Oxford Cambridge and RSA

Tuesday 20 May 2025 – Morning

AS Level Chemistry B (Salters)

H033/02 Chemistry in depth

Time allowed: 1 hour 30 minutes

You must have:
- the Data Sheet for Chemistry B

You can use:
- a scientific or graphical calculator
- an HB pencil

H033/02

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

Centre number | | | | | | Candidate number | | | | |

First name(s) _____

Last name _____

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 **70**.
- 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.

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1 Catalytic converters on cars use metals such as platinum as heterogeneous catalysts.

Catalytic converters turn exhaust emissions such as carbon monoxide and nitrogen monoxide into less hazardous products.

(a)

(i) Explain the meaning of the term **heterogeneous** here.

Catalyst and the reactants are in different physical states [1]

(ii) Why is carbon monoxide hazardous?

Toxic

[1]

(iii) Write an equation for the reaction of carbon monoxide with nitrogen monoxide to give less hazardous products.

$2CO + 2NO \longrightarrow 2CO_2 + N_2$

[1]

(iv) A simple model to explain the function of a heterogeneous catalyst involves four steps.

Complete **Step 2** and **Step 3** in the sequence below.

Step 1 Reactants are adsorbed onto the surface of the catalyst.

Step 2 Bonds break in reactants

Step 3 Bonds form in product

Step 4 Products are desorbed from the surface of the catalyst.

[1]

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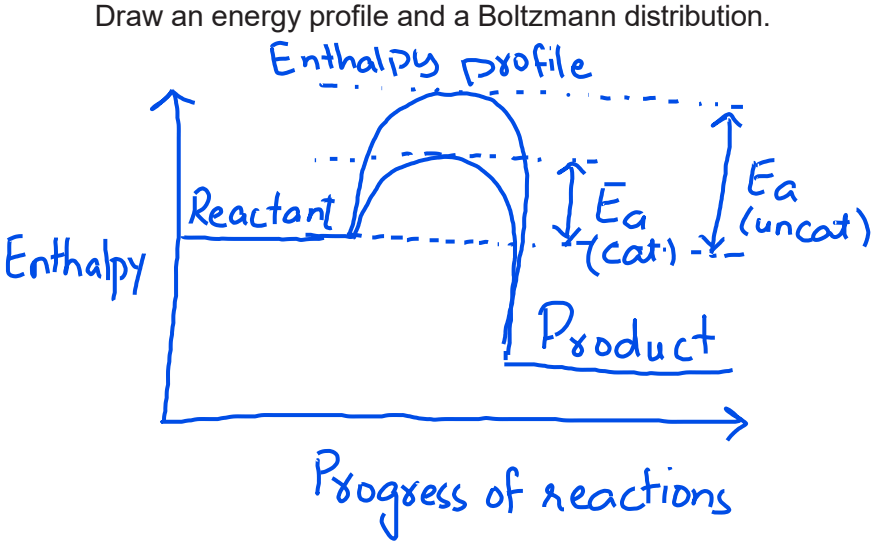
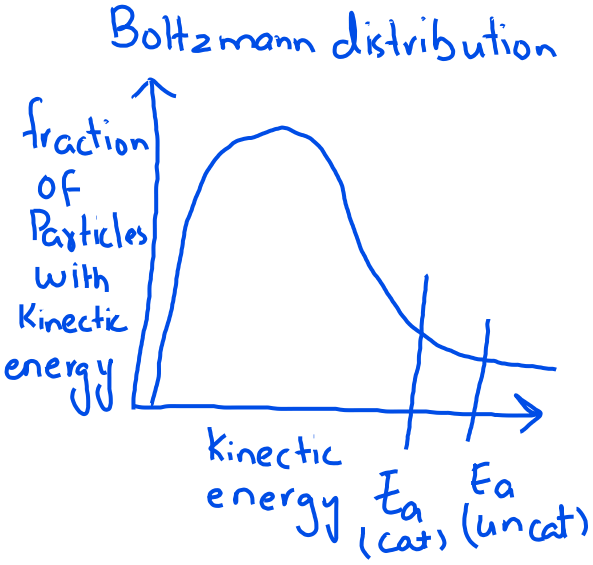
(b)* Explain how a catalyst increases the rate of a reaction.
Draw an energy profile and a Boltzmann distribution.





- Activation energy is the minimum kinetic energy required for colliding particles to react
- A catalyst provides an alternative pathway of lower activation energy
- A catalyst provides a greater fraction of particles with sufficient energy to react successfully
- Energy barrier for catalyzed reaction is lower than for uncatalyzed one

[6]

Extra answer space if required.

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2 Ethanol is an important alcohol that is made industrially by the hydration of ethene.

(a) Give the conditions required for this industrial process.

Heat and pressure

H_3PO_4

Catalyst

[2]

(b) Ethanol can also be made in the laboratory by a two-step process as shown:

$CH_2=CH_2 + H_2SO_4 \rightarrow CH_3CH_2OSO_3H$ **Step 1**

$CH_3CH_2OSO_3H + H_2O \rightarrow CH_3CH_2OH + H_2SO_4$ **Step 2**

Write the overall equation for this two-step process.

$CH_2=CH_2 + H_2O \rightarrow CH_3CH_2OH$

[1]

(c) A student does the two-step process in part **(b)** using an alkene that is a liquid at room temperature. The reaction is exothermic.

(i) The alkene has a boiling point of 30 °C and is highly flammable.

Suggest a practical arrangement that the student should use to avoid loss of the alkene as a vapour.

Carry out the reaction in a flask fitted with a reflux condenser.

[1]

(ii) When the student has carried out both steps, a mixture is left. This mixture contains an alcohol.

The student finds that drops of this mixture turn bromine water from brown to colourless.

Suggest what this colour change tells the student about the conversion of the alkene into alcohol.

The conversion has not gone to completion

[1]

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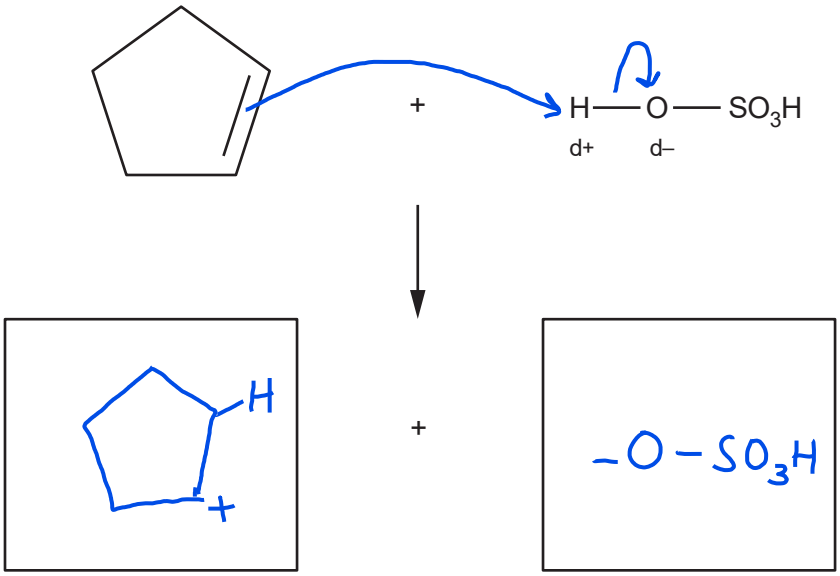
(d) Cyclopentene can be made into cyclopentanol using sulfuric acid.

Complete the first part of **step 1** of the mechanism for the addition of sulfuric acid to form a carbocation.

Show 'curly arrows' and charges.



[4]

(e) Cyclopentene reacts with hydrogen in the presence of a catalyst.

Name a catalyst that allows this hydrogenation to occur at room temperature and pressure.

Platinum ..... **[1]**

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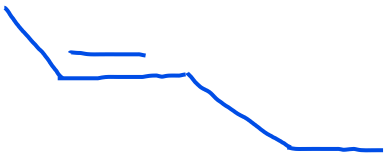
(f) The student then looks at the isomers with the molecular formula C_5H_{10}.

(i) There are two **unbranched** stereoisomers that are unsaturated with the molecular formula C_5H_{10}.

Draw **skeletal** formulae for these two stereoisomers and give the systematic name of each one, using the *E*/*Z* nomenclature.

Explain why this type of stereoisomerism arises.

Skeletal formula		
Name	Z-pent-2-ene	E-pent-2-ene

Explanation ..... Each C atom of the C=C has two different groups bonded .....

.....

[3]

(ii) There are other **branched** unsaturated isomers of molecular formula C_5H_{10}.

Give the **name** of **one** of these isomers.

State the **type** of isomerism by which this isomer is related to the stereoisomers in part **(f)(i)**.

Name of isomer ..... 2-methylbut-1-ene .....

Type of isomerism ..... Structural .....

[2]

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3 A student investigates the reactions of some of the elements and compounds of Group 2.

(a) The student begins by comparing the reactivities of the metals with water.

(i) Write an equation for the reaction of calcium with water.

$$Ca + 2H_2O \longrightarrow Ca(OH)_2 + H_2$$

[1]

(ii) The relative reactivities of the Group 2 elements are related to their ionisation enthalpies.

Write an equation for the **first** ionisation enthalpy of calcium.

Show state symbols.

$$Ca_{(g)} \longrightarrow Ca^+_{(g)} + e^-$$

[2]

(iii) Describe and explain, in terms of electrons, the difference between the reactivities of calcium and barium.

- Ba is more reactive than Ca
- The outer electrons is in the last shell are further from the nucleus
- The attraction between the nucleus and the outer electrons is less
- The outer electrons are lost easily in Ba than in Ca and so the reactivity increases

[4]

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(b) A student makes a pure sample of hydrated magnesium sulfate using magnesium carbonate.

Describe and explain the method the student should use.

- React $MgCO_3$ with Sulfuric acid until reactant is in excess.
- Filter to remove excess reactant.
- Evaporate to dryness
- filter crystals of hydrated magnesium sulfate
- Dry on absorbent paper

[4]

(c)* A batch of Na_2SO_3 has partially oxidised to Na_2SO_4.
Two students each have a 1.00 g sample of this partially oxidised batch.

Each student dissolves their sample in dilute hydrochloric acid.
Only the Na_2SO_3 reacts, as shown in **Equation 3.1**.

$$Na_2SO_3(s) + 2HCl(aq) \rightarrow 2NaCl(aq) + SO_2(g) + H_2O(l) \qquad \textbf{Equation 3.1}$$

Student 1 then adds an excess of barium chloride solution to the resulting solution.
The reaction shown in **Equation 3.2** occurs.

$$Na_2SO_4(aq) + BaCl_2(aq) \rightarrow BaSO_4(s) + 2NaCl(aq) \qquad \textbf{Equation 3.2}$$

Student 1 washes and dries the precipitate and obtains 0.33 g of dry $BaSO_4$ (M_r = 233.4).

Student 2 repeats the method but uses a volume of barium chloride solution that is **not** an excess.

Use the result from **Student 1** to calculate the percentage by mass of the **Na_2SO_3** in the 1.00 g sample.

Explain the effect that the mistakes made by **Student 2** would have on the percentages they calculated. **[6]**

- Amount $BaSO_4$ = $\frac{\text{mass}}{Mr}$ = $\frac{0.33}{233.4}$ = 1.41×10^{-3}
- Amount Na_2SO_4 : Amount $BaSO_4$
  1 : 1
  1.41×10^{-3} : 1.41×10^{-3}

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- mass Na_2SO_4 = moles x Mr = $1.41 \times 10^{-3} \times 142.1$ = 0.20g
- mass Na_2SO_3 = 1.000 − 0.20 = 0.80g
- %age by mass Na_2SO_3 = $\frac{0.8}{1.000} \times 100 = 80\%$

Effect of procedural error

Student 2

- If less $BaCl_2$ is used, Less barium sulfate is precipitated
- This would suggest that less Na_2SO_4 is present
- This would give a higher percentage of Na_2SO_4 in the mixture.

Extra answer space if required.

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(d) Five students each do experiments to find the value of *x* in the formula of the hydrated salt $MgSO_4 \cdot xH_2O$.

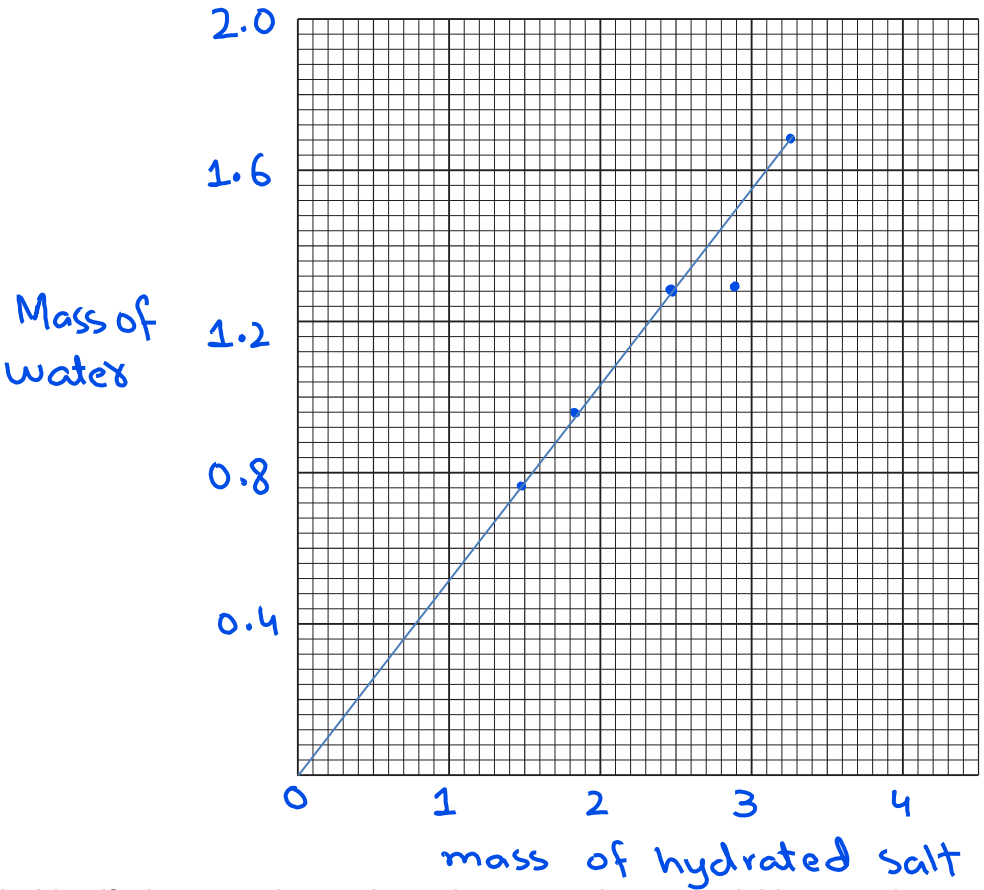
The students heat samples of the hydrated salt to constant mass.
Their results are shown in the table.

	Student				
	A	**B**	**C**	**D**	**E**
Mass of hydrated salt / g	1.51	1.89	2.50	2.92	3.30
Mass contents after heating / g	0.74	0.92	1.22	1.62	1.61
Mass of water / g	0.77	0.97	1.28	1.30	1.69

(i) Plot a graph of mass of water against mass of hydrated salt on the graph paper below.

Include the origin.

Draw a line of best fit.



[3]

(ii) Identify the anomalous point and suggest what caused this anomaly.

Anomalous point ..... Group D .....

Suggested cause of anomaly ..... hydrated salt was not healed to constant mass. .....

[1]

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(iii) Calculate the value of x in the formula $MgSO_4 \cdot xH_2O$. Use the results from **Student C**.

Ratio of $MgSO_4 : H_2O$ (g) = 1.22 : 1.28

Ratio of $MgSO_4 : H_2O$ (mol) = $\frac{1.22}{120} : \frac{1.28}{18}$

$= (1.01 \times 10^{-2}) : (7.111 \times 10^{-2})$

Simplest mole ratio of $MgSO_4 : H_2O$

$= \frac{1.01 \times 10^{-2}}{1.01 \times 10^{-2}} : \frac{7.111 \times 10^{-2}}{1.01 \times 10^{-2}}$

$1 : 7.04$

x = 7 **[3]**

(e) Magnesium exists as three isotopes: magnesium-24, 78.60%, magnesium-25, 10.11% and magnesium-26, 11.29%.

Calculate a value for the A_r of magnesium.

Give your answer to **2** decimal places.

$A_r = \frac{(24 \times 78.60) + (25 \times 10.11) + (26 \times 11.29)}{100}$

$A_r = \frac{1886.4 + 252.75 + 293.54}{100}$

$A_r = \frac{2433}{100}$

$A_r = 24.33$

A_r = 24.33 **[2]**

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4 Esters are used as solvents.

(a) A student reacts propanoic acid, CH_3CH_2COOH, with propan-2-ol, $CH_3CH(OH)CH_3$ to prepare an ester.

(i) Classify propan-2-ol as primary, secondary, or tertiary, explaining your reasoning.

Classification ..... secondary .....

Reasoning ..... the OH group is bonded to a carbon atom to which two other C-atoms are bonded .....

[2]

(ii) Give the reaction conditions that the student should use for this esterification reaction.

..... Heat under reflux .....

..... **[1]**

(iii) Write a structural formula for the ester produced in this reaction.

$CH_3CH_2COOCH(CH_3)_2$

[1]

(b) Another student wants to measure the equilibrium constant for the reaction between ethanoic acid, CH_3COOH, and ethanol, CH_3CH_2OH.

$CH_3COOH + CH_3CH_2OH \rightleftharpoons CH_3COOCH_2CH_3 + H_2O$ **Equation 4.1**

The student says that at equilibrium the forward and backward reactions have stopped and the composition of the mixture remains constant.

Comment on what the student says, giving the correct chemistry where necessary.

..... The Student is not correct to say that the forward and backward reactions have Stopped, instead they are happening at equal rates. ..... **[2]**

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(c) The student mixes 20.0 cm^3 ethanoic acid with 20.0 cm^3 ethanol and leaves the mixture to stand for one week at 25 °C after which it has reached equilibrium.

(i) The density of ethanol is 0.790 g cm^{-3}. Calculate the amount (in mol) of ethanol in the 20.0 cm^3 used.

mass = Density x volume = 0.790x20 = 15.8g

Mr of ethanol = 46

mole of ethanol = $\frac{\text{mass}}{Mr} = \frac{15.8}{46} = 0.343$

Amount of ethanol = 0.343 mol **[2]**

(ii) The student then uses a 1.00 cm^3 volumetric pipette to transfer 1.00 cm^3 of the mixture to a conical flask containing 100 cm^3 of ice-cold water.

The student titrates the contents of the conical flask with 0.100 mol dm^{-3} sodium hydroxide.

The mean titre is 29.50 cm^3.

Ethanoic acid reacts with sodium hydroxide as shown:

$CH_3COOH + NaOH \rightarrow CH_3COONa + H_2O$

Show that the amount of ethanoic acid in the 40.0 cm^3 of the equilibrium mixture is 0.118 mol.

Amount NaOH in mean titre = $\frac{29.50}{1000} \times 0.100$

$= 2.95 \times 10^{-3}$

Amount CH_3COOH = amount NaOH

Amount CH_3COOH in 40 cm^3 = $2.95 \times 10^{-3} \times 40$

$= 0.118$ mol

[2]

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(d) The student uses further calculations to work out the amounts and concentrations of the four components of the 40.0 cm^3 of equilibrium mixture.

(i) Complete the table by calculating the equilibrium concentration of ethanoic acid.

Component	**Equilibrium amount in 40 cm^3 equilibrium mixture /mol**	**Equilibrium concentration in 40 cm^3 equilibrium mixture /mol dm^{-3}**
CH_3COOH	0.118	$\frac{0.118}{40} \times 1000 = 2.95$
CH_3CH_2OH	0.111	2.78
$CH_3COOCH_2CH_3$	0.232	5.80
H_2O	0.232	5.80

[1]

(ii) Write the expression for the equilibrium constant for the reaction in **Equation 4.1**.

$CH_3COOH + CH_3CH_2OH \rightleftharpoons CH_3COOCH_2CH_3 + H_2O$ **Equation 4.1**

$K_c = \dfrac{[CH_3COOCH_2CH_3][H_2O]}{[CH_3COOH][CH_3CH_2OH]}$ **[1]**

(iii) Calculate the numerical value for this equilibrium constant.

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

$K_c = \dfrac{5.80 \times 5.80}{2.95 \times 2.78} = 4.10$

Numerical value of equilibrium constant = 4.10 **[2]**

(e) Suggest why the student uses a 1.00 cm^3 volumetric pipette and not a small measuring cylinder for transferring 1.00 cm^3 of the equilibrium mixture for the titration.

To reduce the uncertainty in the calculation of the equilibrium constant **[1]**

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(f) Suggest why the student adds the sample of equilibrium mixture to 100 cm^3 of ice-cold water before carrying out the titration.

This prevents the position of the equilibrium shifting.

[1]

(g) The student is given some values of the equilibrium constant at various temperatures.

As temperature increases, the numerical value of the equilibrium constant decreases.

Explain what the student can deduce about the enthalpy change of the forward reaction in **Equation 4.1** from this information.

- Increase temperature shift the position of equilibrium to the left hand side of reactants
- The equilibrium shift to oppose the change
- The enthalpy change for the foxwaxd is exothermic

[3]

END OF QUESTION PAPER

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EXTRA ANSWER SPACE

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