Surname	Centre Number	Candidate Number
First name(s)		2

wjec cbac

GCE A LEVEL

A410U30-1

S23-A410U30-1

eduqas Part of WJEC

FRIDAY, 23 JUNE 2023 – MORNING

CHEMISTRY – A level component 3

Chemistry in Practice

1 hour 15 minutes

For Examiner's use only		
Question	**Maximum Mark**	**Mark Awarded**
1.	**10**	
2.	**17**	
3.	**6**	
4.	**10**	
5.	**17**	
Total	**60**	

A410U301
01

ADDITIONAL MATERIALS

- 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 **Q3**.

JUN23A410U30101

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Answer **all** questions.

1. The hydration of anhydrous sodium thiosulfate is represented by the following equation.

$$Na_2S_2O_3(s) + 5H_2O(l) \longrightarrow Na_2S_2O_3.5H_2O(s) \qquad \Delta H_1$$

It is not possible to measure the enthalpy change for this reaction directly. However, it is possible to measure the enthalpy changes of solution when hydrated sodium thiosulfate and anhydrous sodium thiosulfate are in turn dissolved in water.

$$Na_2S_2O_3.5H_2O(s) + aq \longrightarrow Na_2S_2O_3(aq) \qquad \Delta H_2$$

$$Na_2S_2O_3(s) + aq \longrightarrow Na_2S_2O_3(aq) \qquad \Delta H_3$$

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

Part I: Enthalpy change of solution of hydrated sodium thiosulfate, $Na_2S_2O_3.5H_2O$ (ΔH_2)

An experiment was carried out to determine ΔH_2.

- 50.0 cm^3 of water was added to an insulated polystyrene cup and the temperature was recorded every 30 seconds.
- At exactly 2 minutes, 12.38 g of hydrated sodium thiosulfate was added to the water in the cup and stirred.
- The temperature was recorded every 30 seconds for a further 8 minutes.
- The resulting temperature / time plot is shown opposite.

(a) Draw appropriate lines on the graph and use these to determine the maximum temperature change, ΔT. [2]

ΔT = ... °C

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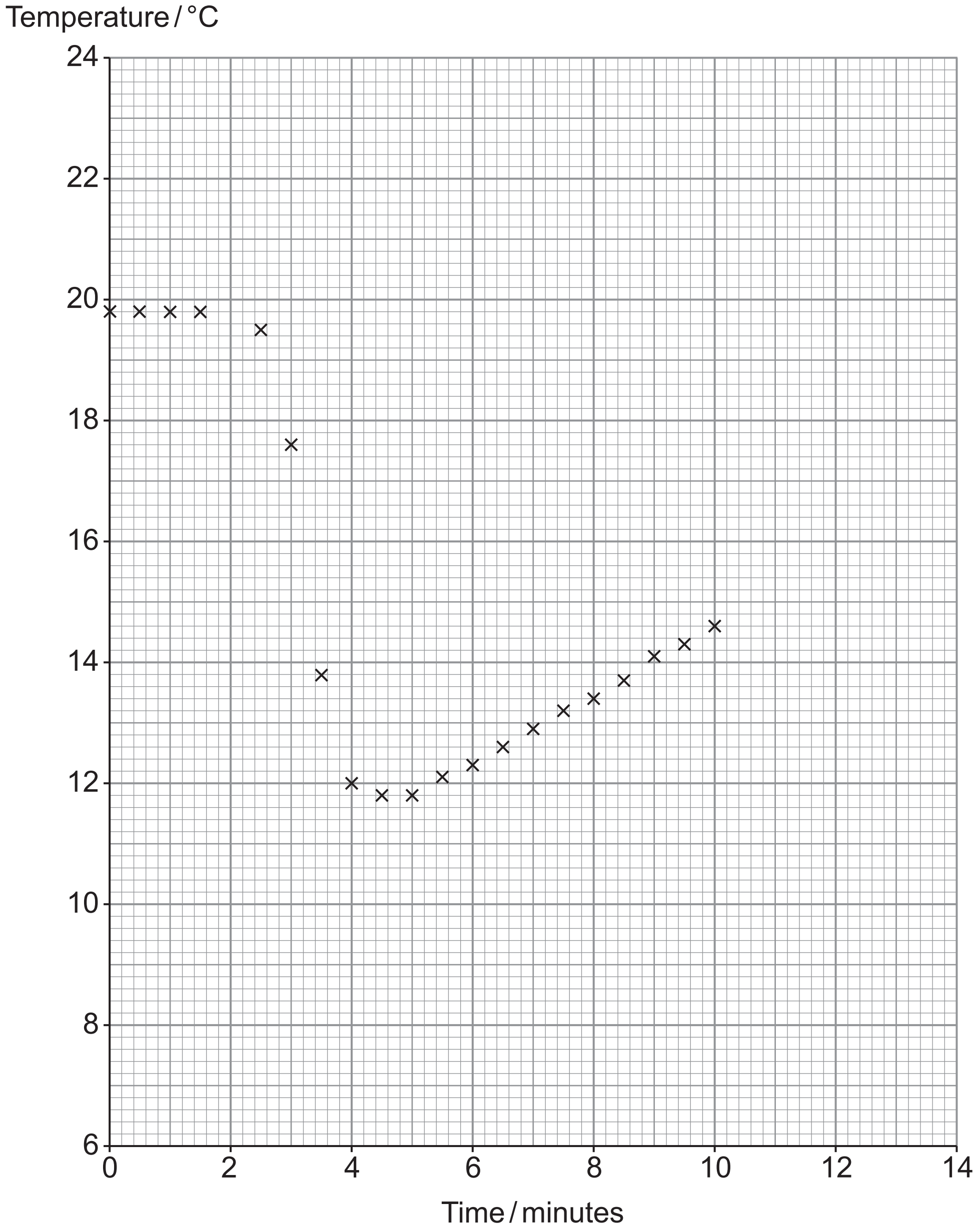

(b) Calculate the molar enthalpy change of solution of hydrated sodium thiosulfate, ΔH_2. [2]

ΔH_2 = ... $kJ\,mol^{-1}$

A410U301 03

Examiner only

(c) Give **one** assumption made when finding the value of ΔH_2 from the experimental results. [1]

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(d) Using your result in (a), deduce the maximum temperature change expected if twice the volume of water is used with the same mass of hydrated sodium thiosulfate. [1]

.... °C

Part II: Enthalpy change of solution of anhydrous sodium thiosulfate, $Na_2S_2O_3$ (ΔH_3)

To determine ΔH_3, a student measured 50.0 cm^3 of water into an insulated polystyrene cup and added a known mass of anhydrous sodium thiosulfate whilst stirring. The temperature recorded increased from 20.2°C to a maximum of 23.6°C.

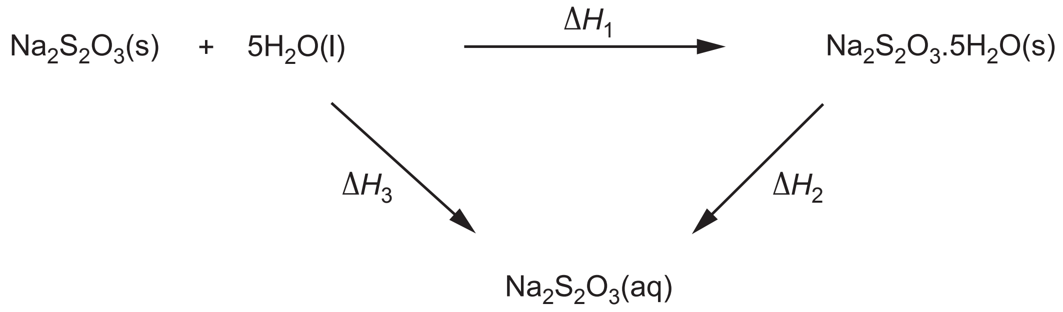
(e) If the value obtained for the molar enthalpy change of solution of anhydrous sodium thiosulfate, ΔH_3, was –14.2 $kJ\,mol^{-1}$, calculate the mass of anhydrous sodium thiosulfate added. [2]

Mass = ... g

Examiner only

Part III: Enthalpy change of hydration of anhydrous sodium thiosulfate (ΔH_1)

(f) The Hess's cycle connecting the three enthalpy terms is given below. Use this to calculate the value of ΔH_1. [1]



ΔH_1 = ... $kJ\,mol^{-1}$

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

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A410U301 05

10

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2. This question considers two different methods of preparing soluble salts.

Method 1: Solid and solution

In this method, an insoluble solid is added to a suitable solution to form a soluble salt.

One example is the reaction of excess copper(II) carbonate with hydrochloric acid to form copper(II) chloride.

$$CuCO_3(s) + 2HCl(aq) \longrightarrow CuCl_2(aq) + CO_2(g) + H_2O(l)$$

(a) State why this method uses excess copper(II) carbonate and not excess hydrochloric acid. [1]

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(b) Describe the practical steps for making pure, crystalline copper(II) chloride from solid copper(II) carbonate and hydrochloric acid. [3]

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(c) (i) In an experiment to prepare copper(II) chloride, a student was given 60.0 cm^3 of 0.500 $mol\,dm^{-3}$ hydrochloric acid.

Calculate the minimum mass of copper(II) carbonate (M_r 123.5) required for complete reaction. [2]

Mass = ... g

(ii) Hydrated copper(II) chloride, $CuCl_2.xH_2O$, is formed as a green crystalline solid.

Calculate the value of x if 2.56 g of pure $CuCl_2.xH_2O$ was obtained. [2]

x = ...

A410U301 07

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Method 2: Solution and solution

In this method, exact quantities of both reactants are used so that the final solution only contains the required salt.

A method that allows this is titration. One example is the titration of aqueous sodium carbonate with hydrochloric acid to form sodium chloride.

$$Na_2CO_3(aq) + 2HCl(aq) \longrightarrow 2NaCl(aq) + CO_2(g) + H_2O(l)$$

Methyl orange can be used as an indicator in this titration.

A student proposes to make solid sodium chloride by the following method.

Step 1	Fill a burette to the 0.00 cm^3 mark with approximately 0.50 mol dm^{-3} hydrochloric acid solution
Step 2	Carefully transfer 25.0 cm^3 of 0.250 mol dm^{-3} sodium carbonate solution to a conical flask
Step 3	Add 2–3 drops of methyl orange indicator
Step 4	Add the hydrochloric acid to the conical flask until the endpoint is near
Step 5	Continue to add acid drop by drop, washing down the walls of the flask with deionised water, until the indicator just changes colour
Step 6	Evaporate the solution formed to leave solid sodium chloride

(d) (i) State why it is not necessary to fill the burette to exactly zero (step 1). [1]

....

....

(ii) State why the walls of the flask should be washed down with deionised water before the indicator changes colour (step 5). [1]

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(iii) The teacher said that the method would not give pure sodium chloride.

State how the student should adapt the method in order to get pure solid sodium chloride. [1]

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(iv) Suggest **one** further improvement to the method. [1]

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(e) The student then decides to prepare a sample of solid potassium sulfate by titration, using the improved method.

He transfers 25.0 cm^3 of 0.250 $mol\,dm^{-3}$ potassium carbonate solution to a conical flask and titrates against approximately 0.50 $mol\,dm^{-3}$ sulfuric acid.

(i) Give the equation for the reaction of potassium carbonate with sulfuric acid. [1]

....

(ii) Explain why, in the preparation of solid potassium sulfate, the percentage error in the burette reading will be considerably greater than in the preparation of sodium chloride.

You should refer to the equations for the preparation of both salts in your answer. [2]

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A410U301
09

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(iii) $25.0\,cm^3$ of the $0.250\,mol\,dm^{-3}$ potassium carbonate solution was used in the preparation of potassium sulfate.

Calculate the volume, in cm^3, of carbon dioxide gas formed at 298 K and 1 atm. [2]

Volume = ... cm^3

17

Examiner only

3. Transition metals display basic or amphoteric behaviour.

Describe how you would use sulfuric acid and sodium hydroxide solution to determine whether iron(II) oxide and chromium(III) oxide are basic or amphoteric.

Include observations and equations in your answer. [6 QER]

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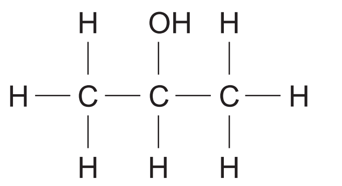
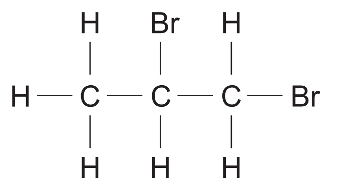
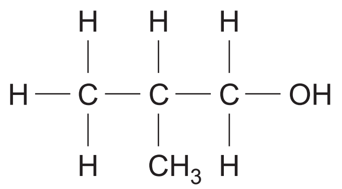
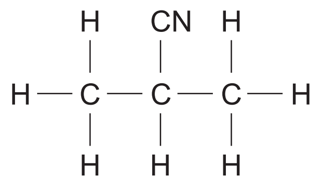
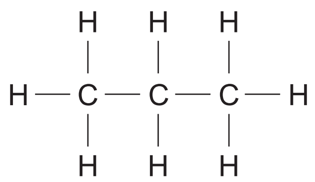
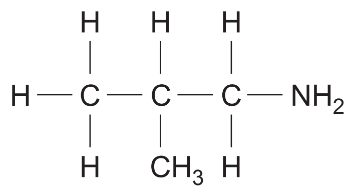
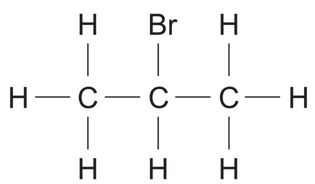
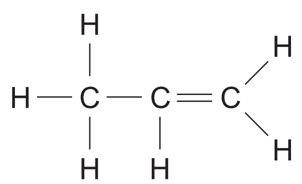
6

4. You are required to show how **each** of the eight compounds (**A–H**) below can be formed from any one of the other seven compounds.

Complete the table opposite, giving the **letter** of the starting compound, the reagent(s) and any necessary reaction conditions.

You may use each starting compound once, more than once or not at all. [10]

A		**B**	
C		**D**	
E		**F**	
G		**H**	

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Starting compound	Product	Reagent(s)	Conditions
	A		
	B		
	C		
	D		
	E		
	F		
	G		
	H		

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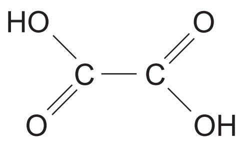
5. Ethanedioic acid, $H_2C_2O_4$, is a dicarboxylic acid which occurs in many plants. The structure of ethanedioic acid is shown below.



Ethanedioic acid has two acidic hydrogens and therefore has two acid dissociation constants, K_{a1} and K_{a2}.

None of the second hydrogens dissociate until all of the first hydrogens have dissociated.

The acid dissociation constants have values of 5.62×10^{-2} and 5.25×10^{-5} mol dm^{-3}, but not necessarily in this order.

(a) Write equations to represent both stages in the dissociation of ethanedioic acid.

For both dissociations, give the value of the respective dissociation constant and explain your choice. [3]

Equation	Value of K_a / mol dm^{-3}

Explanation for choice of K_a value

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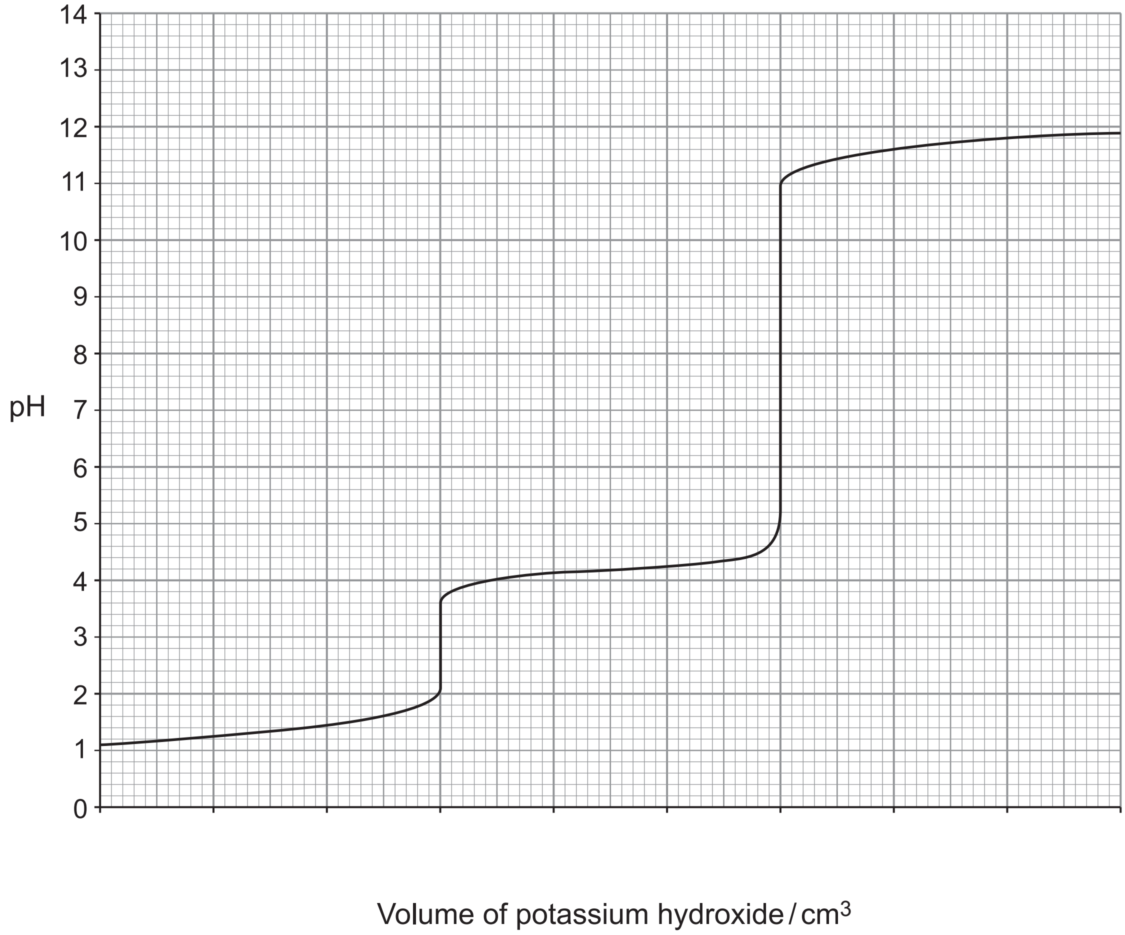
Turn over.

Examiner only

(b) The titration curve shows how the pH changes as a solution of potassium hydroxide is added to 30.0 cm^3 of a 0.112 mol dm^{-3} ethanedioic acid solution.



(i) Show that the initial pH of the 0.112 mol dm^{-3} solution of ethanedioic acid is 1.1. [3]

Examiner only

(ii) The potassium hydroxide solution had a concentration double that of the ethanedioic acid.

Complete the scale on the x-axis of the graph. Show your reasoning. [2]

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(c) Explain the terms **weak** and **dilute** as applied to acid solutions. [2]

Weak ....

....

Dilute ....

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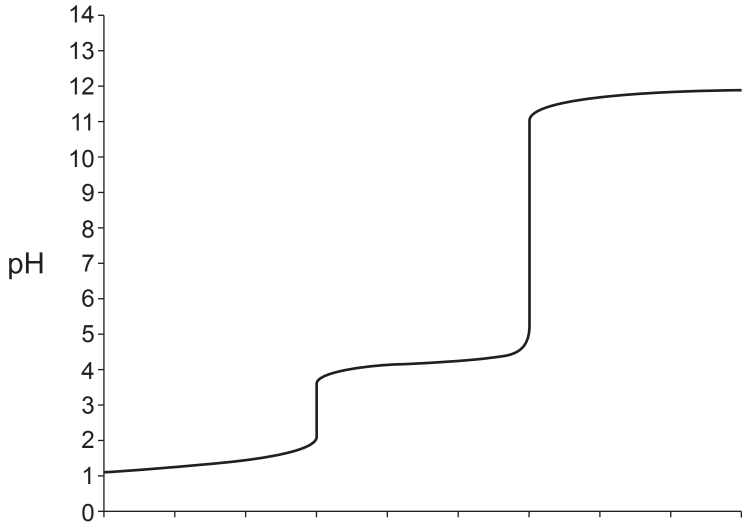
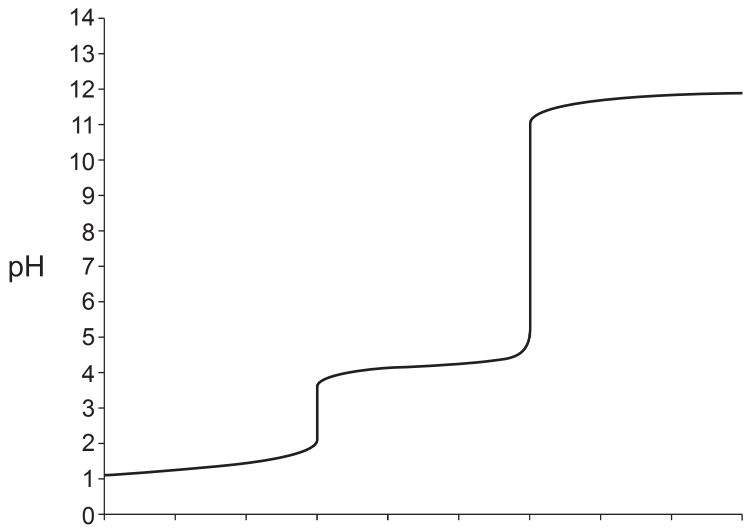
(d) (i) Sketch the titration curve obtained if the titration were repeated using 30.0 cm^3 of ethanedioic acid solution of **lower concentration**.

The concentration of the potassium hydroxide solution remains unchanged. [2]



(ii) Sketch the titration curve obtained if the titration were repeated using 30.0 cm^3 of a **different**, **weaker** dibasic acid, but of the **same concentration** as the ethanedioic acid.

Again, the concentration of the potassium hydroxide solution remains unchanged. [2]



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(e) (i) Outline how an indicator works. [1]

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(ii) Explain why two indicators are used in the titration of ethanedioic acid with potassium hydroxide solution. [2]

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17

END OF PAPER

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

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GCE A LEVEL

A410U30-1A

S23-A410U30-1A

FRIDAY, 23 JUNE 2023 – MORNING

CHEMISTRY – A level component 3
Data Booklet

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

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

1 dm^3 = 1000 cm^3
1 m^3 = 1000 dm^3
1 tonne = 1000 kg
1 atm = 1.01×10^5 Pa

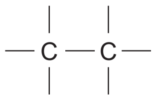
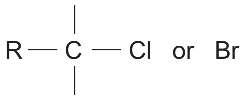
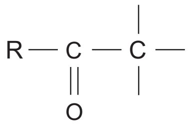
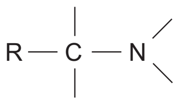
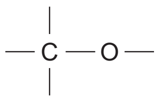
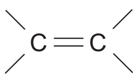
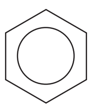
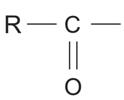
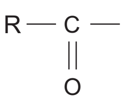
Multiple	Prefix	Symbol
10^{-9}	nano	n
10^{-6}	micro	µ
10^{-3}	milli	m

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

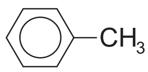
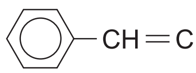
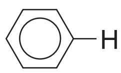
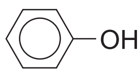
Infrared absorption values

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
 (carboxylic acid / ester)	160 to 185
 (aldehyde / ketone)	190 to 220

^{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
$CH_3-C(=O)-$	2.0 to 2.5
$-CH_2-C(=O)-$	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 *
$R-C(=O)H$	9.8 *
$R-C(=O)OH$	11.0 *

*variable figure dependent on concentration and solvent

THE PERIODIC TABLE

Key

A_r (relative atomic mass) Symbol Name Z (atomic number)

s block (Groups 1–2) · d block · p block (Groups 3–0) · f block

Period	1	2											3	4	5	6	7	0
1	1.01 H Hydrogen 1																	4.00 He Helium 2
2	6.94 Li Lithium 3	9.01 Be Beryllium 4											10.8 B Boron 5	12.0 C Carbon 6	14.0 N Nitrogen 7	16.0 O Oxygen 8	19.0 F Fluorine 9	20.2 Ne Neon 10
3	23.0 Na Sodium 11	24.3 Mg Magnesium 12											27.0 Al Aluminium 13	28.1 Si Silicon 14	31.0 P Phosphorus 15	32.1 S Sulfur 16	35.5 Cl Chlorine 17	40.0 Ar Argon 18
4	39.1 K Potassium 19	40.1 Ca Calcium 20	45.0 Sc Scandium 21	47.9 Ti Titanium 22	50.9 V Vanadium 23	52.0 Cr Chromium 24	54.9 Mn Manganese 25	55.8 Fe Iron 26	58.9 Co Cobalt 27	58.7 Ni Nickel 28	63.5 Cu Copper 29	65.4 Zn Zinc 30	69.7 Ga Gallium 31	72.6 Ge Germanium 32	74.9 As Arsenic 33	79.0 Se Selenium 34	79.9 Br Bromine 35	83.8 Kr Krypton 36
5	85.5 Rb Rubidium 37	87.6 Sr Strontium 38	88.9 Y Yttrium 39	91.2 Zr Zirconium 40	92.9 Nb Niobium 41	95.9 Mo Molybdenum 42	98.9 Tc Technetium 43	101 Ru Ruthenium 44	103 Rh Rhodium 45	106 Pd Palladium 46	108 Ag Silver 47	112 Cd Cadmium 48	115 In Indium 49	119 Sn Tin 50	122 Sb Antimony 51	128 Te Tellurium 52	127 I Iodine 53	131 Xe Xenon 54
6	133 Cs Caesium 55	137 Ba Barium 56	139 La ▸ Lanthanum 57	179 Hf Hafnium 72	181 Ta Tantalum 73	184 W Tungsten 74	186 Re Rhenium 75	190 Os Osmium 76	192 Ir Iridium 77	195 Pt Platinum 78	197 Au Gold 79	201 Hg Mercury 80	204 Tl Thallium 81	207 Pb Lead 82	209 Bi Bismuth 83	(210) Po Polonium 84	(210) At Astatine 85	(222) Rn Radon 86
7	(223) Fr Francium 87	(226) Ra Radium 88	(227) Ac ▸▸ Actinium 89															

▸ Lanthanoid elements	140 Ce Cerium 58	141 Pr Praseodymium 59	144 Nd Neodymium 60	(147) Pm Promethium 61	150 Sm Samarium 62	(153) Eu Europium 63	157 Gd Gadolinium 64	159 Tb Terbium 65	163 Dy Dysprosium 66	165 Ho Holmium 67	167 Er Erbium 68	169 Tm Thulium 69	173 Yb Ytterbium 70	175 Lu Lutetium 71
▸▸ Actinoid elements	232 Th Thorium 90	(231) Pa Protactinium 91	238 U Uranium 92	(237) Np Neptunium 93	(242) Pu Plutonium 94	(243) Am Americium 95	(247) Cm Curium 96	(245) Bk Berkelium 97	(251) Cf Californium 98	(254) Es Einsteinium 99	(253) Fm Fermium 100	(256) Md Mendelevium 101	(254) No Nobelium 102	(257) Lr Lawrencium 103