



Society of Chemists and Technologists of Macedonia
Chemistry competitions for elementary and high schools

NATIONAL CHEMISTRY COMPETITION

May 14, 2026

- 1) The tests are stapled with an envelope on the top. In the envelope there is piece of paper on which you should fill in the requested data: name and surname, school, supervisor etc. and then close and **seal the envelope!**
- 2) Do not put any signature, or a mark on the envelope and on the test (the code should be filled in by the jury). If any signature or mark is found on the test or envelope, the competitor will be disqualified.
- 3) You should write on the test using a **blue pen**, answers written with pencil will not be considered.
- 4) It is not allowed to use textbooks, any other book, notebook, paper, the periodic table, cell phone etc. Cell phones should be left on the teacher's desk or out of the test room.
- 5) Any conversation between the competitors is forbidden. If you have any question, then the teacher in the room should call the responsible person for the competition.
- 6) Read the test carefully and answer the questions following the instructions by writing down the solution and answer in the designated space in the test. The jury **will evaluate only the answers written in the designated space for it**, and the procedures for solving the problems will be checked. The back of every page of the test, that is empty, can be used for free writing and it will not be checked and evaluated!
- 7) The maximal number of points is **50**: 40 from the theoretical problems and 10 from the experimental problem.
- 8) The competition lasts **180 minutes**. The tests that are handed after the given time will not be considered for scoring.

We wish you success!

For the jury only

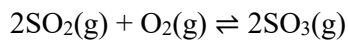
Теориски проблеми: _____

Замислен експеримент: _____

Вкупно поени: _____

Прегледал (Име и презиме)

1. In a large industrial factory, engineers are working on optimizing the production of sulfuric acid, one of the most important chemicals in the world. A key step in this process (known as the contact process) is the conversion of sulfur dioxide into sulfur trioxide, and the reaction is carried out at a temperature of 1100 K.



In the reactor, temperature and pressure are carefully controlled, since even small changes can significantly affect the yield.

- A. In a closed reaction vessel with a volume of 2.00 dm³, 0.120 mol of SO₂ and 0.120 mol of O₂ are introduced. The system is heated to 1100 K and allowed to reach equilibrium. After equilibrium is established, the amount of SO₃(g) in the reactor is 0.060 mol.

- i. Write the expression for calculating the equilibrium constant (K_c) for the reaction described by the equation given above.

Solution:

(1)

- ii. Calculate the concentration of O₂(g) after equilibrium has been established.

Solution:

(3)



THEORETICAL PROBLEMS

iii. Calculate the equilibrium constant, K_c , for the reaction of formation of $\text{SO}_3(\text{g})$ at 1100 K.

Solution:

(3)

B. The standard enthalpies of formation, $\Delta_f H^\ominus$ are -297 kJ/mol for $\text{SO}_2(\text{g})$ and -395 kJ/mol for $\text{SO}_3(\text{g})$.

i. Calculate the reaction enthalpy ($\Delta_r H$) for the reaction in which 2 mol of $\text{SO}_2(\text{g})$ are converted into 2 mol of $\text{SO}_3(\text{g})$.

Solution:

(2)

ii. Determine whether the reaction is exothermic or endothermic.

(0.5)

C. In which state of matter is sulfur trioxide at room temperature (around $25 \text{ }^\circ\text{C}$)?

(0.5)

D. Explain the steps for producing sulfuric acid from sulfide ore (pyrite, FeS_2) or sulfur. Is a catalyst required in any step? (If yes, state in which step).

(2.5)

E. List **three** uses (application) of sulfuric acid.

(1.5)

2. The iron content in a sample of tablets used as a dietary supplement is determined by means of an oxidation–reduction titration.

According to the manufacturer's declaration, each tablet contains 320 mg of iron(II) sulfate. To verify the declared value, a student weighed the mass of 5 tablets (10.2567 g) and then crushed the tablets in order to obtain as homogeneous a sample as possible.

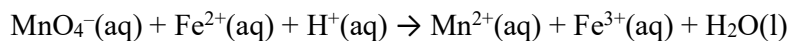
From the homogenized sample, 1.0568 g was accurately weighed and quantitatively transferred into an Erlenmeyer flask. A certain amount of sulfuric acid was added in order to dissolve the tablet. The mixture was then filtered, and the filtrate was collected in a 100.0 cm^3 volumetric flask, which was subsequently filled up to the mark with distilled water.

Afterwards, using a volumetric pipette, 20.00 cm^3 of the solution containing iron was transferred into an Erlenmeyer flask, sulfuric acid was added (the titration takes place in a strongly acidic medium), and titration was carried out with a standard KMnO_4 solution with a concentration of 0.00175 mol/dm^3 , until the appearance of a pale pink coloration, which indicated that the analyte (Fe^{2+} solution) and the titrant (KMnO_4 solution) had reacted in stoichiometric proportions (the moment known as the equivalence point). To reach the equivalence point, 25.50 cm^3 of the KMnO_4 solution was consumed.



THEORETICAL PROBLEMS

The reaction between the analyte and the titrant in acidic medium can be represented by the following equation:



A. Balance the redox equation using the redox scheme method.

(2)

B. Underline the correct term:

Fe^{2+} is an oxidizing agent/reducing agent, and the process of electron loss is oxidation/reduction.

(1)

C. Calculate the mass of FeSO_4 ($M = 151.91 \text{ g/mol}$) in the sample. Express the result as mass in mg (FeSO_4) / 1 tablet and compare the obtained value with the declared value of 320 mg. $M(\text{FeSO}_4) = 151.91 \text{ g/mol}$, $M(\text{Fe}) = 55.85 \text{ g/mol}$.

Solution:

(4)

3. In acid–base reactions, depending on their strength, concentration, and stoichiometric ratio, solutions with different pH values can be obtained. These reactions are often accompanied by a change in pH and the release of heat.

In the food and pharmaceutical industries, during salt production, knowing the enthalpy change during a reaction is crucial for selecting an appropriate type of reactor, controlling temperature, preventing overheating, and ensuring process safety. To determine the most suitable type of reactor for the production of potassium chloride (KCl) by a neutralization process, a calorimetric experiment was carried out in a polystyrene cup (which can be considered a calorimeter with negligible heat capacity).

In the cup, 100.0 cm³ of KOH solution with a concentration of 1.00 mol/dm³ is placed (initial temperature of the solution is 19.7 °C). Then, 120.0 cm³ of HCl solution with a concentration of 1.00 mol/dm³ is added (at the same initial temperature of 19.7 °C). The acid is added in a slight excess to ensure complete reaction of the base. After rapid mixing, the maximum temperature of the mixture reaches 25.9 °C.

Considering that these are dilute solutions, assume that the density of the initial solutions and the reaction mixture is 1.00 g/cm³, and that the specific heat capacity of the mixture is 4.18 J g⁻¹ °C⁻¹ (the same as for pure water).

- A. Calculate the amount of heat released during the neutralization reaction.

Solution:

(2)

- B. Write the reaction equation and calculate the enthalpy ($\Delta_n H$) на неутрализација. of neutralization. In the calculation, only the heat capacity of the solution should be considered (the heat capacities of the cup and thermometer should be neglected).

Solution:



THEORETICAL PROBLEMS

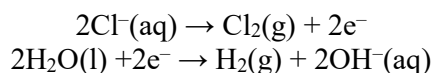
(4)

- C. If in the same experiment a weak acid (e.g., CH₃COOH) is used instead of a strong acid (HCl) with the same concentration and volume, is the temperature change (ΔT) expected to be **greater, smaller, or the same**? Explain the answer.

(2)

4. In a small pilot plant for alkali production, engineers are testing a new process for obtaining basic solutions by electrolysis. Instead of pure NaCl, a cheaper raw material is used: technical salt containing a mixture of NaCl and KCl with mass fractions of 70% NaCl and 30% KCl.

To carry out the experiment, an analyst prepared 500.0 cm³ of solution by dissolving 5.85 g of the mixture in distilled water. The resulting solution was then subjected to electrolysis, during which the following half-reactions occur:



- A. At which electrode (cathode or anode) is Cl₂ released, and at which is OH⁻ formed?

(1)

- B. Write the equation that describes the overall reaction occurring during the electrolysis process.

(1)



THEORETICAL PROBLEMS

- C. Calculate the amounts of NaCl ($M = 58.5 \text{ g/mol}$) and KCl ($M = 74.5 \text{ g/mol}$) in the initial solution, as well as the total amount of Cl^- ions.

Solution:

(4)

- D. Calculate the amount of OH^- formed during electrolysis and determine the pH of the resulting solution.

Solution:

(3)

- E. Predict what the pH value of a solution obtained by mixing **equimolar amounts** (i.e., exact stoichiometric ratio) of the following pairs will be (answer with > 7 , $= 7$, or < 7):

- i. NaOH and CH_3COOH , pH _____ 7
ii. KOH and HBr, pH _____ 7
iii. NH_4OH and HCl, pH _____ 7
iv. $\text{Ba}(\text{OH})_2$ and HCl, pH _____ 7

(4×0.5=2)



THOUGHT EXPERIMENT

“FROM THE REACTIVITY SERIES TO CORROSION PROTECTION”

A group of students has the task of determining the relative reactivity of several metals and proposing a method for protecting iron from corrosion.

In the laboratory, the properties of the metals Mg, Zn, Pb, and Cu are being investigated. The students carry out the following experiments:

Experiment	Metal	Salt solution	Observations
I	Zn	copper(II) sulfate	Brown deposit formed and the blue colour of the solutions fades
II	Zn	lead(II) nitrate	Grey crystals formed on the piece of zinc
III	Cu	lead(II) nitrate	No reaction
IV	Zn	magnesium nitrate	No reaction

A. Write the ionic equation for the reaction occurring in experiment I. Which metal/ion is oxidized, and which is reduced?

(1.5)

B. What does the appearance of a metallic layer in experiments I and II mean? Write the half-reactions that describe this process.

(1.5)

C. What can be concluded from experiment III about the reactivity of Cu and Pb? Which is the stronger reducing agent?

(1)



THOUGHT EXPERIMENT

D. Arrange the metals from most reactive (strongest reducing agent) to least reactive.

_____ > _____ > _____ > _____

(2)

E. The students want to construct a galvanic cell using Zn and Cu.

i. Which metal will be the anode?

ii. Which metal will be the cathode?

iii. In which direction will the electrons flow?

(1.5)

F. An iron (Fe) construction needs to be protected from corrosion.

i. Which metal should be chosen for protection: Mg, Zn, or Cu, and why?

	(1)
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ii. Will iron act as the cathode or the anode?

(0.5)

iii. How does the corrosion protection of iron using Zn differ from using Cr?

	(1)
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END OF THE TEST