46th National Chemistry Olympiad

Symeres, Nijmegen

PRACTICAL TEST

Marking scheme

Thursday June 5 2025

Experiment 1 The cracking of PET 40 points

Maximum score 10

The following practical skills will be assessed:

- safety, working cleanly and independence
- handling of the glassware

Maximum score 5

Assessment of terephthalic acid yield:

The score for yield is determined by comparing the yield (calculated by the organization) with the yield of an experiment performed by the organization.

Maximum score 5

Assessment of terephthalic acid purity:

The purity of the product is determined using an NMR spectrum, possibly in combination with a Karl-Fischer determination.

The score is determined by comparing the measured purity with the purity of the product obtained in an experiment performed by the organization.

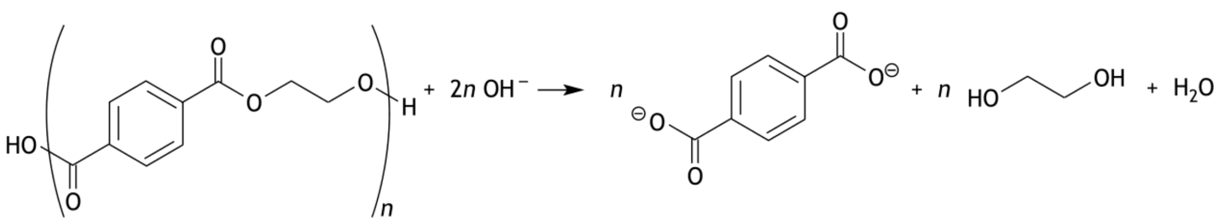
□1 Maximum score 3

- numerical values of the masses noted 1
- accuracy of the numerical values in accordance with the accuracy of the balance used 1
- correct units noted 1

□2 Maximum score 1

□3 Maximum score 6

A correct answer can be expressed as follows:



- structure of PET and OH^- before the arrow 1
- structure of the terephthalate ion after the arrow 1
- structure of ethane-1,2-diol after the arrow 1
- H_2O after the arrow 1
- correct coefficients 2

If in an otherwise correct answer the coefficient 2 is used for OH^- and no coefficients are given after the arrow 5

▫4 Maximum score 5

An example of a correct answer is:

The repeating unit of PET is $C_{10}H_8O_4$. Its molar mass is 192.16 (g mol^{-1}).

Suppose 1000 mg of PET has been weighed, this is equal to $\frac{1000}{192.6} = 5.20$ mmol repeating units.

Therefore $2 \times \frac{1000}{192.16} = 10.4$ mmoles of KOH are needed.

Added were $\frac{0.88 \times 1000}{56.106} = 16$ mmoles of KOH, (an excess).

- the repeating unit of PET is $C_{10}H_8O_4$ (may be implicit from the correct molar mass) 1
- correct molar mass of the repeating unit of PET: 192.16 (g mol^{-1}) 1
- calculation of the number of mmoles of repeating unit in the number of mg of weighed PET 1
- calculation of the number of mmoles of KOH required for the complete conversion of PET 1
- calculation of the number of mmoles of KOH added (and conclusion) 1

▫5 Maximum score 5.

An example of a correct calculation is :

(This example assumes m g PET and a yield of p g terephthalic acid.)

p g terephthalic acid is $\frac{p}{166.13}$ mol.

Therefore, there were (on average) $\frac{p}{166.13}$ moles of repeating units in the PET molecules. That is $\frac{p}{166.13} \times 192.16$ g.

The mass percentage is therefore $\frac{\frac{p}{166.13} \times 192.16}{m} \times 100\,\%$.

- calculation of the molar mass of terephthalic acid 1
- calculation of the number of moles of terephthalic acid formed 1
- notion that the average number of moles of repeating units in the PET molecules is equal to the number of moles of terephthalic acid formed 1
- calculation of the number of grams of PET in the examined piece of PET 1
- calculation of the mass percentage 1

Note:
When the same incorrect value has been used in question 4 and question 5 for the molar mass of the PET repeating unit, do not penalize this in question 5.

Experiment 2 The determination of the amount of sodium perborate monohydrate in one sachet of Bikosan 40 points

Maximum score 10
The following practical skills are assessed:

- safety, working cleanly and independence
- handling of glassware

6 Maximum score 8

- the mass of the total contents of the Bikosan sachet and the mass of the Bikosan sample 1
- burette readings read to two decimal places 2
- difference between the duplicates of the titrations 5

The scores for the differences between the duplicates are determined per titration as follows:

If the difference in volume between the duplicates is ≤ 0.10 mL	5
If 0.10 mL < the difference in volume between the duplicates ≤ 0.20 mL	4
If 0.20 mL < the difference in volume between the duplicates ≤ 0.30 mL	3
If 0.30 mL < the difference in volume between the duplicates ≤ 0.50 mL	2
If 0.50 mL < the difference in volume between the duplicates ≤ 0.70 mL	1
If the difference in volume between the duplicates is > 0.70 mL	0

The final score is the average of the scores for both titrations.

7 Maximum score 14

If the average consumption of the titration with thiosulfate solution is V mL and the concentration of thiosulfate solution is c mol L^{-1}, then $V \times c$ mmoles of $S_2O_3^{2-}$ are added.

This corresponds to $\frac{V \times c}{2}$ mmol I_2.

Therefore 10.00 mL of the solution from the volumetric flask contained $\frac{V \times c}{2}$ mmol H_2O_2.

The Bikosan sample released $\frac{V \times c}{2} \times \frac{100.0}{10.00}$ mmol H_2O_2, and the Bikosan sample contained

$\frac{V \times c}{2} \times \frac{100.0}{10.00}$ mmol $NaBO_3.H_2O$.

This corresponds to $\frac{V \times c}{2} \times \frac{100.0}{10.00} \times 99.82$ mg $NaBO_3.H_2O$.

If the mass of the contents of the Bikosan sachet is m_1 g and the mass of the Bikosan sample is m_2 g, then the amount of $NaBO_3.H_2O$ in a Bikosan sachet is:

$$\frac{\frac{V \times c}{2} \times \frac{100.0}{10.00} \times 99.82 \times \frac{m_1}{m_2}}{1000} \text{ g.}$$

· calculation of the average consumption 2
· calculation of the number of mmoles of $S_2O_3^{2-}$ that reacted in the titrations 1
· conversion to the number of mmoles of H_2O_2 in the 10.00 mL solution (equals the number of mmoles of I_2 formed) 1
· conversion of the number of mmoles of H_2O_2 in the 10.00 mL solution to the total number of mmoles of H_2O_2 formed from the Bikosan sample 1
· calculation of the molar mass of $NaBO_3.H_2O$ (99.82 g mol^{-1}) 1
· conversion to the amount (in mg) of $NaBO_3.H_2O$. in the Bikosan sample 1
· conversion to the amount (in g) of $NaBO_3.H_2O$ in a Bikosan sachet 2
· result 5

The score for the result is determined by comparing the result (calculated by the organization) with the result of an experiment performed by the organization.

▫8 Maximum score 4

An example of a correct answer is:

$$4\,e^- + O_2 + 4\,H^+ \rightarrow 2\,H_2O \quad (\times 1)$$
$$2\,I^- \rightarrow I_2 + 2\,e^- \quad (\times 2)$$
$$O_2 + 4\,H^+ + 4\,I^- \rightarrow 2\,I_2 + 2\,H_2O$$

The reaction with oxygen produces extra iodine. More thiosulfate is therefore used, resulting in a too high value for *V*. The calculated amount of $NaBO_3.H_2O$ in a Bikosan sachet will be too high.

· in the total reaction equation O_2 and H^+ before the arrow and H_2O after the arrow 1
· in the total reaction equation I^- before the arrow and I_2 after the arrow and correct coefficients 1
· correct explanation that a too high value of *V* is used in the calculation 1
· consistent conclusion 1

▫9 Maximum score 4

A correct answer can be formulated as follows:
Hydrogen peroxide can also act as a reducing agent, and permanganate is a strong enough oxidizing agent (in an acidic environment) to react with it. Therefore, it is possible. You should then add the sulfuric acid solution to the (10.00 mL) Bikosan solution and titrate with the potassium permanganate solution.

· hydrogen peroxide can also react as a reducing agent 1
· permanganate (in an acidic environment) is a strong enough oxidizing agent to react with hydrogen peroxide (possibly with reference to the table of redox potentials from the data booklet) 1
· correct conclusion 1
· acidify the Bikosan solution and titrate with the potassium permanganate solution 1

If an answer is given such as: „It is not possible because two oxidizers cannot react with each other.” 1