



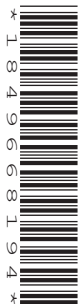
Oxford Cambridge and RSA

**Friday 20 June 2025 – Morning**

**A Level Chemistry B (Salters)**

**H433/03 Practical skills in chemistry**

**Time allowed: 1 hour 30 minutes**



**You must have:**

- the Practical Insert (inside this document)
- the Data Sheet for Chemistry B

**You can use:**

- a scientific or graphical calculator
- an HB pencil



Please write clearly in black ink. **Do not write in the barcodes.**

Centre number

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Candidate number

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First name(s)

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Last name

StemUp Model Solution

**INSTRUCTIONS**

- Use black ink. You can use an HB pencil, but only for graphs and diagrams.
- Write your answer to each question in the space provided. If you need extra space use the lined page at the end of this booklet. The question numbers must be clearly shown.
- Answer **all** the questions.
- Where appropriate, your answer should be supported with working. Marks might be given for using a correct method, even if your answer is wrong.

**INFORMATION**

- The total mark for this paper is **60**.
- The marks for each question are shown in brackets [ ].
- Quality of extended response will be assessed in questions marked with an asterisk (\*).
- This document has **16** pages.

**ADVICE**

- Read each question carefully before you start your answer.

- 1 This question is about the properties of some Group 2 alkaline earth metals and their compounds.

(a)

- (i) The term 'alkaline' refers to oxides and hydroxides of the Group 2 elements.

Explain why calcium oxide is described as alkaline.

Include an appropriate equation.

Explanation: *CaO reacts with (dissolves in) water to form hydroxide ions in solution,  $\text{OH}^-(\text{aq})$ , which make it alkaline.*

Equation:  *$\text{CaO}(\text{s}) + \text{H}_2\text{O}(\text{l}) \rightarrow \text{Ca}^{2+}(\text{aq}) + 2\text{OH}^-(\text{aq})$*

[2]

- (ii) Explain why the Group 2 elements are known as **s block** elements.

*Their outermost (highest energy) electrons are in an s sub-shell (s orbital):  $ns^2$ .*

[1]

- (b) Strontium sulfate is used in fireworks. Strontium gives a red colour when ignited.

A frequency of red light from the strontium spectrum is  $4.62 \times 10^{14}$  Hz.

Calculate the energy per mole of photons of this frequency in  $\text{kJ mol}^{-1}$ .

Give your answer to an **appropriate** number of significant figures.

$$E = hf = 6.63 \times 10^{-34} \times 4.62 \times 10^{14} = 3.063 \times 10^{-19} \text{ J per photon}$$

$$\text{per mole: } 3.063 \times 10^{-19} \times 6.02 \times 10^{23} = 1.844 \times 10^5 \text{ J mol}^{-1}$$

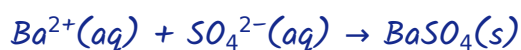
$$\div 1000 = 184.4 \text{ kJ mol}^{-1} = 184 \text{ kJ mol}^{-1} \text{ (3 s.f.)}$$

Energy = .....184.....  $\text{kJ mol}^{-1}$  [3]

- (c) Barium sulfate is very insoluble in water.
- (i) Solutions containing sulfate ions give a white precipitate with barium chloride solution.

Write an **ionic** equation for the formation of this white precipitate.

Include state symbols.



[1]

- (ii) A solution has  $[\text{SO}_4^{2-}] = 0.10 \text{ mol dm}^{-3}$ .

Calculate the smallest  $[\text{Ba}^{2+}]$  in the solution which will just give a white precipitate.

For barium sulfate,  $K_{\text{sp}} = 1.0 \times 10^{-10} \text{ mol}^2 \text{ dm}^{-6}$ .

$$K_{\text{sp}} = [\text{Ba}^{2+}][\text{SO}_4^{2-}]$$

$$[\text{Ba}^{2+}] = K_{\text{sp}} \div [\text{SO}_4^{2-}] = 1.0 \times 10^{-10} \div 0.10$$

$$[\text{Ba}^{2+}] = 1.0 \times 10^{-9} \text{ mol dm}^{-3}$$

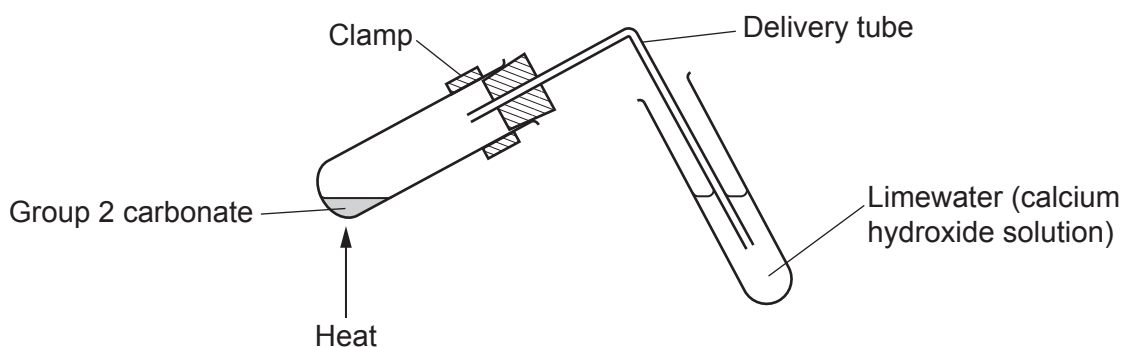
$$[\text{Ba}^{2+}] = \dots\dots\dots 1.0 \times 10^{-9} \dots\dots\dots \text{mol dm}^{-3} \quad [2]$$

- (d) Calcium and potassium are in the same period of the periodic table.

Explain why calcium has the higher melting point.

*Calcium forms  $\text{Ca}^{2+}$  ions and delocalises two electrons per atom, whereas  
potassium forms  $\text{K}^+$  ions and delocalises only one.  
The attraction between the  $2+$  ions and the delocalised electrons is stronger in  
calcium, so more energy is needed to break the metallic bonding.* [2]

- (e)\* A group of students use the apparatus below to show the trend in thermal stability of the Group 2 carbonates.



Describe how the students should use this apparatus **safely** to show the trend.

Describe the observations that the students should obtain and explain the theory behind these observations.

*Method: put one spatula of magnesium carbonate in the boiling tube, clamp it and dip the delivery tube into limewater. Heat gently at first, then more strongly, and time how long it takes for the limewater to go cloudy (milky). Repeat with the same amount of each of the other carbonates ( $\text{CaCO}_3$ ,  $\text{SrCO}_3$ ,  $\text{BaCO}_3$ ) using the same flame and fresh limewater each time.*

*Safety: before stopping heating, lift the delivery tube out of the limewater to prevent suck-back of cold limewater into the hot tube (which could crack it). Let the apparatus cool before dismantling it as it gets very hot.*

*Observations:  $\text{CO}_2$  is given off,  $\text{MCO}_3 \rightarrow \text{MO} + \text{CO}_2$ , which turns the limewater milky. The limewater goes milky most quickly with  $\text{MgCO}_3$  and takes longer and longer down the group;  $\text{BaCO}_3$  takes longest (may hardly change).*

*Explanation: the quicker the limewater goes cloudy, the less thermally stable the carbonate. Down the group the cation size increases (same 2+ charge), so the charge density falls. A small cation such as  $\text{Mg}^{2+}$  polarises (distorts) the* [6]

Extra answer space if required.

1(e) continued

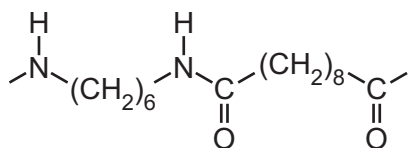
electron cloud of the carbonate ion more, weakening the C-O bonds, so the  
carbonate decomposes more easily. So thermal stability increases down Group 2.

2 This question is about two useful polymers, nylon and polystyrene.

(a) There are several different nylon structures.

One type of nylon can be made in the laboratory by the polymerisation reaction of the two monomers, 1,6-diaminohexane and 'sebacoyl chloride'.

The repeat unit of the nylon formed is shown:



nylon repeat unit

(i) Name the nylon shown in this repeat unit.

*Nylon-6,10 (polyamide 6,10)* ..... [1]

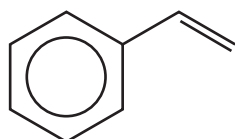
(ii) The monomer sebacoyl chloride is an acyl chloride.

Draw a **skeletal** formula for sebacoyl chloride.  
Use the nylon repeat unit above to help you.



[2]

(b) The monomer styrene is shown:



styrene

Styrene polymerises to polystyrene.

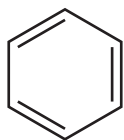
This type of polymerisation differs from the type of polymerisation that forms nylon.

Name the **types** of polymerisation that form polystyrene and nylon.

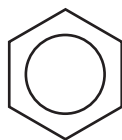
Explain how these types of polymerisation differ.

*Polystyrene forms by addition polymerisation; nylon forms by condensation polymerisation.*  
*In addition polymerisation the monomer is unsaturated (has a C=C) and the monomers just add together, so the polymer is the only product and its formula is a multiple of the monomer formula.*  
*In condensation polymerisation each time two monomers join a small molecule is also made (lost), here HCl.* ..... [4]

- (c) The aromatic ring in styrene can be represented by either of the two structures below.



structure A



structure B

- (i) Explain, in terms of bond lengths, why **structure A** is a **less** accurate representation than **structure B**.

Structure A suggests alternating short ( $C=C$ ) and longer ( $C-C$ ) bonds, so the bonds would differ in length.  
In the actual benzene ring all the  $C-C$  bond lengths are the same (between single and double). [2]

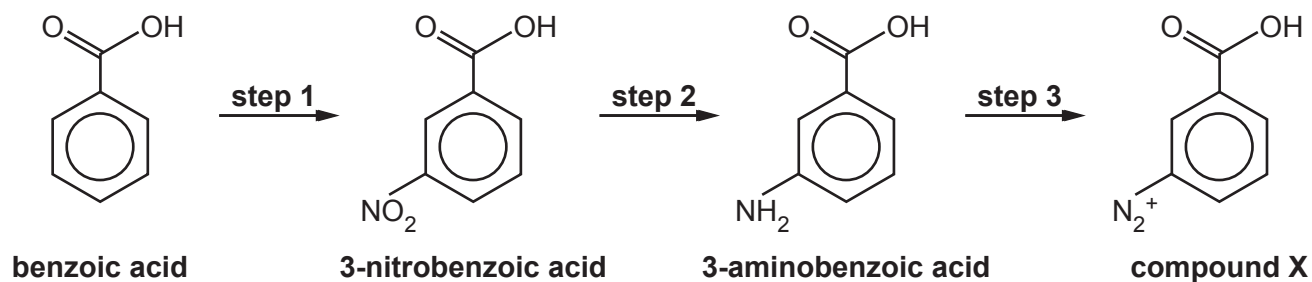
- (ii) The aromatic rings in styrene are stabilised by delocalisation.

Explain what **delocalisation** means.

Some electrons (the  $\pi$  electrons) are spread out (evenly) around the ring in a  $\pi$  molecular orbital, formed by sideways overlap of  $p$  orbitals, so they are not attached to (shared between) specific carbon atoms. [2]

(d) Styrene can be oxidised to benzoic acid.

Compound **X** can be made from benzoic acid as shown:



(i) Give the reagents for **steps 1, 2 and 3**.

(Use the Data Sheet if necessary.)

**step 1** *concentrated nitric acid and concentrated sulfuric acid (mixture)*.....

**step 2** *tin and concentrated hydrochloric acid (then NaOH)*.....

**step 3** *sodium nitrite ( $\text{NaNO}_2$ ) and dilute HCl, below 10 °C*.....

[3]

(ii) Name the functional group shown at the bottom left in compound **X**.

*Diazonium (ion)*..... [1]

(iii) Suggest a type of useful compound that can be made using compound **X**.

*An azo dye*..... [1]

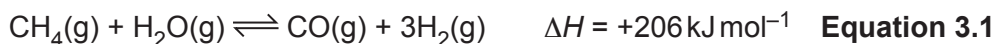
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**Turn over for the next question**

- 3 Methanol,  $\text{CH}_3\text{OH}$ , is produced by the chemical industry as a building block for many everyday products.

- (a) Methanol can be made industrially from methane by a two-step process.

The **first step** involves the steam reforming of the methane:



- (i) For the forward reaction in **Equation 3.1**,  $\Delta_{\text{sys}}S = +216 \text{ J mol}^{-1} \text{ K}^{-1}$ .

Explain how **Equation 3.1** shows that the value of  $\Delta_{\text{sys}}S$  will be positive.

*There are more moles of gas on the product side (4 mol) than the reactant side (2 mol).* [1]

- (ii) A student says that the forward reaction in **Equation 3.1** is feasible at all temperatures.

Comment on the student's statement, giving the correct chemistry where necessary.

*The student is incorrect. For a reaction to be feasible  $\Delta S_{\text{total}}$  must be positive.  
 $\Delta S_{\text{sur}} = -\Delta H \div T = -206\,000 \div T$ , which is negative. At low temperatures  $\Delta S_{\text{sur}}$  is more negative than  $\Delta S_{\text{sys}}$  (+216) is positive, so  $\Delta S_{\text{total}}$  is negative.  
 $\Delta S_{\text{total}} = 0$  when  $T = 206\,000 \div 216 = 953.7 \text{ K}$ , so it is only feasible above about 954 K (higher temperatures).* [3]

- (b) The **second step** in the manufacture of methanol involves the reaction:



The process operates at a pressure of 5 MPa and a temperature of 700 K in the presence of a copper-based catalyst.

- (i) A mixture containing 3.20 mol of carbon monoxide and 2.50 mol of hydrogen is allowed to reach equilibrium in a container of volume  $2.00 \text{ dm}^3$  under the above conditions. 0.488 mol of methanol is formed.

Calculate the value of the equilibrium constant,  $K_c$ , for **Equation 3.2** under these conditions.

Give the units.

$$\text{At equilibrium: } n(\text{CH}_3\text{OH}) = 0.488 \text{ mol, } n(\text{CO}) = 3.20 - 0.488 = 2.712 \text{ mol}$$

$$n(\text{H}_2) = 2.50 - (2 \times 0.488) = 1.524 \text{ mol}$$

$$[\text{CH}_3\text{OH}] = 0.488 \div 2.00 = 0.244 \quad [\text{CO}] = 2.712 \div 2.00 = 1.356$$

$$[\text{H}_2] = 1.524 \div 2.00 = 0.762 \text{ mol dm}^{-3}$$

$$K_c = [\text{CH}_3\text{OH}] \div ([\text{CO}][\text{H}_2]^2)$$

$$K_c = 0.244 \div (1.356 \times 0.762^2) = 0.244 \div 0.7874 = 0.310$$

$$\text{units: } \text{mol dm}^{-3} \div (\text{mol dm}^{-3})^3 = \text{dm}^6 \text{ mol}^{-2}$$

$$K_c = \dots 0.310 \dots \text{ units } \text{dm}^6 \text{ mol}^{-2} \dots [5]$$

- (ii) Explain, using **Equation 3.2**, why the equilibrium yield of methanol increases with increasing pressure, and suggest why an even higher pressure is **not** used.

There are fewer moles of gas on the right-hand side (1 mol) than on the left

(3 mol).

So increasing the pressure moves the position of equilibrium to the right, to

reduce the pressure, increasing the yield of methanol.

Even higher pressure is not used because of the cost of the energy and

equipment, and the increased risk of explosion (safety). [3]

Question 3(b)(iii) starts on Page 12

- (iii) A copper-based catalyst is used in the reaction.  
Catalysts speed up reactions.

Explain why catalysts only affect the **rate** at which equilibrium is set up and **not** the equilibrium yield.

*A catalyst increases the rate of both the forward and backward reactions  
by the same amount (it lowers the activation enthalpy of both equally), so the  
position of equilibrium is unchanged.*

[2]

**13**  
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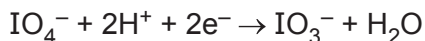
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**Question 4 starts on Page 14**

4 This question refers to the **Practical Insert** that is provided with this paper.

- (a) In the paperclip solution,  $\text{IO}_4^-$  ions oxidise  $\text{Mn}^{2+}$  ions to  $\text{MnO}_4^-$ , being reduced themselves to  $\text{IO}_3^-$  ions.

The oxidation and reduction half equations for this reaction are:



Write the full ionic equation for the reaction.



[2]

- (b)\* At the end of **Part 1** of their method, the students have a solution of  $\text{MnO}_4^-$  in a beaker.

They need to make the solution up to  $100.0\text{ cm}^3$ .

How should they do this accurately?

*Pour the  $\text{MnO}_4^-$  solution from the beaker into a  $100\text{ cm}^3$  volumetric flask, using a funnel (and pouring down a glass rod) so none is lost. Rinse the beaker, glass rod and funnel with deionised (distilled) water and add all the rinsings to the flask, so all of the  $\text{MnO}_4^-$  is transferred. Add deionised water until the level is close to the mark, then add the last few drops with a dropping pipette (or wash bottle) until the bottom of the meniscus is exactly on the graduation mark, viewed at eye level. Put the stopper in and invert (shake) the flask several times so that the solution is thoroughly mixed and has a uniform concentration.*

[6]

Extra space if needed.

.....

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.....

.....

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- (c) Explain why a green filter is used in the colorimeter.

*Green is the complementary colour to purple ( $\text{MnO}_4^-$ ), so the purple solution absorbs green light, so using a green filter gives the maximum absorbance and the most sensitive readings.* [2]

- (d) Use the students' results to calculate the percentage by mass of manganese in a paperclip.

*From the calibration graph,  $[\text{MnO}_4^-] = 14.5 \times 10^{-5} \text{ mol dm}^{-3}$*

*$n(\text{Mn}) = n(\text{MnO}_4^-) = 14.5 \times 10^{-5} \times (100.0 \div 1000) = 1.45 \times 10^{-5} \text{ mol}$*

*mass of Mn =  $1.45 \times 10^{-5} \times 54.9 = 7.96 \times 10^{-4} \text{ g}$*

*mass of paperclip = 0.198 g*

*% Mn =  $(7.96 \times 10^{-4} \div 0.198) \times 100 = 0.402 \%$*

Percentage by mass = ..... *0.40* ..... % [3]

**END OF QUESTION PAPER**

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