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)

____

THEORETICAL PROBLEMS

Write down the solution procedure and the answer in the space provided for that purpose!
Solutions written outside the designated space will not be graded!
A Periodic table of the elements is given on the last page of the test!

1. Bromine and its isotopes

Bromine occurs in nature as a mixture of two stable isotopes:

1. ^{79}**Br** with an exact mass of **78,92 u**
2. ^{81}**Br** with an exact mass of **80,92 u**

1A. If the relative atomic mass of bromine given in the periodic system is 79.90, calculate the molar fraction of each of the isotopes.

5 pt.

1B. Do the isotopes ^{79}Br and ^{81}Br have different chemical properties? 1+1 pt.

YES NO
Explanation:

____

____

1C. How many different types of Br_2 molecules exist with regards to the isotopic composition? ______

What are their molecular masses (use the integer values 79 u and 81 u)?

____

What is the probability (in percent) for the occurrence of each of those molecules in nature? Predict approximately.

____

1+1+1 pt.

2. Analysis of a Carbonate Mixture

Hundreds of millions of years ago, what we see today as towering mountain ranges – like the Alps in Europe or our own Jakupica and Galičica – were the floors of warm, shallow oceans. Billions of marine organisms deposited their calcium shells, creating thick layers of limestone ($CaCO_3$).

However, at a certain point, seawater rich in magnesium began to circulate through these deposited layers. In a quiet chemical process called **dolomitization**, part of the calcium in the lattice was replaced by magnesium. Thus, the mineral **dolomite** was born – a natural mixture of $CaCO_3$ and $MgCO_3$.

While they may look like ordinary stone from a distance, the ratio of magnesium to calcium is very important for science and industry. For example, in agriculture: soils often become acidic due to artificial fertilizers or acid rain, and ground dolomite is used for soil neutralization.

- If the soil has a magnesium deficiency (which is at the heart of the chlorophyll molecule), dolomite with a high percentage of $MgCO_3$ is needed, and if only a pH correction is required, ordinary limestone is sufficient.

You have a sample of a mineral mixture containing only pure $MgCO_3$ and $CaCO_3$, and your task is to determine the composition of the mixture using two different approaches on two separate samples of the same material.

METHOD A: Thermal Analysis (Gravimetry)
You take a first sample of the mixture with a mass of **10.00 g**. You place it in a porcelain crucible and heat it in a muffle furnace at 900 °C until constant mass. The mass of the residue after heating to solid oxides is **5.12 g**.

METHOD B: Reaction with Acid (Gasometry)
You take a second sample of the same mixture, also with a mass of **10.00 g**. You add an excess of concentrated hydrochloric acid (HCl) to this sample and collect the released gas in a eudiometer (a special vessel for collecting gases).

Tasks:

2.1. Chemical equations **1 pt.**

Write the balanced chemical equations for:

- The thermal decomposition of both carbonates.
- The reaction of both carbonates with HCl.

2.2. Calculation of the Composition (from Method A) **7 pt.**

Calculate the mass of $MgCO_3$ and $CaCO_3$ in 10 g of the mixture. Set up a system of equations where x is the mass of $MgCO_3$, and y is the mass of $CaCO_3$.
Help: First equation: total mass of the mixture ($x + y = 10.00$). Second equation: total mass of the solid residue.

2.3. Prediction (for Method B) **2 pt.**

Based on the masses (x and y) that you obtained in the previous step, calculate what volume of gas (in dm^3) should theoretically be measured in Method B. If you were unable to obtain a result in task 2.2, assume 5 g of $MgCO_3$ and 5 g of $CaCO_3$.

3. Biochemical Challenge: "The Green Heart of Photosynthesis"

Magnesium is a vital element for plants. It is not only the central atom in the chlorophyll molecule (enabling photosynthesis) but also serves as an activator for numerous enzymes and is found in ionic form within the cell sap. In this task, you need to determine what portion of this metal is "trapped" within the green pigment.

PART 1: Determining the Molecular Formula of the "Green Heart"

Upon analysis of pure chlorophyll *a*, the following mass fractions were obtained:

- C: 73,94 %
- H: 8,13 %
- Mg: 2,72 %
- N: 6,27 %
- O: 8,94 %

Task **3.1**: Determine the empirical formula of chlorophyll. Determine the true molecular formula using the information that its relative molecular mass is 893.5.

5 pt.

PART 2: Quantitative Analysis of a Spinach Leaf

Сега кога ја знаеш формулата, да го пресметаме количеството на магнезиум во реален примерок имајќи ги предвид следните експериментални податоци:

- A single fresh spinach leaf has a mass of 2.50 g.
- It has been measured that this spinach leaf contains 1.20 mg of total chlorophyll for every 1.00 g of fresh mass.
- Total Magnesium: Using a specific method (Atomic Absorption Spectroscopy), it was determined that the total amount of magnesium in the leaf (from all sources) is 1.60 mg.

Task **3.2**: Calculate the total mass of chlorophyll in this leaf with mass of 2,50 g. 1 pt.

Task **3.3**: Calculate the mass of magnesium (in mg) contained within the calculated mass of chlorophyll. 3 pt.

Task **3.4**: Calculate what percentage (%) of the total magnesium in the leaf (1.60 mg) belongs to the chlorophyll. 1 pt.

4. The Chemistry of the Deep Breath

When divers descend to great depths (over 60 meters), the pressure becomes so high that ordinary air is no longer safe. At high pressure, nitrogen acts as a narcotic ("deep-sea drunkenness"), and oxygen becomes toxic to the body. To solve this problem, chemists created **Trimix** – an artificial mixture where most of the nitrogen is replaced with **helium**, which is light, inert, and does not cause narcosis.

Laboratory Data: Composition of Gas Mixtures
The table below shows the volume fractions (φ) of the components in natural air and in the specially prepared mixture **Trimix 10/70**

Component	Normal Air (φ)	Trimix 10/70 (φ)	Molar mass (M)
Oxygen (O_2)	21%	10%	32,00 g/mol
Nitrogen (N_2)	78%	20%	28,01 g/mol
Helium (He)	0%	70%	4,00 g/mol
Argon (Ar)	1%	0%	39,95 g/mol

Based on the data from the table, respond to the following requirements:

4.1. Mole Fractions and Average Masses (1+1+1 pt.)

- Assuming that the gases behave ideally, calculate the **mole fractions (x_i)** for each gas in both mixtures.
- Calculate the **average molar mass (<M>)** for both the ordinary air and the Trimix mixture.
- How many times is the Trimix mixture "lighter" than ordinary air?

Enter the mole fractions into the table:

Component	Air (x)	Trimix 10/70 (x)
Oxygen (O_2)	______%	______%
Nitrogen (N_2)	______%	______%
Helium (He)	______%	______%
Argon (Ar)	______%	______%

4.2. Mass Analysis and Comparison (4+1 pt.)

- Calculate the **mass fractions (*w*/%)** of oxygen and nitrogen in both mixtures.
- **Comparison**: Although the volume fraction of nitrogen in Trimix is reduced nearly fourfold (from 78% to 20%), calculate by how much its **mass fraction** has been reduced.

4.3. Physiology of Pressure (1+1 pt.)

A diver is at a depth where the total pressure of the gas they are breathing is **10 bar**.

- Calculate the **partial pressure p_i** of oxygen in the Trimix mixture at this depth. Also, calculate it for a situation where the tank contains ordinary air.
- If the maximum allowable partial pressure for oxygen is **1.4 bar**, is the Trimix mixture safe? What would happen if the diver breathed ordinary air at this depth?

Help: Average molar mass: $\langle M \rangle = \Sigma(x_i \cdot M_i)$; **Partial pressure:** $p_i = x_i \cdot P_{total}$

5. Thought Experiment OR Imaginary Experiment
The Mystery of the Yellow Non-metal X and the Crystal of Metal M

Intrduction

In a school laboratory, several unlabeled substances have been found. Your task as a young chemist is to follow the path of the reactions of a non-metal, identify the most abundant metal in the Earth's crust, and finally determine the precise molecular formula of the resulting crystal.

PART I: Qualitative Analysis

Follow the described transformations and identify the substances:

1. **Combustion**: A solid non-metal with a characteristic yellow color (**substance X**) is ignited. It burns with a blue flame and releases a colorless gas (**substance Y**) with a sharp odor of a burnt matchstick.
2. **Catalysis**: In the presence of a catalyst (V_2O_5), the gas **Y** reacts with additional oxygen and converts into **substance Z**.
3. **Hydration**: Substance **Z** is carefully dissolved in water, yielding a strong, diprotic inorganic acid (**substance A**). This acid is sometimes called the "mother of all chemicals".
4. **Reaction with Metal**: The solution of acid **A** reacts with metal **M** (the most abundant metal in the Earth's crust). In this reaction, a flammable gas **G** is released, and a solution of salt **S** is formed.
5. **Confirmation**: When a solution of barium chloride is added to the solution of salt **S**, a thick, white precipitate forms which does not dissolve in nitric acid.

PART II: Quantitative Analysis

Based on the data from PART I, solve the following tasks:

Task A: Volume of Gas G

It is known that in the series of reactions described in PART I, every mole of the starting element **X** theoretically yields exactly one mole of gas **G**. By applying the formulas for the amount of substance and molar volume, calculate the volume of gas **G** (in **dm^3**) that would be released under standard conditions if exactly **3.21 g** of pure element **X** are burned at the start.

Task B: Formula of the Hydrated Salt

By carefully evaporating the solution of salt **S**, you obtain pure crystals which are a hydrated salt (crystal hydrate). To discover its exact formula, you perform a thermal analysis:

1. You take a sample of the hydrated salt **S** with a mass of **33.33 g**.
2. You heat it until all the chemically bound water has evaporated.
3. The mass of the remaining "dry" (anhydrous) salt is **17.11 g**.

Requirements (record these on the following 2 pages):

5.1. Discover the identity of: **X, Y, Z, A, M, S**, and **G**.

5.2. Write all the balanced chemical equations for the processes in PART I.

5.3. Calculate the volume of gas **G**.

5.4. Determine the formula of the hydrated salt.

Answers:

PART I.

5.1. Write the chemical symbols of the corresponding elements and the formulas of the compounds. (7x0.3=2.1 pt.)

X	**Y**	**Z**	**A**	**M**	**S**	**G**

5.2. Write the equations of the chemical reactions: (5x0.6=3.0 pt.)

1	
2	
3	
4	
5	

PART II.

5.3

V = ________ **dm³**

(2,5 pt.)

5.4

Formula: ________________________

(2,5 pt.)

PERIODIC TABLE OF THE ELEMENTS

1 **H** 1.008																	2 **He** 4.003
3 **Li** 6.941	4 **Be** 9.012											5 **B** 10.81	6 **C** 12.01	7 **N** 14.01	8 **O** 16.00	9 **F** 19.00	10 **Ne** 20.18
11 **Na** 22.99	12 **Mg** 24.31											13 **Al** 26.98	14 **Si** 28.09	15 **P** 30.97	16 **S** 32.07	17 **Cl** 35.45	18 **Ar** 39.95
19 **K** 39.10	20 **Ca** 40.08	21 **Sc** 44.96	22 **Ti** 47.88	23 **V** 50.94	24 **Cr** 52.00	25 **Mn** 54.94	26 **Fe** 55.85	27 **Co** 58.93	28 **Ni** 58.69	29 **Cu** 63.55	30 **Zn** 65.39	31 **Ga** 69.72	32 **Ge** 72.61	33 **As** 74.92	34 **Se** 78.96	35 **Br** 79.90	36 **Kr** 83.80
37 **Rb** 85.47	38 **Sr** 87.62	39 **Y** 88.91	40 **Zr** 91.22	41 **Nb** 92.91	42 **Mo** 95.94	43 **Tc** (98)	44 **Ru** 101.1	45 **Rh** 102.9	46 **Pd** 106.4	47 **Ag** 107.9	48 **Cd** 112.4	49 **In** 114.8	50 **Sn** 118.7	51 **Sb** 121.8	52 **Te** 127.6	53 **I** 126.9	54 **Xe** 131.3
55 **Cs** 132.9	56 **Ba** 137.3	57 **La** 138.9	72 **Hf** 178.5	73 **Ta** 181.0	74 **W** 183.8	75 **Re** 186.2	76 **Os** 190.2	77 **Ir** 192.2	78 **Pt** 195.1	79 **Au** 197.0	80 **Hg** 200.6	81 **Tl** 204.4	82 **Pb** 207.2	83 **Bi** 209.0	84 **Po** (209)	85 **At** (210)	86 **Rn** (222)
87 **Fr** (223)	88 **Ra** 226.0	89 **Ac** 227.0	104 **Rf** (261)	105 **Db** (262)	106 **Sg** (263)	107 **Bh** (262)	108 **Hs** (265)	109 **Mt** (266)	110 **Ds** (281)	111 **Uuu** (272)	112 **Uub** (285)	113 **Uut** (284)	114 **Uuq** (289)	115 **Uup** (288)			

58 **Ce** 140.1	59 **Pr** 140.9	60 **Nd** 144.2	61 **Pm** (145)	62 **Sm** 150.4	63 **Eu** 152.0	64 **Gd** 157.3	65 **Tb** 158.9	66 **Dy** 162.5	67 **Ho** 164.9	68 **Er** 167.3	69 **Tm** 168.9	70 **Yb** 173.0	71 **Lu** 175.0
90 **Th** 232.0	91 **Pa** 231.0	92 **U** 238.0	93 **Np** (237)	94 **Pu** (244)	95 **Am** (243)	96 **Cm** (247)	97 **Bk** (247)	98 **Cf** (251)	99 **Es** (252)	100 **Fm** (257)	101 **Md** (258)	102 **No** (259)	103 **Lr** (262)