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

GCE A LEVEL

A410U30-1

Z22-A410U30-1

THURSDAY, 23 JUNE 2022 – MORNING

CHEMISTRY – A level component 3

Chemistry in Practice

1 hour 15 minutes

For Examiner's use only		
Question	**Maximum Mark**	**Mark Awarded**
1.	**14**	
2.	**15**	
3.	**11**	
4.	**13**	
5.	**7**	
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. Do not use gel pen or correction fluid. You may use a pencil for graphs and diagrams only.

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

Answer **all** questions.

Write your answers in the spaces provided in this booklet. 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.

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)(i)

© WJEC CBAC Ltd.

stemup.co.uk

Examiner only

Answer **all** questions.

1. A student was given four sets of compounds as shown below. He was asked to carry out a **chemical** test on each set of compounds that would allow him to distinguish between the compounds within each set.

For each set of compounds:

- Describe **one** chemical test the student could use. You may use the same reagents for more than one set.
- Give the **relevant observations** that would allow the student to distinguish between the compounds.
- Give an equation for **one** reaction that gives an observable change. State symbols are not required. [14]

Set **1**	
Solutions of	**A** barium nitrate **B** aluminium nitrate **C** magnesium nitrate
Chemical test	*Add aqueous sodium hydroxide, NaOH(aq), dropwise and then in excess to each solution.*
Observations	*A (barium nitrate): no precipitate forms, no change.* *B (aluminium nitrate): white precipitate forms, which dissolves in excess NaOH.* *C (magnesium nitrate): white precipitate forms, which does not dissolve in excess.*
Equation	$Mg(NO_3)_2 + 2NaOH \rightarrow Mg(OH)_2 + 2NaNO_3$

Set **2**	
Solutions of	**D** phenol **E** ethanol **F** cyclohexene
Chemical test	*Add bromine water, $Br_2(aq)$, to each solution at room temperature and shake.*
Observations	*D (phenol): $Br_2(aq)$ is decolourised (orange to colourless) and a white precipitate forms.* *E (ethanol): no observable change (stays orange).* *F (cyclohexene): $Br_2(aq)$ is decolourised, but no precipitate.*
Equation	$C_6H_{10} + Br_2 \rightarrow C_6H_{10}Br_2$

© WJEC CBAC Ltd.

stemup.co.uk

Examiner only

Set **3**	
Solutions of	**G** chlorobenzene, C_6H_5Cl **H** (chloromethyl)benzene, $C_6H_5CH_2Cl$
Chemical test	*Warm gently with aqueous NaOH, then add dilute HNO_3 followed by silver nitrate solution, $AgNO_3(aq)$.*
Observations	*G (chlorobenzene): no observable change (no precipitate).* *H ((chloromethyl)benzene): a white precipitate (of AgCl) forms.*
Equation	*$Ag^+ + Cl^- \rightarrow AgCl$*

Set **4**	
Solutions of	**I** methyl ethanoate, CH_3COOCH_3 **J** ethanamide, CH_3CONH_2
Chemical test	*Warm gently with aqueous NaOH and hold damp red litmus paper at the mouth of the test tube.*
Observations	*I (methyl ethanoate): no observable change, the damp red litmus paper stays red.* *J (ethanamide): a pungent-smelling gas (NH_3) is given off which turns damp red litmus paper blue.*
Equation	*$CH_3CONH_2 + NaOH \rightarrow CH_3COONa + NH_3$*

A410U301
03

14

© WJEC CBAC Ltd.

stemup.co.uk

Examiner only

2. The percentage purity of a sample of powdered magnesium hydroxide was determined by a back titration as follows.

Step	Method
1	2.762 g of a sample of powdered magnesium hydroxide was transferred into a 250 cm^3 beaker, and approximately 200 cm^3 of 0.460 mol dm^{-3} hydrochloric acid added. The solution was warmed gently and stirred until the powder had all reacted.
2	This solution was transferred quantitatively into a 250 cm^3 volumetric flask and **made up to the mark with more of the same hydrochloric acid**. The flask was shaken well to ensure the solution was homogeneous. The solution was labelled as solution **W**.
3	A burette was prepared by rinsing twice with an appropriate solution before filling with 0.148 mol dm^{-3} aqueous sodium hydroxide. The initial burette reading was taken.
4	25.0 cm^3 of solution **W** was transferred into a conical flask and 3–4 drops of phenolphthalein indicator added. The excess hydrochloric acid present was titrated with the sodium hydroxide until the solution turned a permanent pink colour. The volume of sodium hydroxide used was recorded.
5	The titration was repeated until concordant volumes of sodium hydroxide were obtained.

(a) Give the equation for the reaction of magnesium hydroxide with hydrochloric acid (step 1). [1]

$Mg(OH)_2 + 2HCl \rightarrow MgCl_2 + 2H_2O$

© WJEC CBAC Ltd.

stemup.co.uk

Examiner only

(b) (i) Describe how the solution was transferred quantitatively into the volumetric flask (step 2). [1]

Pour the solution into the volumetric flask through a funnel, then rinse the beaker, glass rod and funnel with more of the hydrochloric acid, making sure all the washings go into the flask.

(ii) State why the solution is transferred in this way. [1]

So that no analyte is lost: everything that was in the beaker goes into the flask, so you know exactly what is in the flask.

(c) (i) Identify the appropriate solution with which to rinse the burette (step 3). [1]

The same sodium hydroxide solution used to fill the burette.

(ii) Complete the results table below and use the concordant results to calculate the mean titre. [3]

Volume of NaOH(aq)	Titration 1	Titration 2	Titration 3	Titration 4	Titration 5
Initial burette reading / cm^3	2.90	0.55	6.15	21.90	0.90
Final burette reading / cm^3	25.95	23.25	28.00	43.85	22.80
Titre / cm^3	23.05	22.70	21.85	21.95	21.90

Concordant titres: 21.85, 21.95 and 21.90 cm^3

mean = (21.85 + 21.95 + 21.90) ÷ 3 = 21.90 cm^3

Mean titre = 21.90 cm^3

A410U301
05

© WJEC CBAC Ltd.

stemup.co.uk

Examiner only

(d) (i) Calculate the number of moles of excess hydrochloric acid in 250 cm^3 of solution **W**. [2]

$n(NaOH) = 0.148 \times 21.90 \div 1000 = 3.24 \times 10^{-3}$ mol

= n(excess HCl) in 25.0 cm^3 of solution W

in 250 cm^3: $3.24 \times 10^{-3} \times 10 = 0.0324$ mol

Number of moles of excess HCl = 0.0324 mol

(ii) Calculate the number of moles of hydrochloric acid that reacted with the powdered magnesium hydroxide. [2]

n(HCl) added = $0.460 \times 250 \div 1000 = 0.115$ mol

n(HCl) reacted = $0.115 - 0.0324 = 0.0826$ mol

Number of moles of HCl that reacted = 0.0826 mol

(iii) Calculate the percentage purity of the sample of powdered magnesium hydroxide. [2]

$n(Mg(OH)_2) = 0.0826 \div 2 = 0.0413$ mol

mass $Mg(OH)_2 = 0.0413 \times 58.32 = 2.409$ g

% purity = $2.409 \div 2.762 \times 100 = 87.2$

Percentage purity = 87.2 %

(e) The actual percentage purity is 80.3%.

Suggest the name of a contaminant that would prevent this experimental analysis from giving an accurate percentage purity. Explain your answer. [2]

Magnesium oxide: it would also react with the HCl, using more acid per gram than $Mg(OH)_2$, so the calculated purity is too high.

15

© WJEC CBAC Ltd.

stemup.co.uk

Examiner only

3. The standard enthalpy change for the thermal decomposition of potassium hydrogencarbonate is represented by the following equation.

$$2KHCO_3(s) \longrightarrow K_2CO_3(s) + CO_2(g) + H_2O(g) \qquad \Delta H_1$$

It is not possible to measure the enthalpy change for this reaction directly. However, it is possible to measure accurately the enthalpy changes for the following two reactions in a school laboratory.

$$KHCO_3(s) + HCl(aq) \longrightarrow KCl(aq) + CO_2(g) + H_2O(l) \qquad \Delta H_2$$

$$K_2CO_3(s) + 2HCl(aq) \longrightarrow 2KCl(aq) + CO_2(g) + H_2O(l) \qquad \Delta H_3$$

These enthalpy values can then be used to calculate ΔH_1 using Hess's Law.

Part 1: Enthalpy change of reaction of potassium carbonate (ΔH_3)

In an experiment to determine ΔH_3, a student used 30.0 cm^3 of 2.00 mol dm^{-3} hydrochloric acid and 2.29 g of powdered anhydrous potassium carbonate.

(a) Outline a method to determine the temperature change during the reaction. [2]

Put the acid in an insulated polystyrene cup and measure its temperature every 30 s until it is constant. At the next time interval add the powdered K_2CO_3 and stir. Keep recording the temperature every 30 s, then plot a temperature-time graph and extrapolate back to the time of mixing to find ΔT.

(b) If the student calculated the enthalpy change ΔH_3 to be –43.2 kJ mol^{-1}, calculate the change in temperature. You can assume that the acid is in excess. [2]

$n(K_2CO_3) = 2.29 \div 138.2 = 0.0166$ mol

heat released $= 43.2 \times 10^3 \times 0.0166 = 717$ J

$\Delta T = 717 \div (30.0 \times 4.18) = 5.7$ °C

Change in temperature = 5.7 °C

A410U301 07

© WJEC CBAC Ltd.

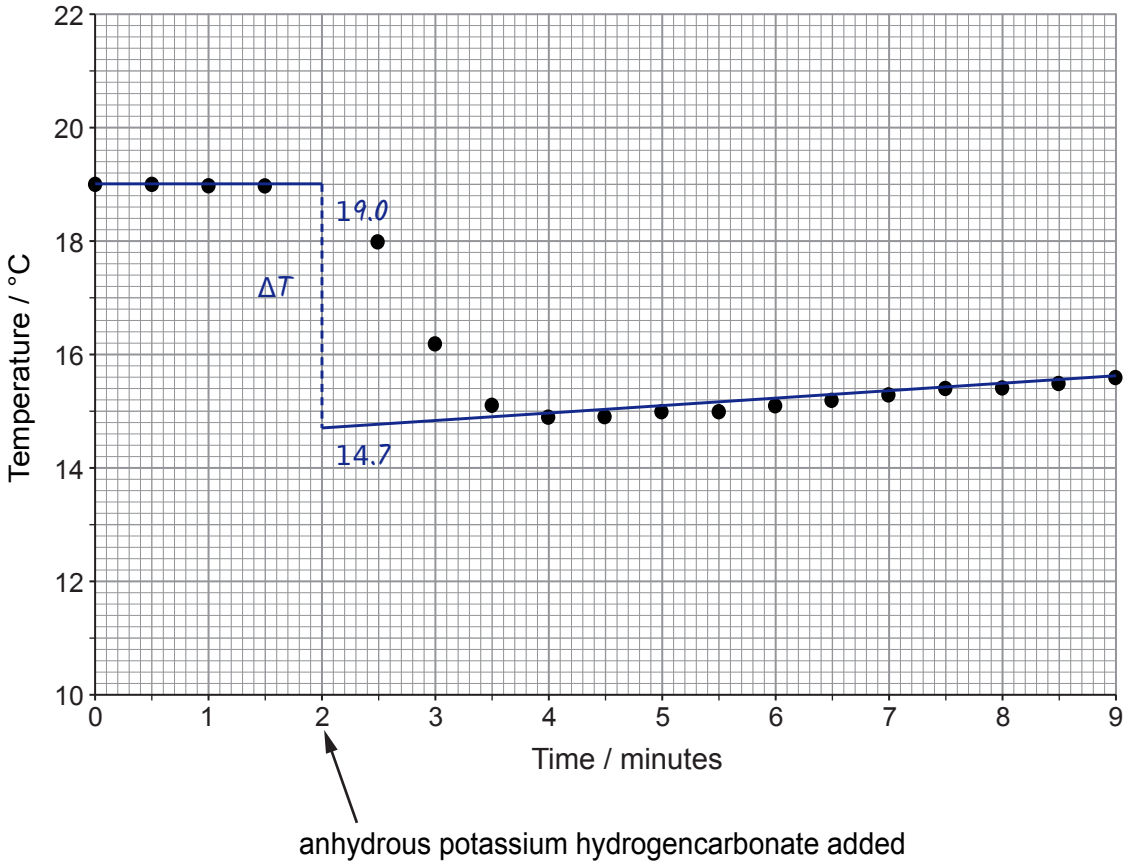
stemup.co.uk

Examiner only

Part 2: Enthalpy change of reaction of potassium hydrogencarbonate (ΔH_2)

A similar experiment was used to determine ΔH_2, using 30.0 cm^3 of hydrochloric acid (an excess) and 4.03 g of anhydrous potassium hydrogencarbonate.

The resulting temperature/time plot is given below.



(c) Determine the maximum temperature change by drawing appropriate lines to complete the graph. [2]

14.7 − 19.0 = −4.3

ΔT = −4.3 °C

(d) Calculate the molar enthalpy change of reaction, ΔH_2. [2]

$n(KHCO_3) = 4.03 \div 100.1 = 0.0403$ mol

$q = 30.0 \times 4.18 \times 4.3 = 539$ J (heat absorbed)

$\Delta H_2 = +539 \div 0.0403 = +13\,400$ J mol^{-1}

ΔH_2 = +13.4 kJ mol^{-1}

© WJEC CBAC Ltd.

stemup.co.uk

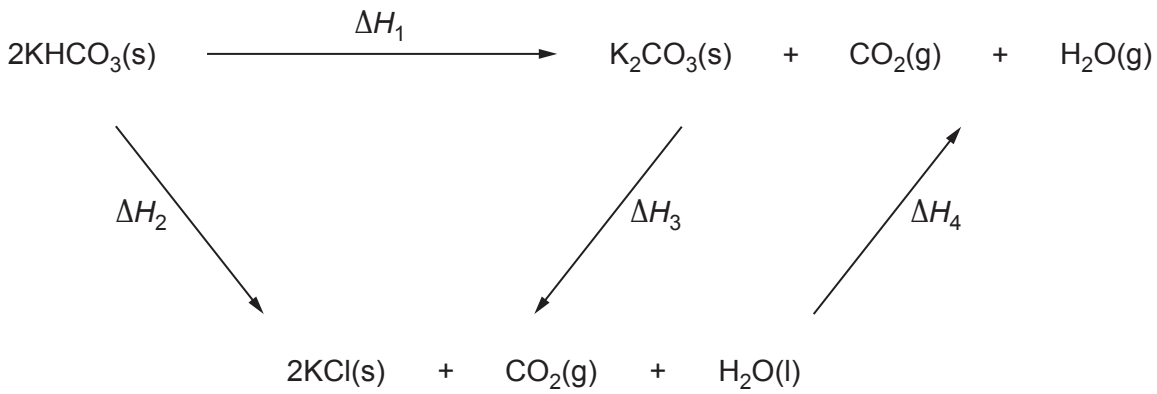
Examiner only

Part 3: Enthalpy change of thermal decomposition of potassium hydrogencarbonate (ΔH_1)

(e) The enthalpy of vaporisation of water, ΔH_4, is 40.8 kJ mol^{-1}.

$$H_2O(l) \longrightarrow H_2O(g) \qquad \Delta H_4$$

Use the Hess's cycle shown below, and the values of ΔH_2, ΔH_3 and ΔH_4, to calculate the value of the standard enthalpy change of thermal decomposition of potassium hydrogencarbonate, ΔH_1. [2]



$\Delta H_1 = 2\Delta H_2 - \Delta H_3 + \Delta H_4$

$= (2 \times 13.4) - (-43.2) + 40.8$

$= 26.8 + 43.2 + 40.8 = +110.8$ kJ mol^{-1}

ΔH_1 = +110.8 kJ mol^{-1}

(f) Suggest **one** reason why the enthalpy change for this reaction cannot be determined directly by calorimetry. [1]

The reaction needs strong heating (a large amount of heat) to take place, so the temperature change due to the reaction cannot sensibly be measured.

11

A410U301 09

© WJEC CBAC Ltd.

stemup.co.uk

BLANK PAGE

PLEASE DO NOT WRITE ON THIS PAGE

© WJEC CBAC Ltd.

stemup.co.uk

Examiner only

4. (a) The indicator thymol blue, which can be represented by the formula H Ind, is a weak acid.

It dissociates in solution and has a pK_a value of 8.9.

$$\underset{\text{yellow}}{H\,Ind(aq)} \rightleftharpoons H^+(aq) + \underset{\text{blue}}{Ind^-(aq)}$$

In an acid-base titration sodium hydroxide is added from a burette using thymol blue as an indicator. State the colour change that will occur, giving a reason for your answer. [2]

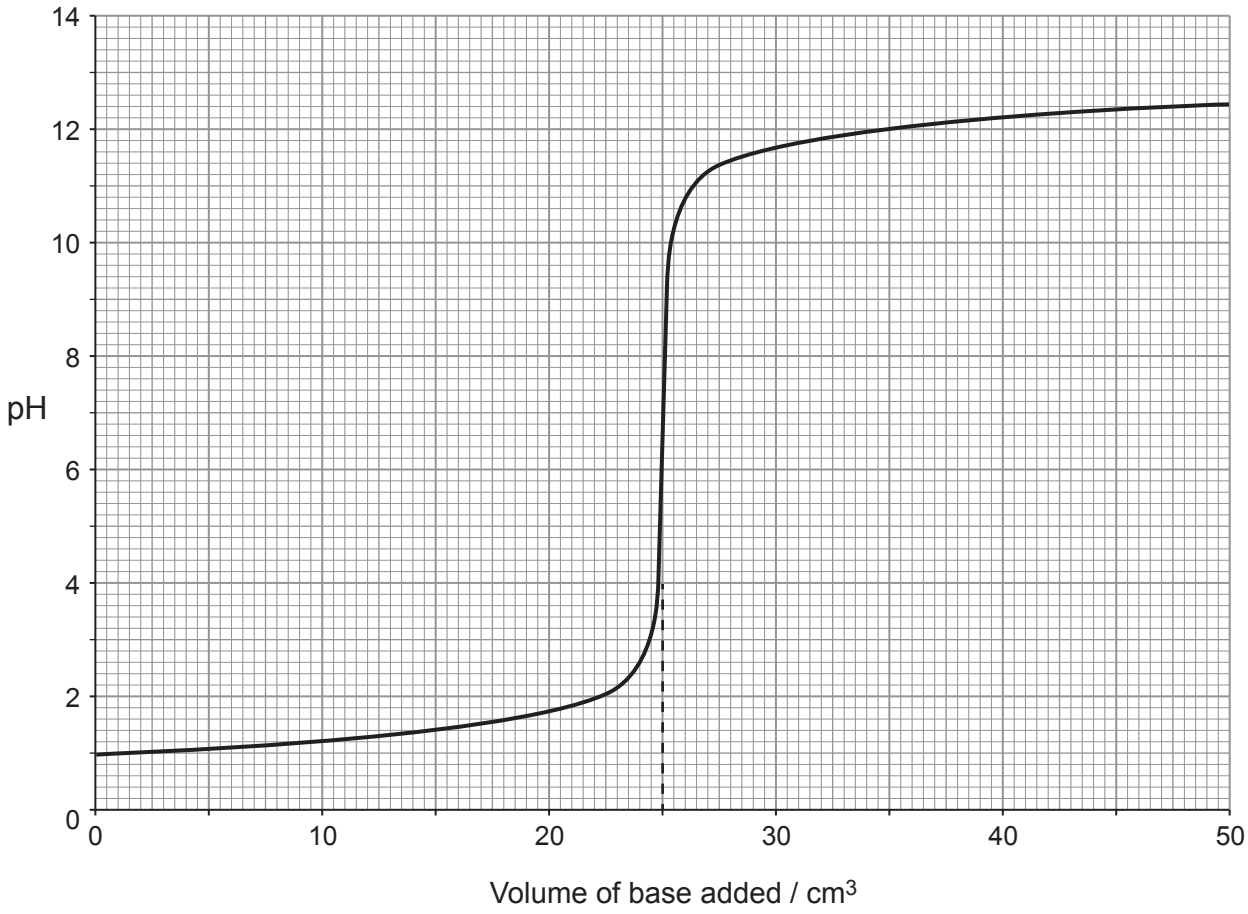
Yellow to blue. The added OH^- ions remove H^+ ions (forming water), so the equilibrium position shifts to the right (RHS), increasing $[Ind^-]$ once the pH rises above about 8.9.

© WJEC CBAC Ltd.

stemup.co.uk

Examiner only

(b) (i) The following curve shows how the pH changes during the titration of a $0.10\,\text{mol}\,\text{dm}^{-3}$ solution of a strong acid against a $0.10\,\text{mol}\,\text{dm}^{-3}$ solution of a strong base.



Draw the titration curve obtained when $50.0\,\text{cm}^3$ of a $0.10\,\text{mol}\,\text{dm}^{-3}$ solution of a strong base is added gradually to $25.0\,\text{cm}^3$ of a $0.10\,\text{mol}\,\text{dm}^{-3}$ solution of a weak acid.

The weak acid has a K_a value of $1.80 \times 10^{-5}\,\text{mol}\,\text{dm}^{-3}$ at 298 K.

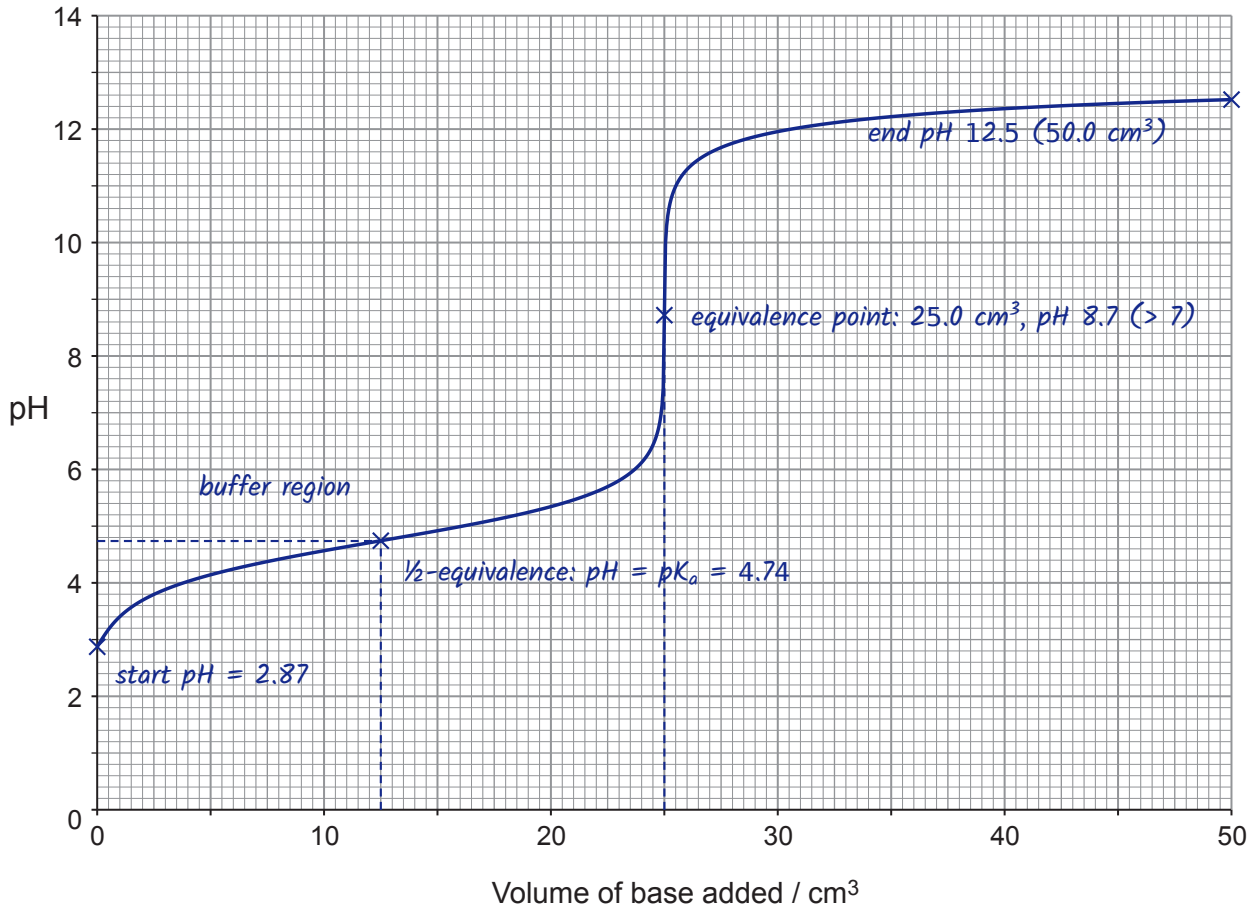
Give the pH values at key points during the titration and explain their significance.

[6 QER]

© WJEC CBAC Ltd.

stemup.co.uk

Examiner only



Start: $[H^+] = \sqrt{(K_a[HA])} = \sqrt{(1.80 \times 10^{-5} \times 0.10)} = 1.34 \times 10^{-3}$ mol dm^{-3}, so initial pH = 2.87 (higher than pH 1 for the strong acid as the weak acid is only partly dissociated).

The pH rises a little, then changes only slowly in the buffer region: the solution contains both HA and its salt A^-, so added OH^- is removed by HA.

At half-equivalence (12.5 cm^3 of base) [salt] = [acid], so $K_a = [H^+]$ and pH = $pK_a = -\log(1.80 \times 10^{-5}) = 4.74$ (about 4.7).

© WJEC CBAC Ltd.

stemup.co.uk

Examiner only

(ii) From the table below, suggest an appropriate indicator to use in this weak acid/strong base titration. Explain your answer. [1]

pH	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Indicator **A**					red		yellow								
Indicator **B**							yellow		blue						
Indicator **C**									colourless		red				

Indicator C, because its pH range (colour change, about pH 8 to 10) lies on the vertical portion of the curve at the equivalence point.

© WJEC CBAC Ltd.

stemup.co.uk

Examiner only

(c) An aqueous buffer was made by mixing 250 cm^3 of 0.262 mol dm^{-3} sodium propanoate and 500 cm^3 of 0.150 mol dm^{-3} propanoic acid at 298 K.

(K_a for propanoic acid = 1.34×10^{-5} mol dm^{-3} at 298 K)

(i) State the function of the sodium propanoate in the buffer solution. [1]

The propanoate ions remove added H^+ ions: $CH_3CH_2COO^- + H^+ \rightarrow CH_3CH_2COOH$, so the pH stays almost constant.

(ii) Calculate the pH of the buffer solution at 298 K. [3]

[propanoic acid] = (0.500 × 0.150) ÷ 0.750 = 0.100 mol dm^{-3}

[propanoate] = (0.250 × 0.262) ÷ 0.750 = 0.0873 mol dm^{-3}

$K_a = [H^+][salt] \div [acid]$, so $[H^+] = K_a \times [acid] \div [salt]$

$[H^+] = 1.34 \times 10^{-5} \times 0.100 \div 0.0873 = 1.54 \times 10^{-5}$ mol dm^{-3}

$pH = -\log(1.54 \times 10^{-5}) = 4.81$

pH = 4.81

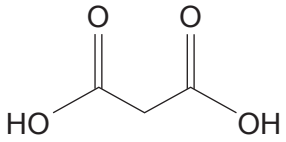
13

© WJEC CBAC Ltd.

stemup.co.uk

Examiner only

5. Malonic acid was first obtained in 1858 by the oxidation of malic acid, which is found in unripe apples.



malonic acid

(a) Give the systematic name of malonic acid. [1]

propanedioic acid

© WJEC CBAC Ltd.

stemup.co.uk

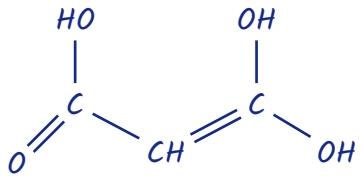
Examiner only

(b) Both malonic acid and compound **X** have the same molecular formula. Some of the properties of compound **X** are given below.

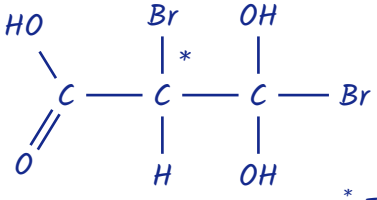
- Compound **X** does **not** show optical or geometric isomerism.
- The simplified ^{1}H NMR spectrum of compound **X** shows three separate peaks in the area ratio 1 : 1 : 2.
- A solution, containing 0.704 g of compound **X**, on reaction with excess sodium carbonate, gives 83.0 cm^3 of a colourless gas at 25°C and 1 atm pressure.
- Compound **X** does **not** react with 2,4-DNPH.
- Compound **X** decolourises aqueous bromine to form compound **Y** which has a chiral carbon.

Use **all** the information to identify and give the structures of compound **X** and compound **Y**. Show the chiral carbon in compound **Y**. [6]

Compound X



Compound Y



* = chiral carbon

No reaction with 2,4-DNPH, so X has no carbonyl group (no aldehyde or ketone C=O).

Decolourises aqueous bromine, so X contains a C=C bond.

Reacts with Na_2CO_3 giving a colourless gas (CO_2), so a carboxylic acid group is present.

$n(CO_2) = 83.0 \times 10^{-3} \div 24.5 = 3.39 \times 10^{-3}$ mol; $n(X) = 0.704 \div 104.04 = 6.77 \times 10^{-3}$ mol.

Ratio CO_2 : X = 1 : 2, so X has only one COOH group ($2RCOOH + Na_2CO_3 \rightarrow 2RCOONa + CO_2 + H_2O$).

(continued on the additional page)

END OF PAPER

7

© WJEC CBAC Ltd.

stemup.co.uk

Question number	Additional page, if required. Write the question number(s) in the left-hand margin.
4(b)(i)	The equivalence point is at 25.0 cm^3 of base ($n(OH^-) = n(HA) = 2.50 \times 10^{-3}$ mol). The vertical section is shorter (about pH 7 to 11) and the pH at the equivalence point is greater than 7 (about 8.7). This is because the solution now contains only the salt of a weak acid and a strong base: the A^- ions are hydrolysed by water, $A^- + H_2O \rightleftharpoons HA + OH^-$, forming OH^- ions. After the equivalence point the curve follows the strong base curve, levelling off at pH 12 to 13 (pH 12.5 when a total of 50.0 cm^3 of base has been added, $[OH^-] = 0.0333$ mol dm^{-3}).
5(b)	No optical isomerism: no carbon atom in X is bonded to four different groups (no chiral carbon). X shows no geometric isomerism because one carbon of the C=C has two identical OH groups attached. The ^1H NMR peaks 1 : 1 : 2 are: carboxylic acid OH (1H), CH=C (1H) and the two alcohol OH groups on the same carbon (2H). Adding Br_2 across the C=C gives Y, $(HO)_2CBr–CHBr–COOH$; the CHBr carbon is chiral as it has four different groups (H, Br, COOH and $CBr(OH)_2$).

Examiner only

© WJEC CBAC Ltd.

stemup.co.uk

Question number	Additional page, if required. Write the question number(s) in the left-hand margin.

Examiner only

© WJEC CBAC Ltd.

stemup.co.uk

BLANK PAGE

PLEASE DO NOT WRITE ON THIS PAGE

© WJEC CBAC Ltd.

stemup.co.uk

GCE A LEVEL

A410U30-1A

Z22-A410U30-1A

THURSDAY, 23 JUNE 2022 – MORNING

CHEMISTRY – A level component 3
Data Booklet

Avogadro constant	N_A	$= 6.02 \times 10^{23}\ \text{mol}^{-1}$
molar gas constant	R	$= 8.31\ \text{J mol}^{-1}\ \text{K}^{-1}$
molar gas volume at 273 K and 1 atm	V_m	$= 22.4\ \text{dm}^3\ \text{mol}^{-1}$
molar gas volume at 298 K and 1 atm	V_m	$= 24.5\ \text{dm}^3\ \text{mol}^{-1}$
Planck constant	h	$= 6.63 \times 10^{-34}\ \text{J s}$
speed of light	c	$= 3.00 \times 10^{8}\ \text{m s}^{-1}$
density of water	d	$= 1.00\ \text{g cm}^{-3}$
specific heat capacity of water	c	$= 4.18\ \text{J g}^{-1}\ \text{K}^{-1}$
ionic product of water at 298 K	K_w	$= 1.00 \times 10^{-14}\ \text{mol}^2\ \text{dm}^{-6}$
fundamental electronic charge	e	$= 1.60 \times 10^{-19}\ \text{C}$

temperature (K) = temperature (°C) + 273

$1\ \text{dm}^3 = 1000\ \text{cm}^3$
$1\ \text{m}^3 = 1000\ \text{dm}^3$
1 tonne = 1000 kg
$1\ \text{atm} = 1.01 \times 10^5\ \text{Pa}$

Multiple	Prefix	Symbol
10^{-9}	nano	n
10^{-6}	micro	μ
10^{-3}	milli	m

Multiple	Prefix	Symbol
10^{3}	kilo	k
10^{6}	mega	M
10^{9}	giga	G

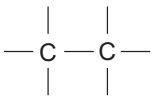
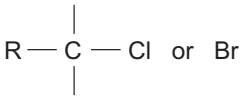
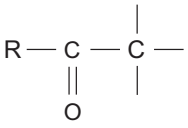
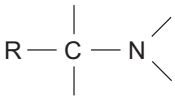
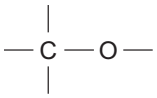
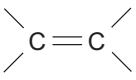
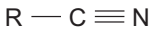
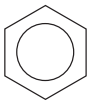
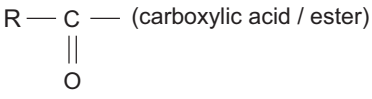
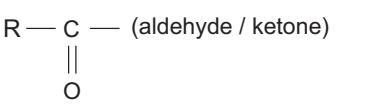
© WJEC CBAC Ltd.

stemup.co.uk

Infrared absorption values

Bond	Wavenumber / cm^{-1}
C — Br	500 to 600
C — Cl	650 to 800
C — O	1000 to 1300
C = C	1620 to 1670
C = O	1650 to 1750
C ≡ N	2100 to 2250
C — H	2800 to 3100
O — H (carboxylic acid)	2500 to 3200 (very broad)
O — H (alcohol / phenol)	3200 to 3550 (broad)
N — H	3300 to 3500

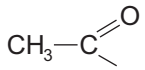
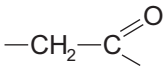
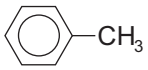
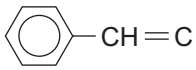
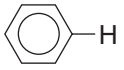
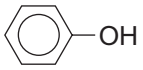
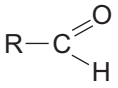
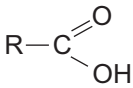
^{13}C NMR chemical shifts relative to TMS = 0

Type of carbon	Chemical shift, δ (ppm)
	5 to 40
	10 to 70
	20 to 50
	25 to 60
	50 to 90
	90 to 150
	110 to 125
	110 to 160
	160 to 185
	190 to 220

© WJEC CBAC Ltd.

stemup.co.uk

^{1}H NMR chemical shifts relative to TMS = 0

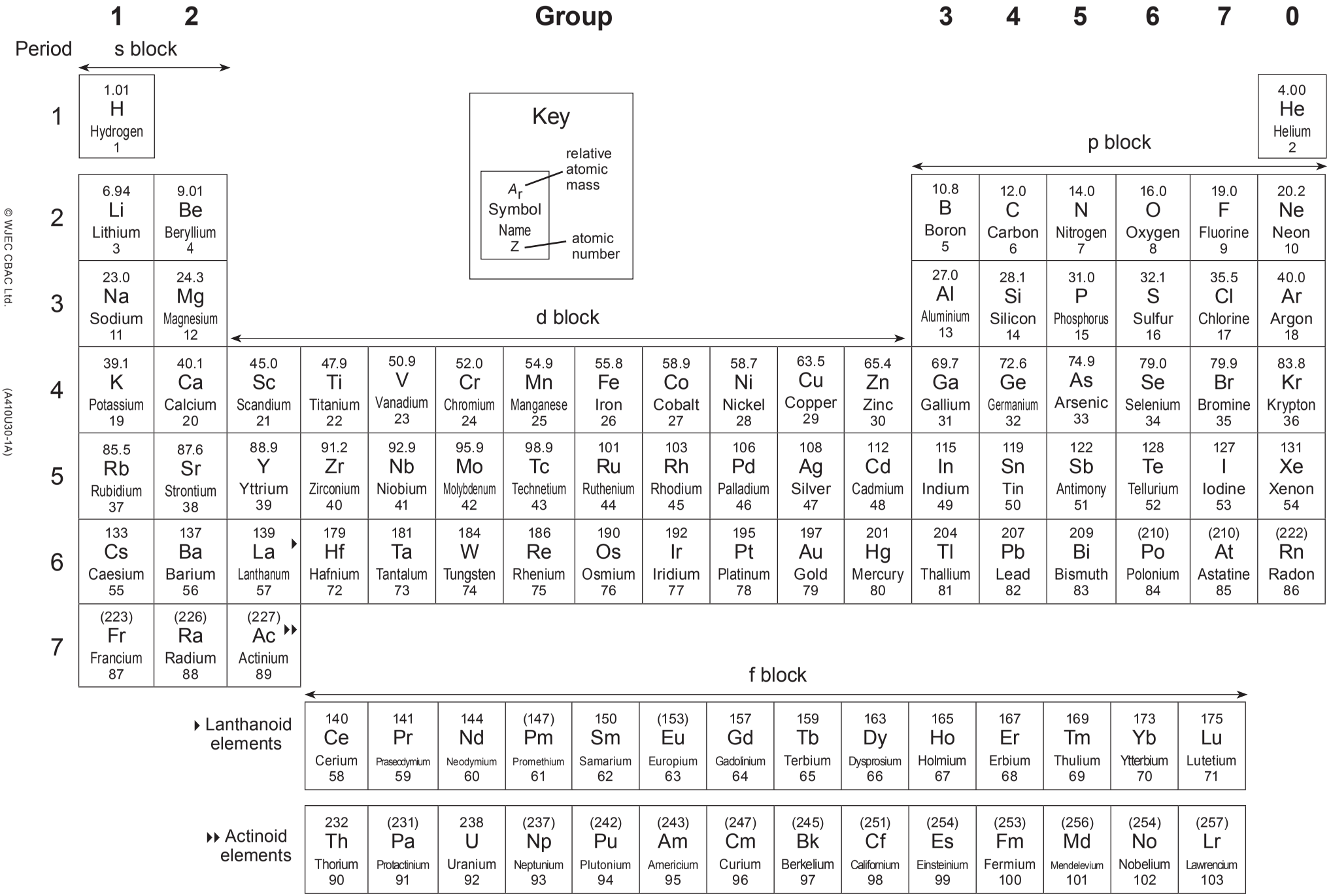
Type of proton	Chemical shift, δ (ppm)
$-CH_3$	0.1 to 2.0
$R-CH_3$	0.9
$R-CH_2-R$	1.3
$CH_3-C\equiv N$	2.0
	2.0 to 2.5
	2.0 to 3.0
	2.2 to 2.3
HC—Cl or HC—Br	3.1 to 4.3
HC—O	3.3 to 4.3
R—OH	4.5 *
—C=CH	4.5 to 6.3
—C=CH—CO	5.8 to 6.5
	6.5 to 7.5
	6.5 to 8.0
	7.0 *
	9.8 *
	11.0 *

*variable figure dependent on concentration and solvent

© WJEC CBAC Ltd.

stemup.co.uk

THE PERIODIC TABLE



© WJEC CBAC Ltd.

(A410U30-1A)

stemup.co.uk