NATIONAL CHEMISTRY OLYMPIAD 2026
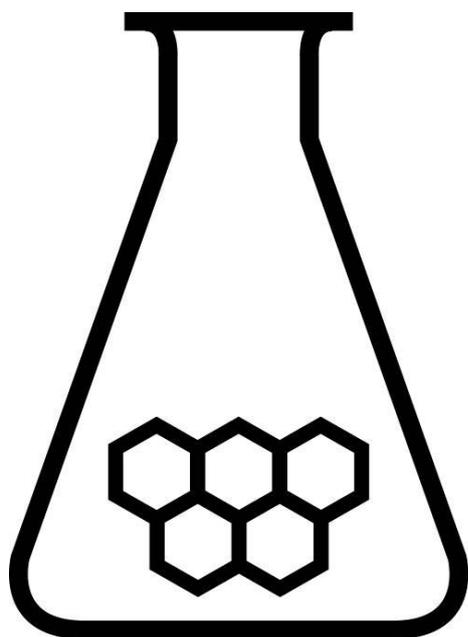
MARKING SCHEME PRELIMINARY ROUND 1

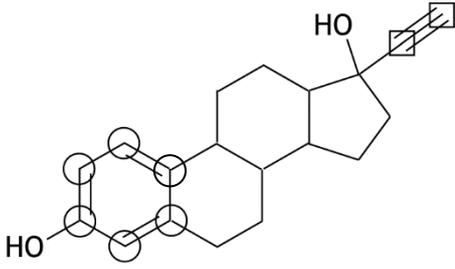### To be held between 12th and 30th January 2026

- This preliminary round consists of 25 multiple choice questions divided over 9 topics, and 2 problems with a total of 8 open questions, in addition to an answer sheet for the multiple choice questions.
- Use the answer sheet to answer the multiple choice questions.
- For the open questions, use a separate answer sheet for each of the two problems. Remember to include your name on each sheet.
- The maximum score for this paper is 73 points.
- The preliminary round lasts two hours in total.
- Required materials: (graphic) calculator and BINAS 7th edition, ScienceData 1st edition or BINAS 5th edition, English version. "Green chemistry" table is included.
- The total number of points available for each question is stated.
- Unless otherwise stated, standard conditions apply: T = 298 K and p = p_0.

▌Problem 1 Multiple choice questions   (total 50 points)

For every correct answer: 2 points

Brief summary

nr.	answer
1	D
2	D
3	D
4	D
5	A
6	C
7	C
8	E
9	D
10	C
11	D
12	B
13	A
14	C
15	E
16	D
17	C
18	B
19	D
20	B
21	A
22	A
23	D
24	C
25	D

		Carbon Chemistry
1	D	All products are shown below. The C atoms indicated with * are asymmetrical. These compounds have two stereo isomers.
2	D	
3	D	See below.
4	D	The repeating unit is $C_6H_{10}O_5$ with a molar mass of $162.14 \text{ g mol}^{-1}$.

degree of polymerization $= \dfrac{3.29 \cdot 10^5 - 18.015}{162.14} = 2.03 \cdot 10^3$

		Thermochemistry
5	A	The energy level of the product is lower than that of the reactants. The reaction is therefore exothermic.
		A catalyst only lowers the energy level of the activated state.

		## Reaction rate and equilibrium
6	C	For the reaction to the right, the heat of reaction is: I: $(2 \times -0.332 \cdot 10^5) + 0.111 \cdot 10^5 = -0.553 \cdot 10^5$ J per 2 mol NO_2 II: $0 + (2 \times 1.43 \cdot 10^5) = 2.86 \cdot 10^5$ J per 3 mol O_2 With an increase in temperature the endothermic reaction is temporarily favoured. Reaction I shifts to the left and reaction II shifts to the right.
7	C	$3.5 \cdot 10^{-4} \times \dfrac{3}{2} = 5.3 \cdot 10^{-4}$ mol s^{-1}
8	E	When the volume increases, the reaction shifts toward the side with the most gas particles. In this case, that is to the right. For this equilibrium, $[CO_2] = K$ applies. Therefore the concentration of CO_2 remains constant.
		## Structures and formulae
9	D	The ions present are Na^+, Mg^{2+} and SO_4^{2-}. With the molar ratio 2 : 2 : 3 of these ions, the total charge is zero and the molar ratio Na^+ : Mg^{2+} is equal to 1 : 1.
10	C	 Can also be calculated: $4 + 3 \times 1 + 5 + 2 \times 6 = 24$ valence electrons, therefore 12 electron pairs. $\dfrac{4 \times 8 + 3 \times 2 - 24}{2} = 7$ bonding electron pairs. So $12 - 7 = 5$ lone pairs.
11	D	

12	B	
		coordination number 2: ☐
		coordination number 3: ○

pH and acid-base

13	A	HClO + H₂O ⇌ ClO⁻ + H₃O⁺

$$[H_3O]^+ = K_a \times \frac{\text{number of moles of HClO}}{\text{number of moles of ClO}^-} = K_a \times \frac{\text{number of moles of HClO}}{\text{number of moles of NaClO}}$$

$$10^{-7.83} = 10^{-7.40} \times \frac{\text{number of moles of HClO}}{\text{number of moles of NaClO}}$$

$$\frac{\text{number of moles of HClO}}{\text{number of moles of NaClO}} = \frac{10^{-7.83}}{10^{-7.40}}$$

$$\frac{\text{number of grams of HClO}}{\text{number of grams of NaClO}} = \frac{10^{-7.83} \times 52.46}{10^{-7.40} \times 74.44} = \frac{1.0}{3.8}$$

14	C	The formation of H_3O^+ causes the pH to decrease. They are all weak acids, and HIO_3 has the highest K_a value. HIO_3 is the strongest weak acid, and the smallest number of moles of this acid is needed to achieve a pH of 2.5.

15	E	HZ + H₂O ⇌ H₃O⁺ + Z⁻

If in a 0.1200 M HZ solution 2.3% of the acid is ionized, then
[Z⁻]equilibrium = 0.023 × 0.1200 = 0.00276 M.

	[HZ]	[Z⁻]	[H₃O⁺]
initial	0.1200	0	0
change	− 0.00276	+ 0.00276	+ 0.00276
equilibrium	0.1172	0.00276	0.00276

$$K_a = \frac{0.00276 \times 0.00276}{0.1172} = 6.5 \cdot 10^{-5}$$

Redox and electrochemistry

16	D	NO₃⁻ + 4 H⁺ + 3 e⁻ → NO + 2 H₂O (×2)
		Cu → Cu²⁺ + 2 e⁻ (×3) +
		3 Cu + 8 H⁺ + 2 NO₃⁻ → 3 Cu²⁺ + 2 NO + 4 H₂O

17	C	$Zn^{2+} + 2\,e^- \rightarrow Zn$
		$\dfrac{5.0}{65.38} = 0.0765$ mol Zn
		$2 \times 0.0765 = 0.153$ mol e^-
		$0.153 \times 96485 = 14758$ C
		$\dfrac{14758}{3.5} = 4.2 \cdot 10^3$ s

Analysis

18	B	When a barium nitrate solution is added to a sodium sulfite solution, a cloudy mixture forms because barium sulfite is a poorly soluble salt.
		When a barium nitrate solution is added to a potassium ethanoate solution, a clear mixture is formed.
19	D	Fragmentation of the Br_2 molecules produces Br^+ ions with $m/z = 79$ and $m/z = 81$.
		There are also three molecular ion peaks with $m/z = 158$, $m/z = 160$ and $m/z = 162$.
20	B	$25.00 \times 0.100 = 0.250$ mmol Ag^+ is added.
		Of this, $0.250 - 7.69 \times 0.0108 = 0.167$ mmol has reacted, with an equal amount of theobromine.
		Therefore, the mass percentage of theobromine is:
		$\dfrac{0.167 \cdot 10^{-3} \times 180.2}{2.95} \times 100\% = 1.02\%$.

Calculations

21	A	CO_2 and H_2O both have the same molar volume, so the molar ratio $CO_2 : H_2O$ is equal to the volume ratio and is therefore 8 : 12.
		The ratio C : H is then 8 : 24 = 1 : 3 as in C_2H_6.
22	A	$\dfrac{47.0}{63.55} = 0.7396$ mol Cu
		That comes from $\dfrac{0.7396}{2} = 0.3698$ mol malachite.
		That is $0.3698 \times 221.1 = 81.76$ g malachite.
		The mass percentage malachite in the ore sample is $\dfrac{81.76}{1000} \times 100\% = 8.18\%$.
23	D	1.00 L 0.100 M $CuSO_4$ solution contains 0.100 mol $CuSO_4$.
		$\dfrac{0.100}{0.327} \times 1000 = 306$ mL
24	C	$\dfrac{486}{108.02} = 4.50$ mol N_2O_5.
		That is equal to $4.50 \times 2 \times 6.02 \cdot 10^{23} = 5.42 \cdot 10^{24}$ nitrogen atoms.

		Green chemistry
25	**D**	For the *E*-factor the following applies: $$E\text{-factor} = \frac{m_{\text{reactants}} - m_{\text{actual yield product}}}{m_{\text{actual yield product}}}$$ With a higher yield, the $m_{\text{actual yield product}}$ is higher, and with a higher atom economy, the $m_{\text{actual yield product}}$ is also higher. Both result in a lower *E*-factor.

Open questions (total 23 points)

▌Problem 2 Pilsner (9 points)

☐1 **Maximum score 2**

CO_2 in solution is acidic / forms H_2CO_3. This acid causes the amount of sodium hydroxide / base needed to reach the endpoint to be higher. This leads to the conclusion that the amount of acid is greater than it actually is, and therefore to a value that is too high for the total amount of organic acids present.

· CO_2 / H_2CO_3 reacts with OH^- 1
· consistent conclusion 1

☐2 **Maximum score 2**

An example of a correct calculation is:

$$\frac{0.433 \times 2 + 0.545 + 1.099 + 0.466 + 0.562 \times 3 + 0.415 \times 2 + 0.362 \times 2}{3.882} = 1.601$$

· correct processing of the number of acidic groups per molecule 1
· remainder of the derivation 1

☐3 **Maximum score 5**

An example of a correct calculation is:

$$3.14 \times 0.0560 \times \frac{330}{25.00} - 3.882 \times 1.601 \times \frac{330}{1000} = 0.27 \ (mmol)$$

or in steps:

3.14 mL 0.056 M caustic soda contains $3.14 \times 0.0560 = 0.176$ mmol OH^-.
This reacts with 0.176 mmol COOH groups in 25.00 mL CO_2-free pilsner.

A bottle of pilsner contains a total of $3.14 \times 0.0560 \times \frac{330}{25.00} = 2.32$ mmol COOH groups.

Per litre of pilsner 3.882 mmol of the organic acids listed in Table 1 are present.
These react with $3.882 \times 1.601 = 6.215$ mmol OH^-.
This means that per litre pilsner 6.215 mmol COOH groups originate from the organic acids listed in Table 1.

A bottle of pilsner contains $3.882 \times 1.601 \times \frac{330}{1000} = 2.05$ mmol COOH groups originating from the organic acids listed in Table 1.
The number of extra COOH groups per bottle of the examined pilsner is

$$3.14 \times 0.0560 \times \frac{330}{25.00} - 3.882 \times 1.601 \times \frac{330}{1000} = 0.27 \ mmol.$$

· calculation of the number of (m)moles of used OH^- 1
· conversion to the total number of (m)moles of COOH groups per bottle of the pilsner examined 1
· calculation of the number of (m)moles of COOH groups originating from the organic acids listed in Table 1 per litre of the pilsner examined 1
· conversion to the number of (m)moles of COOH groups originating from the organic acids listed in Table 1 in the examined bottle of pilsner 1
· calculation of the number of extra mmoles of COOH groups per bottle of the examined pilsner 1

▌Problem 3 Disaster in Beirut (14 points)

□4 **Maximum score 2**

$H_3O^+ + NH_3 \rightarrow NH_4^+ + H_2O$
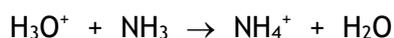
To obtain ammonium nitrate, the water can be removed by evaporation.

· acid-base reaction	1
· evaporation	1

Notes

- *If the acid-base reaction* $H^+ + NH_3 \rightarrow NH_4^+$ *is given, award full marks.*
- *If distillation or crystallisation is given as the separation technique, award full marks.*

□5 **Maximum score 2**

Ionic bonds (between the NH_4^+ and NO_3^- ions) and covalent bonds (between the atoms within the ions).

· ionic bonds	1
· covalent bonds	1

□6 **Maximum score 4**

An example of a correct calculation is:

2750 tonnes NH_4NO_3 would correspond to $\dfrac{2750 \cdot 10^6}{80.043} = 3.436 \cdot 10^7$ mol NH_4NO_3.

This produces $\dfrac{3.436 \cdot 10^7 \times 7}{2} = 1.202 \cdot 10^8$ mol gas.

This has a volume of $\dfrac{1.202 \cdot 10^8 \times 82.1}{1000} = 9.87 \cdot 10^6$ m^3.

· calculation of the number of moles of NH_4NO_3	1
· calculation of the number of moles of gas	1
· conversion to the number of m^3 of gas	1
· significant figures	1

□7 **Maximum score 3**
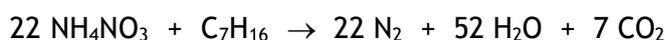
An example of a correct calculation is:
$\Delta E = 4 \times E_v(H_2O(g)) - 2 \times E_v(NH_4NO_3) = 4 \times -2.42 \cdot 10^5 - 2 \times (-3.66 \cdot 10^5) = -2.36 \cdot 10^5$ J per 2 mol NH_4NO_3

This corresponds to $\dfrac{-2,36 \cdot 10^5}{2} = -1.18 \cdot 10^5$ J mol^{-1}.

· absolute values of the enthalpies of formation of all substances	1
· use of coefficients	1
· remainder of the calculation	1

□8 **Maximum score 3**

$22\ NH_4NO_3 + C_7H_{16} \rightarrow 22\ N_2 + 52\ H_2O + 7\ CO_2$

· correct substances before and after the arrow	1
· H and N correctly balanced using only correct formulas before and after the arrow	1
· C and O correctly balanced using only correct formulas before and after the arrow	1