

OXFORD CAMBRIDGE AND RSA EXAMINATIONS

Monday 19 October 2020 – Morning

A Level Chemistry A

H432/03 Unified chemistry

**Time allowed: 1 hour 30 minutes
plus your additional time allowance**

YOU MUST HAVE:

the Data Sheet for Chemistry A

Insert for Question 5(c) (with this document)

YOU CAN USE:

**a scientific or graphical calculator
an HB pencil**

Please write clearly in black ink.

Centre number

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Candidate number

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First name(s) _____

Last name _____

READ INSTRUCTIONS OVERLEAF



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 pages 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 (*).

ADVICE

Read each question carefully before you start your answer.

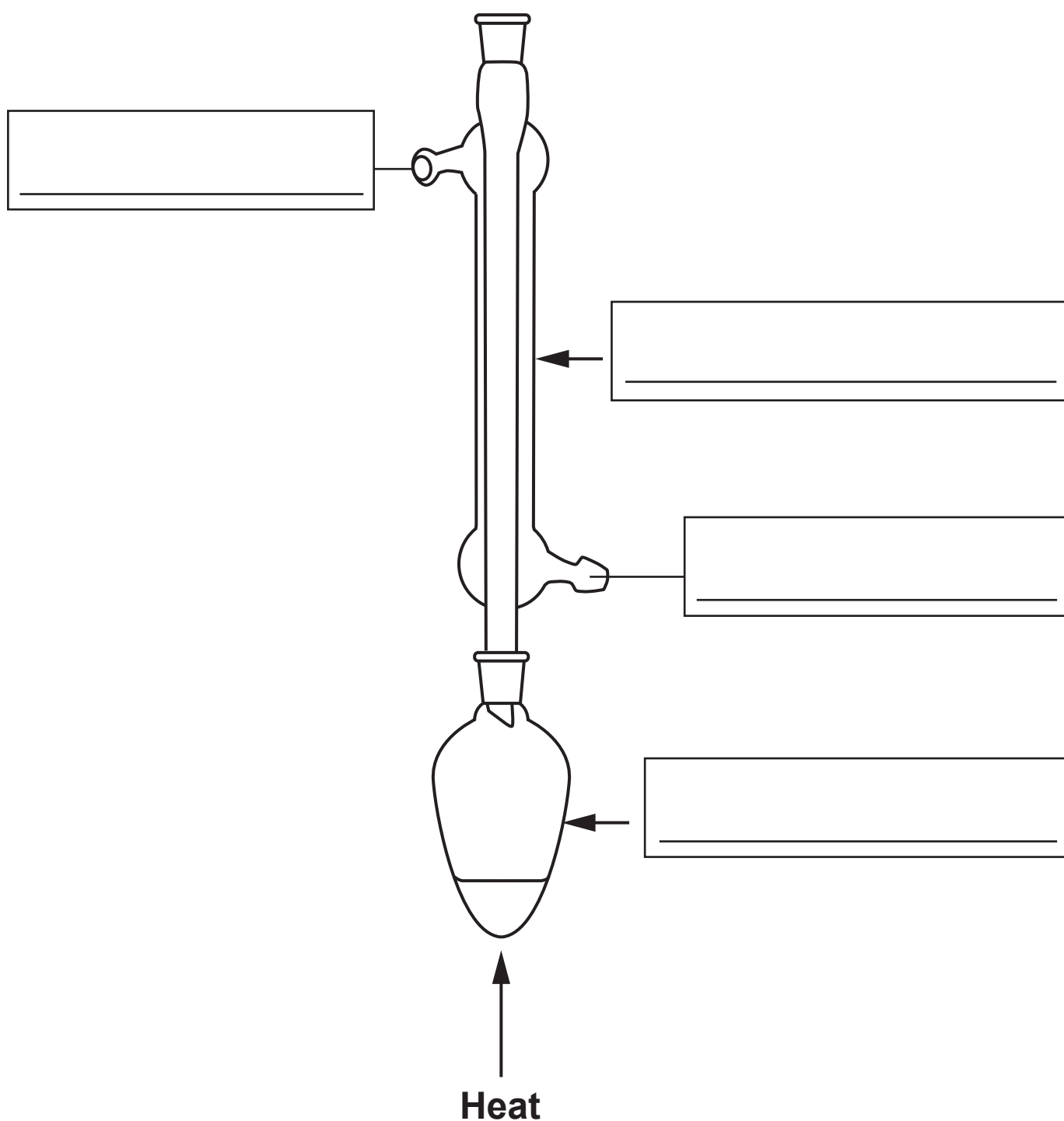
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Answer ALL the questions.

1 This question is about organic chemistry.

(a) This part is about two practical techniques used in organic preparations.

(i) Complete the missing labels on the diagram and name the technique.

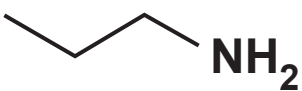
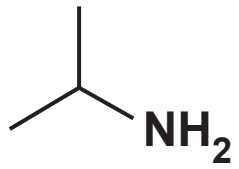
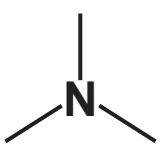


Name of technique: _____ [2]

- (ii) Draw a labelled diagram to show apparatus set up for filtration under reduced pressure (vacuum filtration). Use the space below. [2]**

(b) This part is about amines.

(i) The table shows the structures and boiling points of three amines, which are structural isomers of C_3H_9N .

Amine	Skeletal formula	Boiling point/ $^{\circ}C$
$CH_3CH_2CH_2NH_2$		48–49 $^{\circ}C$
$(CH_3)_2CHNH_2$		33–34 $^{\circ}C$
$(CH_3)_3N$		3–4 $^{\circ}C$

Explain the difference in the boiling points of the three amines. [4]

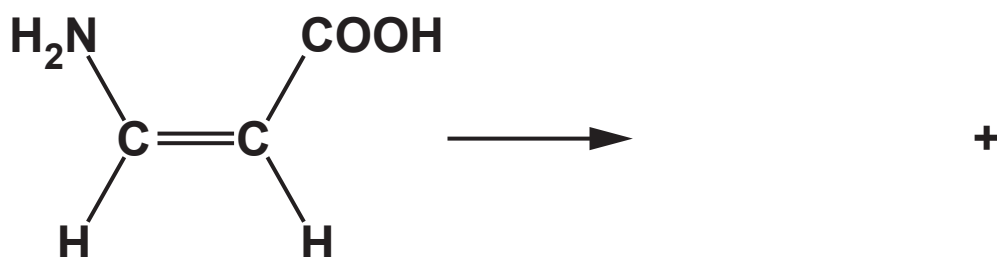
- (ii) Amine A is a liquid at room temperature and pressure.

When vaporised, 0.202 g of the amine produces 72.0 cm^3 of gas at $1.00 \times 10^5 \text{ Pa}$ and 100°C . The ^{13}C NMR spectrum of amine A has 3 peaks.

Determine the molecular formula of A and suggest a possible structure for amine A. Use the space on the opposite page. [6]

- (c) The amino acid $\text{Z-H}_2\text{NCH=CHCOOH}$ can react to form a cyclic compound with the molecular formula $\text{C}_3\text{H}_3\text{NO}$ and one other product.

Complete the equation for this reaction. [2]



Molecular formula of A _____

STRUCTURE OF A

2* Transition metal ions can bond to ligands to form complex ions with different shapes.

Explain what is meant by the terms LIGAND, COORDINATION NUMBER and LIGAND SUBSTITUTION, using suitable examples of complex ions with different shapes, limited to monodentate ligands.

Your answer should include diagrams and equations where appropriate. [6]

Additional answer space if required

- 3 Propane, C_3H_8 , (boiling point -42°C) is used as 'camping gas'. A student plans to determine the enthalpy change of combustion of propane, $\Delta_c H (\text{C}_3\text{H}_8)$, by two methods.

- (a) The student first carries out an experiment using the following apparatus.

A beaker containing 100 cm^3 of water and a thermometer is held above a propane burner by a clamp on a stand.

RESULTS

Mass of propane burner before burning/g	99.218
Mass of propane burner after burning/g	98.976
Initial temperature/ $^\circ\text{C}$	21.60
Maximum temperature reached/ $^\circ\text{C}$	46.10

- (i) Determine the enthalpy change of combustion of propane, in kJ mol^{-1} .

Give your answer to 3 significant figures.

$$\Delta_c H (\text{C}_3\text{H}_8) = \underline{\hspace{2cm}} \text{ kJ mol}^{-1} \text{ [3]}$$

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- (ii) The student finds that the experimental enthalpy change $\Delta_c H$ (C_3H_8) is much less exothermic than the accurate standard enthalpy change $\Delta_c H$ (C_3H_8) in databases.

One reason could be that the student's experiment had not been carried out under standard conditions.

Suggest TWO other reasons for this difference in enthalpy change.

1 _____

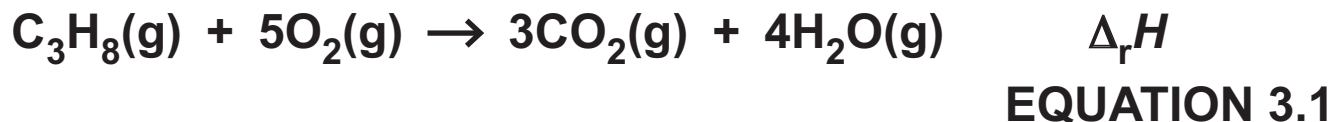
2 _____

[1]

(b)*The student determines the standard enthalpy change of combustion of propane using the bond enthalpies in the table. An experiment is not needed.

Bond	Bond enthalpy / kJ mol ⁻¹
C-H	+413
C-C	+347
C=O	+805
O=O	+498
O-H	+464

The bond enthalpies can be used to determine the standard enthalpy change of reaction, $\Delta_r H$, for EQUATION 3.1:



ENTHALPY CHANGE OF VAPORISATION, $\Delta_{\text{vap}} H$

The standard enthalpy change of vaporisation of water, $\Delta_{\text{vap}} H$, is the enthalpy change for the conversion of 1 mol of $\text{H}_2\text{O}(\text{l})$ into 1 mol of $\text{H}_2\text{O}(\text{g})$ under standard conditions:



Determine the standard enthalpy change of combustion of propane (boiling point -42°C) using the $\Delta_r H$ value for EQUATION 3.1 and $\Delta_{\text{vap}} H$ for water. [6]

[illegible]

Additional answer space if required

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4 A student carries out an investigation to identify two metals, M and X, by two different methods.

(a) The student is provided with a sample of metal M.

The student analyses metal M using a ‘back-titration’ technique:

The metal is reacted with excess acid.

The resulting solution is titrated to determine the amount of acid remaining after the reaction.

STAGE 1

The student adds 100 cm^3 of $2.10\text{ mol dm}^{-3}\text{ HCl(aq)}$ to 6.90 g of M.

An excess of HCl(aq) has been used to ensure that all of metal M reacts.

A redox reaction occurs, forming a solution containing M in the +2 oxidation state.

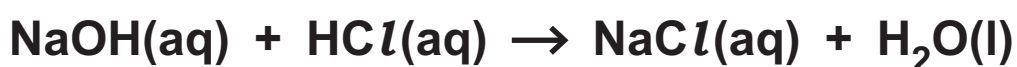
STAGE 2

The resulting solution from STAGE 1 is made up to 250.0 cm^3 with distilled water.

STAGE 3

A 25.00 cm^3 sample of the diluted solution from STAGE 2 is titrated with $0.320\text{ mol dm}^{-3}\text{ NaOH(aq)}$.

The NaOH(aq) reacts with excess HCl(aq) that remains in STAGE 1:



The student repeats the titration to obtain concordant titres.

TITRATION RESULTS (The trial titre has been omitted.)

The burette readings have been recorded to the nearest 0.05 cm^3 .

	1	2	3
Final reading / cm^3	27.80	37.55	32.20
Initial reading / cm^3	0.50	10.00	5.00

- (i) In STAGE 1, a redox reaction takes place between M and HCl(aq) , forming hydrogen and a solution containing M in the +2 oxidation state.

Write an overall equation, with state symbols, for this reaction. Write half-equations for the oxidation and reduction processes.

Overall equation _____

Oxidation half-equation _____

Reduction half-equation _____

[3]

(ii) In **STAGE 1**, suggest **TWO** observations that would confirm that all of metal **M** has reacted.

1 _____

2 _____

[2]

(iii) In **STAGE 3**, write the ionic equation for the reaction taking place in the titration.

[1]

(iv) Metal M can be identified following the steps below.

- 1. The amount, in mol, of excess HCl(aq) that remains after the reaction of M with HCl(aq) .**
- 2. The amount, in mol, of HCl(aq) that reacted with M.**
- 3. The identity of metal M.**

Analyse the results to identify metal M.

Metal M = _____ [6]

- (b) The student is provided with the carbonate of an unknown metal, X_2CO_3 .

The student measures the mass loss when the X_2CO_3 is reacted with an EXCESS of hydrochloric acid. The equation is shown below.



The reaction is carried out using this method:

STEP 1 Add 100 cm^3 $HCl(aq)$ to a conical flask and weigh.

STEP 2 Add X_2CO_3 to the conical flask and immediately reweigh.

STEP 3 After 5 minutes, reweigh the conical flask and contents.

RESULTS

Mass of conical flask + $HCl(aq)$	172.93 g
Mass of conical flask + X_2CO_3 + $HCl(aq)$ before reaction	187.50 g
Mass of conical flask + contents after 5 minutes	184.75 g

- (i) Calculate the amount, in mol, of CO_2 released in the reaction.

Amount of CO_2 = _____ mol [1]

- (ii) Calculate the molar mass of X_2CO_3 and identify metal X.

Molar mass of X_2CO_3 = _____ g mol^{-1}

Metal X = _____ [3]

- (c) After analysing the results, the student was told that their molar mass of X_2CO_3 was incorrect.

The student evaluated the experiment for possible reasons for the incorrect result.

- (i) The student wondered whether the reaction was complete when the mass was recorded after 5 minutes (STEP 3).

How could the student modify the experimental procedure to be confident that the reaction was complete?

[1]

- (ii) The student finds out that carbon dioxide is slightly soluble in water.

State and explain how the solubility of CO_2 would affect the calculated molar mass of X_2CO_3 .

[2]

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- 5 The equilibrium constant K_p and temperature T (in K) are linked by the mathematical relationship shown in EQUATION 5.1 (R = Gas constant in $\text{J mol}^{-1} \text{K}^{-1}$ and ΔH is enthalpy change in J mol^{-1}).

$$\ln K_p = -\frac{\Delta H}{R} \times \frac{1}{T} + \frac{\Delta S}{R} \quad \text{EQUATION 5.1}$$

- (a) The table opposite shows the values of K_p at different temperatures for an equilibrium.

Complete the table by adding the missing values of $\frac{1}{T}$ and $\ln K_p$. [2]

- (b) State and explain how increasing the temperature affects the position of this equilibrium and whether the forward reaction is exothermic or endothermic.

[1]

Temperature, T/K	400	500	600	700	800
K_p	3.00×10^{58}	5.86×10^{45}	1.83×10^{37}	1.46×10^{31}	1.14×10^{26}
$\frac{1}{T} / K^{-1}$	2.50×10^{-3}				
$\ln K_p$	135				

- (c) Plot a graph of $\ln K_p$ against $\frac{1}{T}$ using the axes provided on the insert.

Use your graph and EQUATION 5.1 to determine ΔH , in kJ mol^{-1} , for this equilibrium.

Give your answer to 3 significant figures.

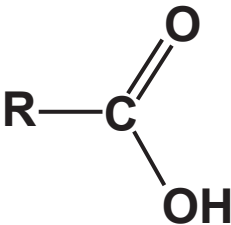
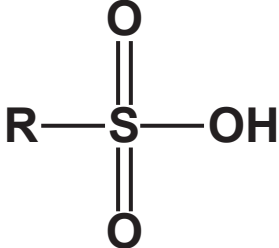
$$\Delta H = \text{_____} \text{ kJ mol}^{-1} [4]$$

- (d) Explain how ΔS could be calculated from a graph of $\ln K_p$ against $\frac{1}{T}$.

 [2]

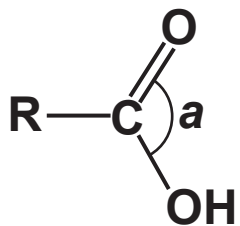
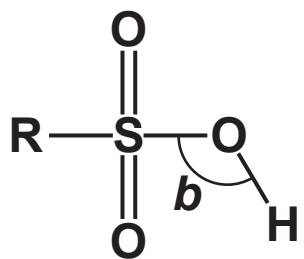
- 6 This question is about two different types of acid found in organic compounds, carboxylic acids and sulfonic acids, as shown in FIG. 6.1.

FIG. 6.1

	
Carboxylic acid	Sulfonic acid

- (a) Complete TABLE 6.1 to predict bond angles *a* and *b* and name the shapes which makes these bond angles in the functional groups of carboxylic acids and sulfonic acids. [2]

TABLE 6.1

Type of acid	Acid	Bond angle	Name of shape
Carboxylic acid		_____	_____
Sulfonic acid		_____	_____

- (b) Ethanoic acid, CH_3COOH , and methanesulfonic acid, $\text{CH}_3\text{SO}_2\text{OH}$, are both monobasic acids. The $\text{p}K_{\text{a}}$ values are shown in the table.

Acid		$\text{p}K_{\text{a}}$
Ethanoic acid	CH_3COOH	4.76
Methanesulfonic acid	$\text{CH}_3\text{SO}_2\text{OH}$	-1.90

A student suggests that 1.0 mol dm^{-3} $\text{CH}_3\text{SO}_2\text{OH}$ should have a lower pH value than 1.0 mol dm^{-3} CH_3COOH .

Write an equation, showing conjugate acid–base pairs, for the equilibrium of $\text{CH}_3\text{SO}_2\text{OH}$ with water and explain, with reasons, whether the student is correct.

Label the conjugate acid–base pairs: A1, B1 and A2, B2.

[4]

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(c) Carboxylic acids and sulfonic acids both form esters.

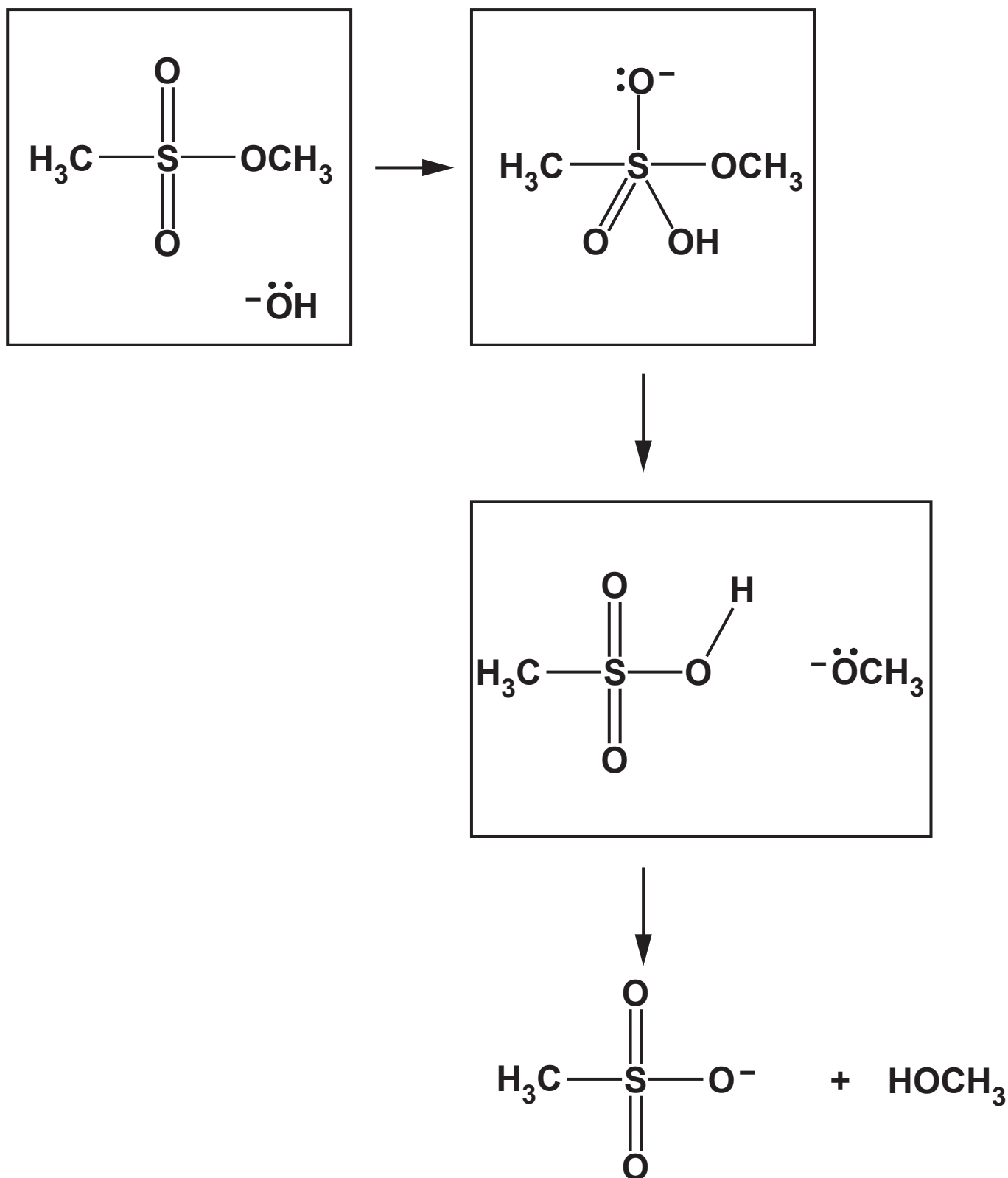
Sulfonic acid esters can be hydrolysed by aqueous alkali.

The equation shows the alkaline hydrolysis of a sulfonic acid ester.



In the 3 BOXES OPPOSITE, add curly arrows to show the mechanism for this reaction.

In the first box, the hydroxide ion acts as a nucleophile. [4]



END OF QUESTION PAPER

ADDITIONAL ANSWER SPACE

If additional space is required, you should use the following lined page(s). The question number(s) must be clearly shown in the margin(s).

[illegible]

[illegible]

[illegible]

