technology. General course. In two books. Book 1 / V. G. Ainstein, M. K. Zakharov, G. A. Nosov [et al.].-10th ed., ster. - SaintPetersburg: Lan, 2023. - 916 p. - ISBN 978-5-507-46494-4. - Text : electronic // Lan : electronic library system. - URL: https://e.lanbook.com/book/309377 (accessed: 20.12.2025). - Access mode: for authorized. users.

4.   Shcherbina, A. E. Organic chemistry. Basic course: Textbook / A. E. Shcherbina, L. G. Matusevich; Edited by A. E. Shcherbina. Moscow: SIC INFRA-M; Minsk: Nov. znanie, 2013. - 808 p.: ill.;. - (Higher education: Bachelor's degree). ISBN 978-5-16-006956-2. - Text: electronic. - URL: https://znanium.com/catalog/product/415732 (accessed: 20.12.2025).

5.   Vasiliev, V. P. Analytical chemistry. In 2 books. textbook for universities, Moscow: Drofa Publ., 2007, 383 p.

6.   Kirsanov Yu. G. Analysis of oil and petroleum product:, Shishov M. G., Konyaeva A. P. Analiz nefti i nefteproduktov : uchebno-metodicheskoe posobie [Analysis of oil and petroleum products: a training manual]. Yekaterinburg: Ural Federal University, EBS DIA, 2016. - 88 p. - ISBN 978-5-7996-1675-5. - Text: electronic / / Digital educational resource IPR SMART : [website]. - URL: https://www.iprbookshop.ru/68420.html (accessed on 02.06.2025). - Access mode: for authorized. users

INTERNATIONAL ACADEMIC COMPETITION
FOR MASTER'S APPLICANTS «MASTERSIUM»

18.04.01 CHEMICAL TECHNOLOGY /

program "ELECTROCHEMICAL PROCESSES AND TECHNOLOGIES FOR

CORROSION PROTECTION OF OIL AND GAS COMPLEX FACILITIES"

Criteria for cheking.

The variant of the final stage of the Competition on 18.04.01 Chemical Technology/program "Electrochemical processes and technologies for corrosion protection of oil and gas complex facilities" includes five tasks of different types. Each task is scored from 0 to 20 points. The highest total score that can be awarded for answers to all questions in the Competition variant, provided that there are no errors, incorrect, incomplete or inaccurate answers, is 100. Incorrect answers are scored 0 points. Partial points may be awarded for incomplete answers. An incomplete answer means an answer that does not contain correct answers to all questions in the task. In this case, only a portion of the points for correct answers to the task is awarded, corresponding to a share of the maximum possible score. The final grade for the assignment is calculated by summing up the points awarded for each question.

Topic 1. General Chemistry

Task: The heat of combustion of ammonia NH3 and gaseous hydrazine N2H4 are 317 and 534 kJ/mol, respectively. In both cases, the combustion products are nitrogen and water vapor. Determine the N–N bond energy in hydrazine if the N≡N bond energy is 945 kJ/mol. Assume that the N–H bond energy is the same in ammonia and hydrazine.

In your answer, provide all necessary reaction equations and calculation steps. Round to the nearest whole unit.

Total: 20 points. Of which:

<div align="center">Criteria for checking (assessing)</div>

№	Criteria	Point
1.	A formal equation for the decomposition reaction of hydrazine has been compiled: $$3N_2H_4 \rightarrow 4NH_3 + N_2$$	5
2.	The reaction heat equation was compiled and calculated taking into account the heat of combustion values, $Q_{comb.}$: $$Q_{comb.} = 3Q_{comb.}(N_2H_4) - 4Q_{comb.}(NH_3) - Q_{comb.}(N_2) =$$ $$= 3 \cdot 534 - 4 \cdot 317 - 0 = 334 \text{ kJ/mol}$$	5
3.	The heat of reaction was calculated taking into account the values of bond energies, E, and the equality of the N–H bond energy in different substances: $$Q = E(N \equiv N) - 3 \cdot E(N-N) = 945 - 3E(N-N) \text{ kJ/mol}$$	5
4.	Unknown binding energy determined: $$945 - 3 \cdot E(N-N) = 334$$ $$E(N-N) = 203 \text{ kJ/mol}$$	5
	TOTAL:	20

Topic 2. Electrochemistry

Basic concepts and theories of electrochemistry, theoretical foundations of the structure and behavior of electrolyte solutions, thermodynamic foundations of processes occurring at the electrode-electrolyte interface, kinetic theories of processes occurring at the electrode-electrolyte interface.

Task:

Calculate the required number of galvanizing drum baths and the equipment utilisation factor in a workshop with an annual capacity of $G_{workshop} = 37500$ kg of small parts with a specific surface area of $S_{sp} = 15,6$ dm2/kg.

The drums operate on sulfuric acid electrolyte at a load of $I = 40$ A and simultaneous loading of parts $G_{load} = 12$ kg. Thickness of zinc coating $d = 7$ μm. The density of zinc $\rho_{Zn} = 7,14$ g/cm³, the electrochemical equivalent of zinc $q_{Zn} = 1,22$ g/(A·h). Current output for zinc $B_{output} = 98$ %; increasing the time of the galvanizing process in drums taking into account the mechanical abrasion of the coatings and insufficient uniformity of pouring of parts by *15 %* ($K = 1,15$). The galvanized surface of the cathode is 3% of the total surface of the loading parts ($K_1 = 1,03$).

Assume that the nominal annual operating time of the electroplating department equipment is 305 days and 4154 hours. The time for loading and unloading parts in drums is 5 minutes. The preparatory and final time per day is 0.5 hours. Equipment downtime for repairs is 4.5% of the nominal annual equipment operating time.

Total: 20 points. Of which:

Criteria for checking (assessing)

№	Criteria	Point
1.	Calculation of the actual annual operating fund of equipment taking into account downtime for repairs: $$T_z = 4154 - 0,045 \cdot 4154 = 3967 \text{ h}$$	2
2.	Calculation of preparatory and final time per year: $$T_0 = 305 \cdot 0,5 = 153 \text{ h}$$	2
3.	The area of the galvanized surface of a single drum load is determined (taking into account the contact surface): $$S_d = G_{load} \cdot S_{sp} \cdot K_1 = 12 \cdot 15,6 \cdot 1,03 = 193 \text{ dm}^2$$	3
4.	The required duration of galvanizing has been determined: $$\tau_1 = K \cdot (S_d \cdot d \cdot \rho_{Zn} / (I \cdot q_{Zn} \cdot B_{output})) =$$ $$= 1,15 \cdot (19300 \cdot 0,0007 \cdot 7,14/(40 \cdot 1,22 \cdot 0,98)) \cdot 60 = 139 \text{ min}$$	3
5.	The coating cycle time has been determined (taking into account the time for loading and unloading parts): $$\tau_2 = 139 + 5 = 144 \text{ min}$$	2

6.	The annual productivity of one drum is calculated: $G_d = G_{load} \cdot (T_z - T_0) / \tau_2 = 12 \cdot (3967 - 153) \cdot 60 / 144 = 19050$ kg	3
7.	The required number of drums in the workshop has been calculated: $n = G_{workshop} / G_d = 37500 / 19050 = 1,97$; accept $n = 2$	3
8.	The equipment utilisation factor has been determined: $K_{ut} = 1,97 / 2 = 0,985$	2
	TOTAL:	20

Topic 3. Organic Chemistry

Fundamental sections of organic chemistry, mechanisms of chemical reactions.

Task.

Write the reaction equations that can be used to carry out the following transformations:

$$benzene + HNO_3 \rightarrow \underline{\textbf{A}} + 3H_2 \rightarrow \underline{\textbf{B}} + CH_3COOH \rightarrow \underline{\textbf{C}}$$

Give names to the resulting compounds $\underline{\textbf{A, B, C}}$.

Compounds $\underline{\textbf{A}}$ and $\underline{\textbf{B}}$ are aromatic substances containing substituents of the I and II types. Indicate what kind of substituent is in the compound $\underline{\textbf{A}}$ and in the compound $\underline{\textbf{B}}$.

How do substituents of type I and II affect the aromatic ring??

Total: 20 points. Of which:

Criteria for checking (assessing)

№	Criteria	Point
1.	The reaction equation has been compiled: $C_6H_6 + + HNO_3 \rightarrow H_2O + C_6H_5NO_2$	3
2.	The reaction equation has been compiled: $C_6H_5NO_2 + 3H_2 \rightarrow H_2O + C_6H_5NH_2$	3

3.	The reaction equation has been compiled:$C_6H_5NH_2 + CH3COOH \rightarrow$ $H_2O + C_6H_5NHC(O)CH_3$	3
4.	The resulting compounds are named **_A, B, C_**(_for each compound-2 points)_ **A** – nitrobenzene, **B**– aminobenzene (aniline) **C** – N-acetylaniline	6
5.	The type of substituents is indicated: Compound **A** contains a substituent of type II, and compound **B** contains a substituent of type I (2 points) The effect of substituents on an aromatic ring is explained. Type I substituents (activating) increase the electron density of the ring, facilitating electrophilic substitution within the ring and orienting the new substituent to the _ortho-_ and _para-_ positions of the ring; type II substituents (deactivating) decrease the electron density, hindering the substitution reaction within the ring and orienting the new substituent to the _meta-_ position of the ring (3 points).	5
	TOTAL:	20

Topic 2. Processes and devices of chemical technology

Basic concepts and patterns of technological processes, classification of chemical technology processes, standard methods for calculating heat and mass transfer processes in the design and operation of technological equipment for chemical industries.

A task.

Saturated steam condenses on the vertical surface of the heat exchanger wall (Figure). The condensate film laminates over the wall surface, continuously increasing in thickness due to condensation of new steam portions on the film surface. The width of the film (y-coordinate) is 1 m. The total height of the wall is H.

The differential of the heat flow from steam to the wall at a distance z from the beginning of the film is expressed by the linear equation:

$$dQ_t = \frac{\lambda}{\delta}(t_\text{п} - t_\text{ст})dz\, b$$

Where λ – is the coefficient of thermal conductivity of the condensate;

δ – is the thickness of the condensate film at a distance z from the beginning of the film;

$t_\text{ст}$ – is the constant temperature of the machine along the length of the film;

$t_\text{п}$ – is the temperature of the outer surface of the film, equal to the vapor temperature;
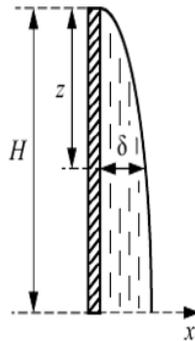
$b = 1$ m is the width of the film (y-coordinate).

Figure – Film condensation

The average condensate flow rate is expressed by the equation:

$$\omega_\text{z ср} = \frac{\rho g \delta^2}{3\mu}$$

The specific heat of steam condensation is r (J/kg). Determine the coefficient of heat transfer from steam to the wall depending on the above parameters.

Total: 20 points. Of these:

Verification (evaluation) criteria

№	Criteria	Mark
1.	Calculation: Boundary conditions for the equation: on the axis of the cylinder $$\left(\frac{dt}{dr}\right)_{r=0} = 0$$ on the surface $$\left(\frac{dt}{dr}\right)_{surf} = -\frac{\alpha}{\lambda}(t_{surf} - t_{mid})$$	2
2.	Calculation: Integrate the equation from the condition $$r\frac{dt}{dr} = -\frac{q_v}{\lambda} \cdot \frac{r^2}{2} + c$$ It follows from the first equation that $c = 0$	2
3.	Calculation: Substituting equation two into equation three, we get: $$\left(\frac{dt}{dr}\right)_{surf} = -\frac{q_v \cdot r_{surf}}{2\lambda} = -\frac{\alpha}{\lambda}(t_{surf} - t_{mid})$$ $$t_{surf} = t_{mid} + \frac{q_v \cdot r_{surf}}{2\alpha}$$	4
4.	Calculation: Wire heater power $$Q_t = I^2 R = 19^2 \cdot 4 = 1444 \, Vt$$	2
5.	Calculation: Heat flow from wire to air: $$q_v = \frac{Q_t}{\pi r_{surf}^2 L} = \frac{1444}{3{,}14 \cdot (10^{-3})^2 \cdot 12} = 3{,}832 \cdot 10^7 \frac{Vt}{м^3}$$	5
	Calculation: Surface temperature $$t_{surf} = t_{mid} + \frac{q_v \cdot r_{surf}}{2\alpha} = 20 + \frac{3{,}832 \cdot 10^7 \cdot 10^{-3}}{2 \cdot 30} = 658{,}7 \ ^{o}C$$	5
	TOTAL:	20

Topic 5. Analytical chemistry. Quality control of petroleum products

<u>A task.</u>

The laboratory received a sample of engine oil to determine the acid number in it. The lower the acid number, the better the working conditions of the oil. in the engine, and the greater its remaining life. An increase in the acid number is an indicator of oil oxidation caused by prolonged use time and/or operating temperature.

To perform the analysis according to GOST 5985-2022, 10.0 g of the analyzed sample was taken. 6.85 ml of 0.05 mol/dm3 alcoholic solution of potassium hydroxide was used for titration with nitrazine yellow.

The titer of the alcoholic solution of potassium hydroxide was determined using a hydrochloric acid solution prepared from 0.1 mol/dm3 fixanal: 21.10 ml ≈ 0.05 mol/dm3 alcoholic solution of potassium hydroxide was used for titration of 10.0 ml of 0.1 mol/dm3 hydrochloric acid solution.

Determine the acid number (mg KOH/g).

Formulate a conclusion about the freshness of the engine oil.

Make up the equation of the chemical reaction (in general form) for this method of determination.

Calculate the titration error with a nitrosine yellow indicator (rT = 6.5) if Cml of the titrant was used to titrate 10.0 ml of 0.1000 M hydrochloric acid solution with a potassium hydroxide solution with the above concentration.

Total: 20 points. That includes:

Verification (evaluation) criteria

№	Criteria	Mark
1.	The titer of potassium hydroxide in hydrochloric acid solution has been established: $$T(COH) = \frac{10 \times 0,0036465 \times 56,104}{36,465 \times 21,10} \times 1000 = 2,65896 \; \frac{mg}{см^3}$$	4

2.	The acid number (KH) of the engine oil has been determined: $$KCH = \frac{6{,}85 \times 2{,}65896}{10{,}0} = 1{,}82 \; mgCON/g$$	4
3.	Formulate a conclusion about the freshness of the engine oil. KCH = 1,82 мг KOH/g. Кислотность в диапазоне 1,5-3,0 мг KOH/g minimal, the oil is fresh.	2
4.	The equation of the chemical reaction is compiled: RCOOH + KOH →RCOOK + H₂O or H⁺ + OH⁻ = H₂O	1
5.	The volume (X) of the consumed titrant (4 points) was determined. The titration error was calculated (5 points). Since the mercury is pT< pH$_{ti}$, titration is completed before reaching the equivalence point. Therefore, the titration error is determined by the amount of untitled acid. $$\Delta = -\frac{(V_{\text{к}} + V_{\text{т}}) \times 10^{-\text{pT}}}{C_{\text{к}} \times V_{\text{к}}} \times 100\%$$ C$_\text{э}$(KOH) = T/M$_\text{э}$ =$\frac{265896,}{56{,}104} \approx$ 0,0474 mol/l According to the law of equivalents, $$V_{KOH} = \frac{C(HCl) \times V(HCl)}{C(KOH)} = \frac{10{,}0 \times 0{,}1000}{0{,}0474} = 21{,}1 \; ml$$ **X** = 21, 1 ml $$\Delta = -\frac{(10 + 21{,}1) \times 10^{-6{,}5}}{10 \times 0{,}1000} \times 100\%$$ $$\Delta \approx - 0, 0001\%$$	9
	TOTAL:	20