Surname	StemUp Model Solution	Centre Number	Candidate Number
First name(s)			2

GCE A LEVEL

A410U30-1

O20-A410U30-1

MONDAY, 19 OCTOBER 2020 – MORNING

CHEMISTRY – A level component 3
Chemistry in Practice

1 hour 15 minutes

For Examiner's use only		
Question	**Maximum Mark**	**Mark Awarded**
1.	**17**	
2.	**12**	
3.	**10**	
4.	**21**	
Total	**60**	

A410U301
01

ADDITIONAL MATERIALS

In addition to this examination paper, you will need a:
- calculator;
- **Data Booklet** supplied by WJEC.

INSTRUCTIONS TO CANDIDATES

Use black ink or black ball-point pen.

Write your name, centre number and candidate number in the spaces at the top of this page.

Answer **all** questions in the spaces provided.

INFORMATION FOR CANDIDATES

The number of marks is given in brackets at the end of each question or part-question.

The maximum mark for this paper is 60.

Your answers must be relevant and must make full use of the information given to be awarded full marks for a question.

The assessment of the quality of extended response (QER) will take place in **Q.4***(b)*(ii).

If you run out of space, use the additional page(s) at the back of the booklet, taking care to number the question(s) correctly.

© WJEC CBAC Ltd.

stemup.co.uk

Examiner only

Answer **all** *questions in the spaces provided.*

1. This question relates to the following eight compounds.

A	$CH_3CH_2CH_2CH_2OH$	butan-1-ol
B	$CH_3CH_2CH_2CH_2Br$	1-bromobutane
C	$CH_3CH_2CH_2CHO$	butanal
D	$(CH_3)_3COH$	
E	$CH_3CH_2CH_2COOH$	butanoic acid
F	$CH_3CH_2CH(OH)CH_3$	butan-2-ol
G	$CH_3CH_2CH_2CH_2NH_2$	butylamine
H	$CH_3CH_2CH_2CH_2CN$	

(a) Give the systematic names of compounds **D** and **H**. [2]

D *methylpropan-2-ol*

H *pentanenitrile*

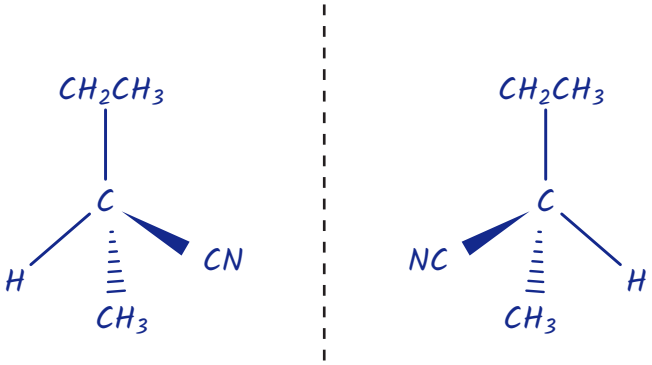
© WJEC CBAC Ltd.

stemup.co.uk

Examiner only

(b) An isomer of compound **H** shows optical isomerism.

(i) Draw diagrams to represent both optical isomers. [1]



(ii) Give **one** difference between the properties of the two optical isomers. [1]

They rotate the plane of plane-polarised light in opposite directions (by the same angle).

(iii) Give **one** reaction common to both optical isomers. Give the reagent and the structural formula of the organic product formed. [2]

Reagent $LiAlH_4$ (in dry ether), reduction

Product $CH_3CH(CH_2NH_2)CH_2CH_3$

A410U301 03

stemup.co.uk

Examiner only

(c) For each pair of compounds shown below, complete the table to describe a chemical test that can be used to distinguish between them.

Where appropriate, give the

- reagent(s) and condition(s) used
- observation(s) for the compound that reacts
- structural formula of the organic compound(s) formed in the positive test [8]

Compounds	Reagent(s) and condition(s)	Observation(s)	Organic compound(s) formed
$CH_3CH_2CH_2CH_2OH$ and $CH_3CH_2CH_2CH_2Br$	*acidified potassium dichromate(VI), heat under reflux*	orange to green solution	*$CH_3CH_2CH_2COOH$ (via $CH_3CH_2CH_2CHO$)*
$CH_3CH_2CH_2CHO$ and $(CH_3)_3COH$	Tollens' reagent (alkaline solution of ammoniacal silver nitrate) warm gently in hot water bath	*silver mirror*	*$CH_3CH_2CH_2COOH$*
$CH_3CH_2CH_2COOH$ and $CH_3CH_2CH(OH)CH_3$	*I_2 / NaOH(aq), warm*	*yellow solid (precipitate)*	CHI_3 and CH_3CH_2COONa
$CH_3CH_2CH_2CH_2NH_2$ and $CH_3CH_2CH_2CH_2CN$	nitric(III) acid (HNO_2) room temperature	*bubbles of gas (effervescence)*	*$CH_3CH_2CH_2CH_2OH$*

© WJEC CBAC Ltd.

stemup.co.uk

Examiner only

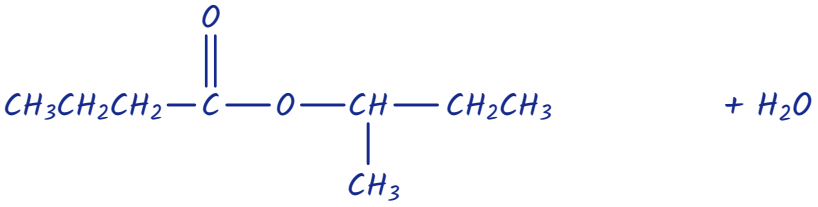
(d) Butanoic acid and butan-2-ol can react to form an ester.

(i) Give the essential reaction conditions. [1]

Heat under reflux with concentrated sulfuric acid (catalyst).

(ii) Give the equation for the reaction. Clearly show the structure of the ester formed. [1]

$CH_3CH_2CH_2COOH + CH_3CH_2CH(OH)CH_3 \rightleftharpoons$



$+ H_2O$

(iii) State how the ester is separated from the reaction mixture. [1]

Add sodium carbonate solution to neutralise the acid, then distillation.

© WJEC CBAC Ltd.

stemup.co.uk

Examiner only

2. A student determined the concentration of a barium chloride solution using the following method.

Step	Method
1	50.0 cm^3 of the barium chloride solution was transferred into a 250 cm^3 beaker and 50.0 cm^3 of 0.506 mol dm^{-3} sodium carbonate solution (an excess) was added. Barium carbonate was precipitated: $Ba^{2+}(aq) + CO_3^{2-}(aq) \longrightarrow BaCO_3(s)$
2	The mixture was filtered into a conical flask, and the beaker and the precipitate were washed four times with small quantities of deionised water. The washings and filtrate were collected in a 200 cm^3 volumetric flask and made up to the mark with deionised water. The flask was shaken well to ensure the solution formed was homogeneous. The solution was labelled as solution **Y**.
3	25.0 cm^3 of solution **Y** was transferred into a conical flask and the unreacted sodium carbonate in the filtrate determined by titration against 0.200 mol dm^{-3} hydrochloric acid using screened methyl orange as an indicator.

(a) Describe how the student could have confirmed experimentally that all of the barium ions had been precipitated in step **1**. [1]

Add more sodium carbonate solution to a sample of the filtrate: no (further) precipitate forms, so all the Ba^{2+} ions had been precipitated.

(b) Write an **ionic** equation for the reaction of carbonate ions with hydrogen ions (H^+) from the hydrochloric acid in step **3**, to form carbon dioxide as one of the products. [1]

$2H^+(aq) + CO_3^{2-}(aq) \rightarrow H_2O(l) + CO_2(g)$

© WJEC CBAC Ltd.

stemup.co.uk

Examiner only

(c) The student obtained the following results using 25.0 cm^3 samples of solution **Y**.

	Titration 1	Titration 2	Titration 3	Titration 4
Initial burette reading / cm^3	0.50	18.45	2.10	19.70
Final burette reading / cm^3	18.45	35.95	19.70	37.25
Titre / cm^3	17.95	17.50	17.60	17.55

(i) **Complete the table** to show the volume of hydrochloric acid used in each titration and calculate an appropriate mean titre. [2]

Concordant titres: 17.50, 17.60, 17.55 (titration 1 is too far out, ignored)

mean = (17.50 + 17.60 + 17.55) ÷ 3 = 17.55

Mean titre = ... 17.55 ..... cm^3

(ii) Identify the titration that has the largest percentage error in the volume of hydrochloric acid used. Give a reason for your choice.

A calculation of the percentage error is **not** required. [1]

Titration 2, because it has the smallest volume of HCl (17.50 cm^3), so the same burette reading error is the largest percentage of the titre.

A410U301 07

© WJEC CBAC Ltd.

stemup.co.uk

Examiner only

(d) The five stages in the calculation of the concentration of the barium chloride solution are set out in the statements below.

(i) Number these stages in the correct order. [1]

	Correct order
Calculate the number of moles of HCl used in the titration of 25.0 cm^3 of solution **Y**	2
Calculate the number of moles of CO_3^{2-} that reacted with 200 cm^3 of solution **Y**	4
Use the balanced equation to calculate the number of moles of unreacted CO_3^{2-} in 200 cm^3 of solution **Y**	3
Calculate the concentration of the barium chloride solution in g dm^{-3}	5
Calculate the total number of moles of CO_3^{2-} added to the 50.0 cm^3 of barium chloride solution	1

(ii) Calculate the concentration of the barium chloride solution in **g dm^{-3}**. [5]

total mol CO_3^{2-} added = 50.0 × 0.506 ÷ 1000 = 0.0253 mol

mol HCl = 17.55 × 0.200 ÷ 1000 = 3.51×10^{-3} mol

unreacted CO_3^{2-} in 25.0 cm^3 = $3.51 \times 10^{-3} \div 2 = 1.755 \times 10^{-3}$ mol

unreacted CO_3^{2-} in 200 cm^3 = $1.755 \times 10^{-3} \times 8 = 0.0140$ mol

CO_3^{2-} reacted = 0.0253 − 0.0140 = 0.0113 mol = mol Ba^{2+}

$[BaCl_2] = 0.0113 \div (50.0 \div 1000) = 0.226$ mol dm^{-3}

$M_r(BaCl_2) = 208$, so concentration = 0.226 × 208 = 47.0 g dm^{-3}

Concentration = ... 47.0 ..... g dm^{-3}

© WJEC CBAC Ltd.

stemup.co.uk

Examiner only

(iii) Calculate the mass of barium carbonate obtained on heating the precipitate to constant mass. [1]

mol $BaCO_3$ = mol $BaCl_2$ = 0.226 × 50.0 ÷ 1000 = 0.0113 mol

mass = 0.0113 × 197.3 = 2.23 g

Mass = ... 2.23 ..... g

12

A410U301
09

stemup.co.uk

Examiner only

3. This question is about the oxides and chlorides of two elements, **X** and **Y**, which exhibit the following properties.

Element	Properties of oxide	Properties of chloride
X	White solid of melting temperature 2800 °C. It is insoluble in water but readily dissolves in dilute acid. Addition of aqueous sodium hydroxide to this solution forms a white precipitate, which is insoluble in excess aqueous sodium hydroxide.	White solid with melting temperature of 712 °C. It is readily soluble in water. Its solution gives a white precipitate with CO_3^{2-}(aq) but no precipitate with SO_4^{2-}(aq).
Y	White solid of melting temperature 1750 °C. It is insoluble in water and does not react with dilute acids or dilute alkalis.	Colourless liquid with boiling temperature of 58 °C. It reacts vigorously with water to give a white precipitate, an acidic solution and misty fumes. At 60 °C and 1 atm pressure, 5.000 g of the chloride of **Y** occupies a volume of 805.5 cm^3.

(a) Use **all** the information provided to suggest the identity of element **X**. Show your reasoning and include **ionic** equations to support your answer. [4]

X is magnesium. The oxide and chloride have high melting temperatures, so they are ionic.

The oxide is basic (dissolves in acid, not amphoteric), so X is a metal.

The carbonate is insoluble, so X is not a Group 1 metal. The hydroxide and carbonate are white, so it is not a transition metal.

The hydroxide is insoluble in excess NaOH and there is no precipitate with sulfate, so X is Mg.

$Mg^{2+}(aq) + 2OH^-(aq) \rightarrow Mg(OH)_2(s)$

$Mg^{2+}(aq) + CO_3^{2-}(aq) \rightarrow MgCO_3(s)$

© WJEC CBAC Ltd.

stemup.co.uk

Examiner only

(b) Use **all** the information provided to suggest the identity of element **Y**. Show your reasoning and include an equation to support your answer. [6]

Y is silicon.

The oxide does not react with acids or alkalis, so it is not a metal oxide; its high melting temperature shows it has a giant covalent (giant molecular) structure.

The low boiling temperature of the chloride shows a simple covalent (molecular) structure.

A giant covalent oxide with a simple molecular chloride suggests a metalloid / Group 4 element.

Misty fumes (HCl) and a white precipitate with water show the chloride is hydrolysed, suggesting Si.

$T = 333\ K$, $p = 1.01 \times 10^5\ Pa$, $V = 805.5 \times 10^{-6}\ m^3$

$n = pV \div RT = (1.01 \times 10^5 \times 805.5 \times 10^{-6}) \div (8.31 \times 333) = 0.0294\ mol$

$M_r = 5.000 \div 0.0294 = 170.1$, so the chloride is $SiCl_4$ $(28.1 + 4 \times 35.5)$

$SiCl_4 + 2H_2O \rightarrow SiO_2 + 4HCl$

10

© WJEC CBAC Ltd.

stemup.co.uk

BLANK PAGE

© WJEC CBAC Ltd.

stemup.co.uk

Examiner only

4. *(a)* Outline a suitable laboratory method to investigate the rate of each of the following reactions at constant temperature.

You may use a chosen method only once.

(i) $Mg(s) + H_2SO_4(aq) \longrightarrow MgSO_4(aq) + H_2(g)$ [1]

Use a gas syringe to measure the volume of hydrogen gas given off at regular time intervals.

(ii) $CH_3COCH_3(aq) + I_2(aq) \longrightarrow CH_2ICOCH_3(aq) + HI(aq)$ [2]

Remove samples at regular time intervals, quench them (add to sodium hydrogencarbonate solution) and titrate the remaining iodine against standard sodium thiosulfate solution, using starch indicator.

© WJEC CBAC Ltd.

stemup.co.uk

Examiner only

(b) The kinetics of the reaction represented by the equation

$$BrO_3^-(aq) + 5Br^-(aq) + 6H^+(aq) \longrightarrow 3Br_2(aq) + 3H_2O(l)$$

can be investigated by measuring the rate at which bromine is produced using a clock reaction. The reaction mixture contains known volumes of $BrO_3^-(aq)$, $Br^-(aq)$ and $H^+(aq)$.

The reaction mixture also contains

- a known volume of aqueous phenol, which removes the bromine produced in the reaction

$$3Br_2(aq) + C_6H_5OH(aq) \longrightarrow C_6H_2Br_3OH(s) + 3H^+(aq) + 3Br^-(aq)$$

- 2–3 drops of methyl orange solution, which is bleached colourless by free bromine

$$Br_2(aq) + \underset{\text{(pink)}}{\text{methyl orange}} \longrightarrow \underset{\text{(colourless)}}{\text{bleached methyl orange}}$$

As soon as all the phenol has been used up by the bromine produced, free bromine will appear in solution and bleach the methyl orange. The time taken for the methyl orange solution to be bleached is recorded.

(i) One group of students studied the kinetics of the bromate/bromide reaction using the clock reaction described above.

They mixed different volumes of the aqueous solutions, all at a concentration of 1.0 mol dm^{-3} and a constant temperature of 298 K.

In each experiment, the total volume was made up to 500 cm^3 with deionised water. The following results were obtained.

Expt	Volume of $BrO_3^-(aq)$ / cm^3	Volume of $Br^-(aq)$ / cm^3	Volume of $H^+(aq)$ / cm^3	Volume of phenol / cm^3	Time taken for methyl orange to be bleached / s	Rate / s^{-1}
1	25.0	125.0	150.0	10.0	336	2.98×10^{-3}
2	25.0	125.0	300.0	10.0	84	1.19×10^{-2}
3	50.0	125.0	300.0	10.0	42	2.38×10^{-2}
4	25.0	62.5	300.0	10.0	168	5.95×10^{-3}

© WJEC CBAC Ltd.

stemup.co.uk

Examiner only

I. **Complete the table** by calculating the values of the rate in these four experiments. [1]

II. Deduce the order of reaction with respect to $BrO_3^-(aq)$, $Br^-(aq)$ and $H^+(aq)$.

Explain how you reached your conclusions. [3]

Order with respect to $BrO_3^-(aq)$ *first order*

Explanation *Expts 2 and 3: $[BrO_3^-]$ doubles, time halves, so the rate doubles (rate ∝ $[BrO_3^-]$).*

Order with respect to $Br^-(aq)$ *first order*

Explanation *Expts 2 and 4: $[Br^-]$ halves, time doubles, so the rate halves (rate ∝ $[Br^-]$).*

Order with respect to $H^+(aq)$ *second order*

Explanation *Expts 1 and 2: $[H^+]$ doubles, time quarters, so the rate increases by a factor of 4 (= 2^2).*

III. Write the rate equation for the overall reaction. [1]

rate = $k[BrO_3^-][Br^-][H^+]^2$

IV. With reference to this rate equation, state what is meant by the overall order of a reaction. [1]

The sum of the powers of the concentration terms in the rate equation: 1 + 1 + 2 = 4, so it is fourth order overall.

© WJEC CBAC Ltd.

stemup.co.uk

Examiner only

V. Calculate the value of the rate constant, giving your answer to an **appropriate** number of significant figures. [4]

Expt 2: $[BrO_3^-] = 25.0 \times 1.0 \div 500 = 0.050$ mol dm^{-3}

$[Br^-] = 125.0 \div 500 = 0.25$ mol dm^{-3}

$[H^+] = 300.0 \div 500 = 0.60$ mol dm^{-3}

k = rate $\div ([BrO_3^-][Br^-][H^+]^2)$

$k = 1.19 \times 10^{-2} \div (0.050 \times 0.25 \times 0.60^2)$

$k = 1.19 \times 10^{-2} \div 4.50 \times 10^{-3} = 2.64$ (3 sig. figs, as the data)

Rate constant = 2.64 mol^{-4} dm^{12} s^{-1}

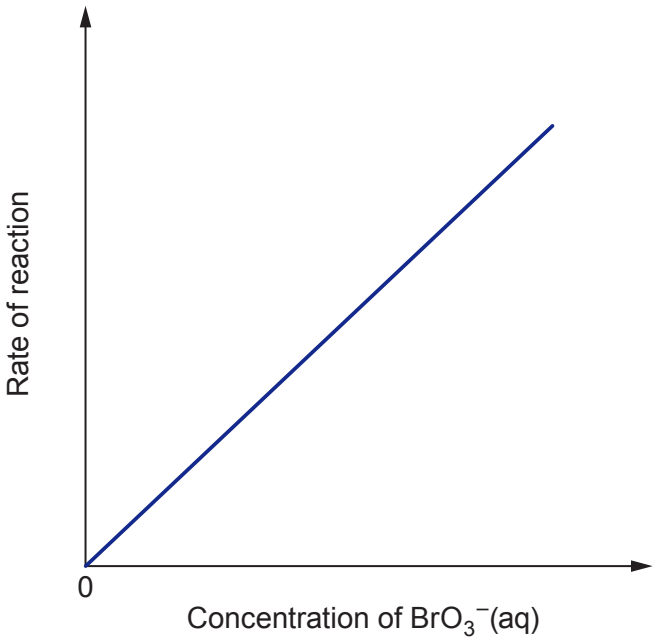
© WJEC CBAC Ltd.

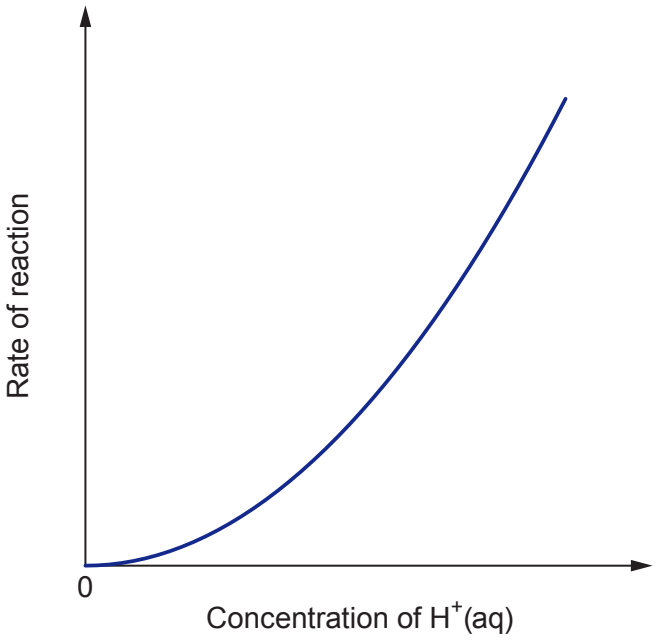
stemup.co.uk

Examiner only

VI. On the axes below, sketch the graph of rate against concentration that would be obtained when the concentrations of $BrO_3^-(aq)$ and $H^+(aq)$ are changed in turn, whilst all other reactant concentrations remain unchanged.

Assume that the temperature remains constant. [2]





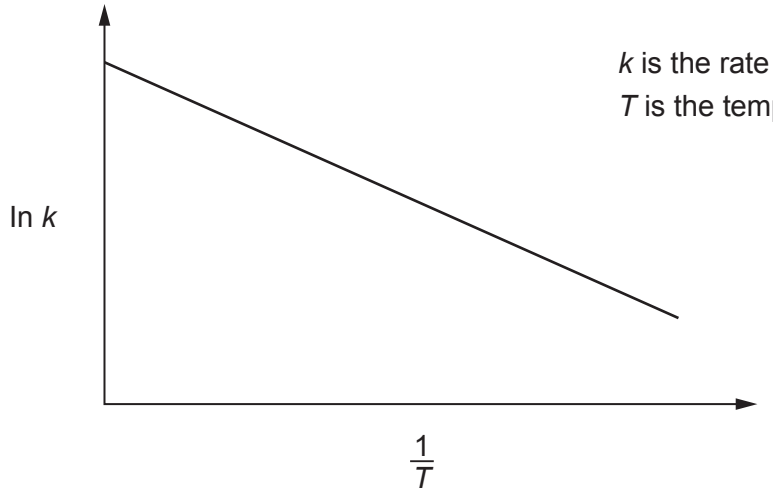
© WJEC CBAC Ltd.

stemup.co.uk

(ii) In an extension to the original work, a group of students carried out an experiment to determine the activation energy of the bromate/bromide reaction.

$$BrO_3^-(aq) + 5Br^-(aq) + 6H^+(aq) \longrightarrow 3Br_2(aq) + 3H_2O(l)$$

They collected suitable results and plotted the graph shown below.



k is the rate constant

T is the temperature (in Kelvin)

stemup.co.uk

Examiner only

Outline the practical steps the students carried out to collect their results. Explain how their results were processed to plot the graph and how the graph would be used to determine the activation energy. [6 QER]

Use the same reaction mixture as before (BrO_3^-, Br^-, H^+, phenol, methyl orange), keeping the initial concentrations of all reactants the same in every experiment.

Warm the separate solutions in a water bath to the chosen temperature, mix them, start the stopclock and record the time taken for the methyl orange to be bleached. Measure the temperature with a thermometer.

Repeat at a number of different temperatures (e.g. 30, 40, 50 and 60 °C) and convert each to Kelvin.

Calculate the rate at each temperature as 1/time. Then calculate the rate constant k at each temperature, $k = \text{rate} \div [BrO_3^-][Br^-][H^+]^2$.

Calculate ln k and 1/T and plot ln k against 1/T.

Arrhenius equation: $k = Ae^{-Ea/RT}$, so $\ln k = \ln A - (E_a/R) \times (1/T)$, a straight line of the form $y = mx + c$.

So the gradient of the line $= -E_a/R$. Measure the gradient, then $E_a = -\text{gradient} \times R$ ($R = 8.31\ J\ K^{-1}\ mol^{-1}$).

21

END OF PAPER

© WJEC CBAC Ltd.

stemup.co.uk

Examiner only

Additional page.

© WJEC CBAC Ltd.

stemup.co.uk