Surname	Centre Number	Candidate Number
First name(s)		2

GCE A LEVEL

A410U10-1

S23-A410U10-1

eduqas Part of WJEC

MONDAY, 12 JUNE 2023 – MORNING

CHEMISTRY – A level component 1

Physical and Inorganic Chemistry

2 hours 30 minutes

	For Examiner's use only		
	Question	Maximum Mark	Mark Awarded
Section A	1. to 6.	15	
Section B	7.	19	
	8.	17	
	9.	13	
	10.	24	
	11.	18	
	12.	14	
	Total	120	

A410U101 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.

Section A Answer **all** questions.
Section B 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 120.

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.7**(a) and **Q.11**(a).

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SECTION A

Answer **all** questions.

1. The electronegativity values of some elements are listed in the table.

Element	Si	F	Cl
Electronegativity value	1.8	4.0	3.5

(a) State what is meant by the term electronegativity. [1]

....

....

(b) Label the bonds below with δ+ and δ– to show any dipoles that are present. [1]

Si — Cl   F — Cl

2. Name the feature of the atomic emission spectrum of hydrogen that can be used to find the ionisation energy of the atom. [1]

....

Examiner only

3. There are many isotopes of the artificial element americium.

(a) One isotope of americium has a half-life of 12 hours.

Calculate the percentage of a sample of this isotope that would remain after 2 days. [2]

Percentage remaining = ... %

(b) Another isotope of americium, ^{238}Am, can decay by either positron emission or by α-emission.

Identify the isotopes produced in both cases. [2]

Positron emission

Element symbol .... Mass number ....

α-emission

Element symbol .... Mass number ....

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4. An iodine clock reaction was studied using different concentrations of reactants.

The time taken for the colour to change was measured.

Concentration of I^- / mol dm^{-3}	Concentration of H_2O_2 / mol dm^{-3}	Time for colour change / s	Rate
0.20	0.10	49.7	....
0.20	0.20	24.9	....
0.40	0.20	12.4	....

(a) (i) Complete the table with the rate values for these experiments. [1]

(ii) Give the unit of rate for these experiments. [1]

Unit ....

(b) Describe the relationship between the concentration of hydrogen peroxide and the rate of reaction. [1]

....

....

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5. Hydrogen chloride forms the strong acid hydrochloric acid when dissolved in water.

In one experiment the pH of the hydrochloric acid formed was 0.32.

(a) Draw a dot and cross diagram for hydrogen chloride. [1]

(b) State what is meant by the term strong acid. [1]

....

....

(c) Calculate the concentration of hydrochloric acid of pH 0.32. [1]

Concentration = ... $mol\,dm^{-3}$

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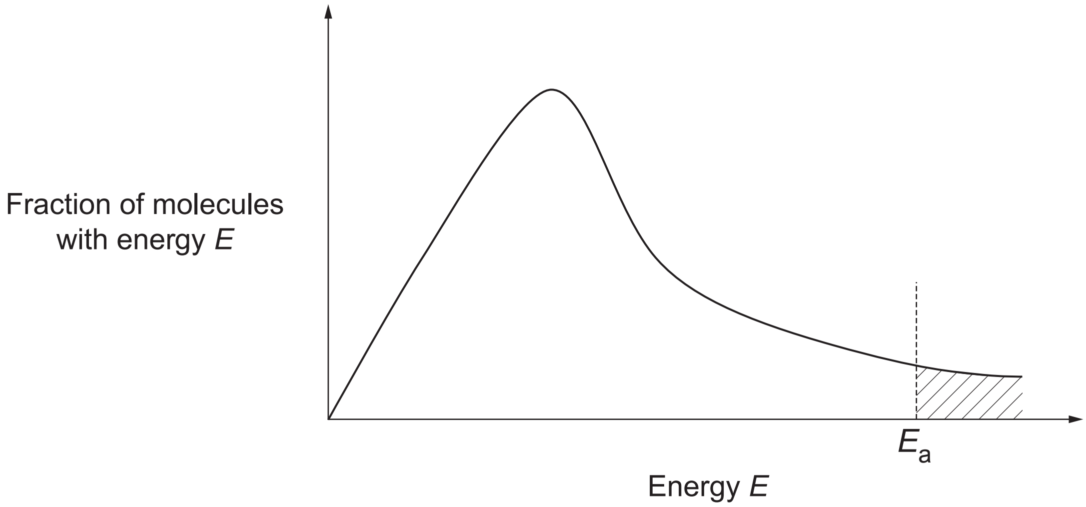
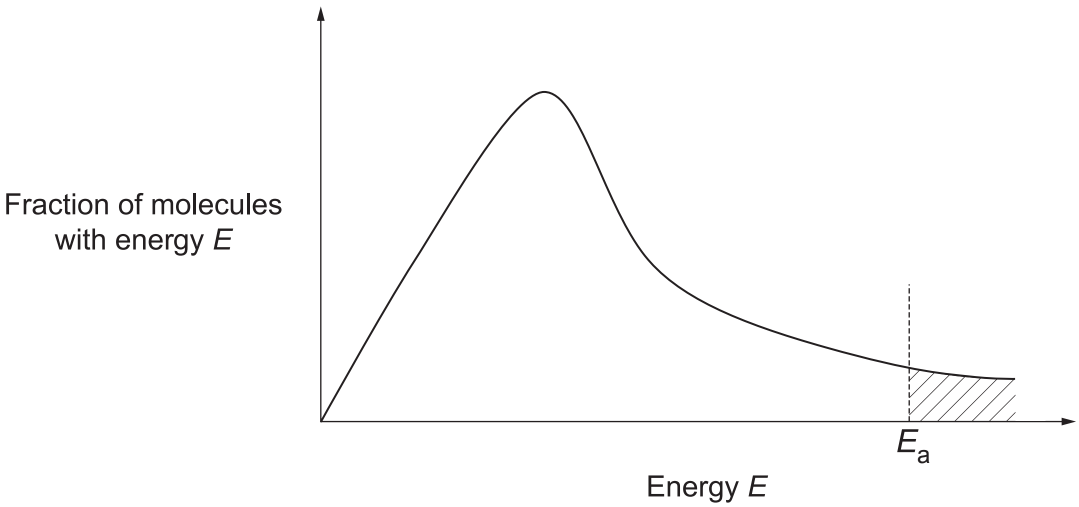
6. The graphs below show the energy distribution of particles at 298 K.

(a) Sketch the distribution at a lower temperature on the same axes. [1]



(b) Label the graph to show how catalysts increase the rate of chemical reactions. [1]



15

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SECTION B

Answer **all** questions.

7. The elements at the top and bottom of Group 4 have very different physical and chemical properties.

(a) Describe the bonding and structures present in lead and **one** common elemental form of carbon.

You should explain how the bonding and structures affect the melting temperatures and electrical conductivity of these elements. [6 QER]

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(b) A student is provided with a mixture of lead(II) oxide, PbO, and lead(IV) oxide, PbO_2.

To find the percentage by mass of each oxide in the sample the student treats the mixture with iodide ions in acid solution.

- Lead(IV) oxide oxidises the iodide ions in acid solution. This produces a precipitate of lead(II) iodide and an aqueous solution of iodine.

$$PbO_2 + 4I^- + 4H^+ \longrightarrow PbI_2 + I_2 + 2H_2O$$

- Lead(II) oxide reacts with the iodide ions in acid solution. This produces a precipitate of lead(II) iodide.

$$PbO + 2I^- + 2H^+ \longrightarrow PbI_2 + H_2O$$

The solution and solid are separated by filtration. The solid is washed in cold water and the washings added to the solution. The solution is titrated using aqueous sodium thiosulfate of concentration 0.100 mol dm^{-3} to find the amount of iodine present. The solid sample is heated to constant mass.

The results are given below.

Mass of precipitate = 2.425 g

Volume of aqueous sodium thiosulfate required = 33.45 cm^3

(i) Give the colour of the lead(II) iodide precipitate. [1]

....

(ii) Calculate the number of moles of lead(II) iodide formed. [2]

Number of moles = ... mol

(iii) The thiosulfate ions act as reducing agents.

$$2S_2O_3^{2-} \longrightarrow S_4O_6^{2-} + 2e^-$$

Write the equation for the reduction of iodine by thiosulfate ions. [1]

....

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(iv) Suggest a suitable indicator for this titration, giving the colour change expected at the endpoint. [2]

....

....

(v) Calculate the number of moles of lead(IV) oxide present. [3]

Number of moles = ... mol

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(vi) Calculate the percentage by mass of lead(IV) oxide in the initial sample. [4]

Percentage by mass = ... %

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8. Transition metals form a range of ions that can combine with ligands to form complex ions.

(a) Write the electron arrangement for the Mn^{2+} ion. [1]

....

(b) (i) Cobalt(II) ions form complexes including $[CoCl_4]^{2-}$ and $[Co(H_2O)_6]^{2+}$.

State the colours of these ions in aqueous solution. [2]

$[CoCl_4]^{2-}$ ....

$[Co(H_2O)_6]^{2+}$ ....

(ii) Explain why octahedral transition metal complexes such as $[Co(H_2O)_6]^{2+}$ are coloured. [3]

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Examiner only

(c) Transition metal compounds are used in heterogeneous catalysts for a range of industrial processes.

(i) State what is meant by the term heterogeneous catalyst. [1]

....

....

(ii) One industrial process that uses a heterogeneous catalyst is the carbonylation of methanol (Method 1).

$$CH_3OH + CO \rightleftharpoons CH_3COOH$$

This reaction is usually carried out in the gas phase.

An equimolar gas phase mixture of CH_3OH and CO is allowed to come to equilibrium and the resultant mixture contains 10.8% CH_3COOH at a total pressure of 3.21×10^6 Pa.

Calculate the value of K_p for this equilibrium giving its unit. [4]

K_p = ...

Unit ....

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(iii) An alternative method of producing CH_3COOH uses carbon dioxide and hydrogen as reactants in place of carbon monoxide (Method 2).

$$CH_3OH + CO_2 + H_2 \rightleftharpoons CH_3COOH + H_2O$$

This reaction occurs in solution using a homogeneous catalyst containing ruthenium and rhodium compounds and converts 14.0% of the methanol to ethanoic acid at a pressure of 4.20×10^6 Pa.

Suggest which of methods 1 and 2 is the better method. Give reasons for your answer. [3]

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(d) Most metals react with acids to produce a salt and hydrogen gas. Copper metal does not react in this way but it does react with nitric acid, HNO_3, in a different reaction.

Use the values of standard electrode potentials given in the table to explain these observations, writing an equation for the reaction you expect to occur between copper metal and nitric acid. [3]

	Standard electrode potential, E^{θ}/V
$2H^+ + 2e^- \rightleftharpoons H_2$	+0.00
$Cu^{2+} + 2e^- \rightleftharpoons Cu$	+0.33
$NO_3^- + 2H^+ + e^- \rightleftharpoons NO_2 + H_2O$	+0.81

Equation

....

....

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9. Most Group 2 elements form oxides with similar properties.

(a) Draw a dot and cross diagram for the formation of magnesium oxide from atoms of its elements. [2]

(b) The enthalpy change of formation of magnesium oxide can be found experimentally by measuring the temperature rise in two reactions and calculating their respective enthalpy changes.

- Adding magnesium metal to an excess of dilute acid
- Adding magnesium oxide to an excess of dilute acid

Two students performed the experiment using the following method.

- Measure 50 cm^3 of hydrochloric acid of concentration 1.0 mol dm^{-3} using a burette and place in a polystyrene cup.
- Place a lid on the cup and fit a thermometer through this. The thermometer measures to the nearest 0.2°C.
- Measure the temperature every 30 seconds for 3 minutes.
- Measure precisely a known amount of magnesium metal.
- Add the solid at precisely 3 minutes, stirring well.
- Measure the temperature every 30 seconds for another 4 minutes.
- Repeat these steps using magnesium oxide.
- Plot the results and calculate the enthalpy changes.

Examiner only

(i) Tom decides to use the same mass of magnesium metal and magnesium oxide in his two experiments. He measures precisely 0.200 g of each and obtains the following results.

Results with magnesium metal

Time / s	0	30	60	90	120	150	180	210	240	270	300	330	360	390	420
Temperature / °C	19.2	19.4	19.4	19.4	19.4	19.4	xx	37.2	38.8	38.8	38.8	38.6	38.6	38.4	38.4

Results with magnesium oxide

Time / s	0	30	60	90	120	150	180	210	240	270	300	330	360	390	420
Temperature / °C	19.2	19.4	19.4	19.4	19.4	19.4	xx	22.0	22.4	22.8	22.8	22.6	22.6	22.6	22.4

Tom's teacher told him that his choice of mass of magnesium oxide has not given him suitable results and that he should repeat his experiment with a different mass.

I. Suggest why Tom's mass of magnesium oxide did not give suitable results. [1]

....

....

II. Tom decides to repeat both experiments using a mass of 1.00 g of each solid.

Suggest **two** reasons why 1.00 g would not be a suitable mass of magnesium metal to use. [2]

....

....

....

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Examiner only

(ii) Cerys carried out the same experiments and obtained the following enthalpy change values. All substances were in their standard states.

$$Mg + 2HCl \longrightarrow MgCl_2 + H_2 \qquad \Delta H = -521\,kJ\,mol^{-1}$$

$$MgO + 2HCl \longrightarrow MgCl_2 + H_2O \qquad \Delta H = -142\,kJ\,mol^{-1}$$

The enthalpy change of formation of H_2O is $-286\,kJ\,mol^{-1}$.

Use this data to calculate the enthalpy change of formation of magnesium oxide. [3]

ΔH = ... $kJ\,mol^{-1}$

 (A410U10-1)

Examiner only

(c) Barium oxide can be formed by heating barium carbonate.

$$BaCO_3(s) \longrightarrow BaO(s) + CO_2(g) \qquad \Delta H = 243\,kJ\,mol^{-1}$$

	$BaCO_3(s)$	$BaO(s)$	$CO_2(g)$
Standard entropy / $J\,K^{-1}\,mol^{-1}$	112	70	214

(i) Give a reason why the standard entropy values of $BaCO_3$ and BaO are lower than that of CO_2. [1]

....

....

(ii) Calculate the minimum temperature required for the thermal decomposition of barium carbonate. [4]

T = ... K

13

10. Chlorine forms a range of oxides and oxyanions. Many of these are reactive species that can oxidise or chlorinate a range of elements and compounds.

(a) Dichlorine heptoxide, Cl_2O_7, is a colourless liquid that can be formed by reaction of ozone with chlorine in the presence of ultraviolet light.

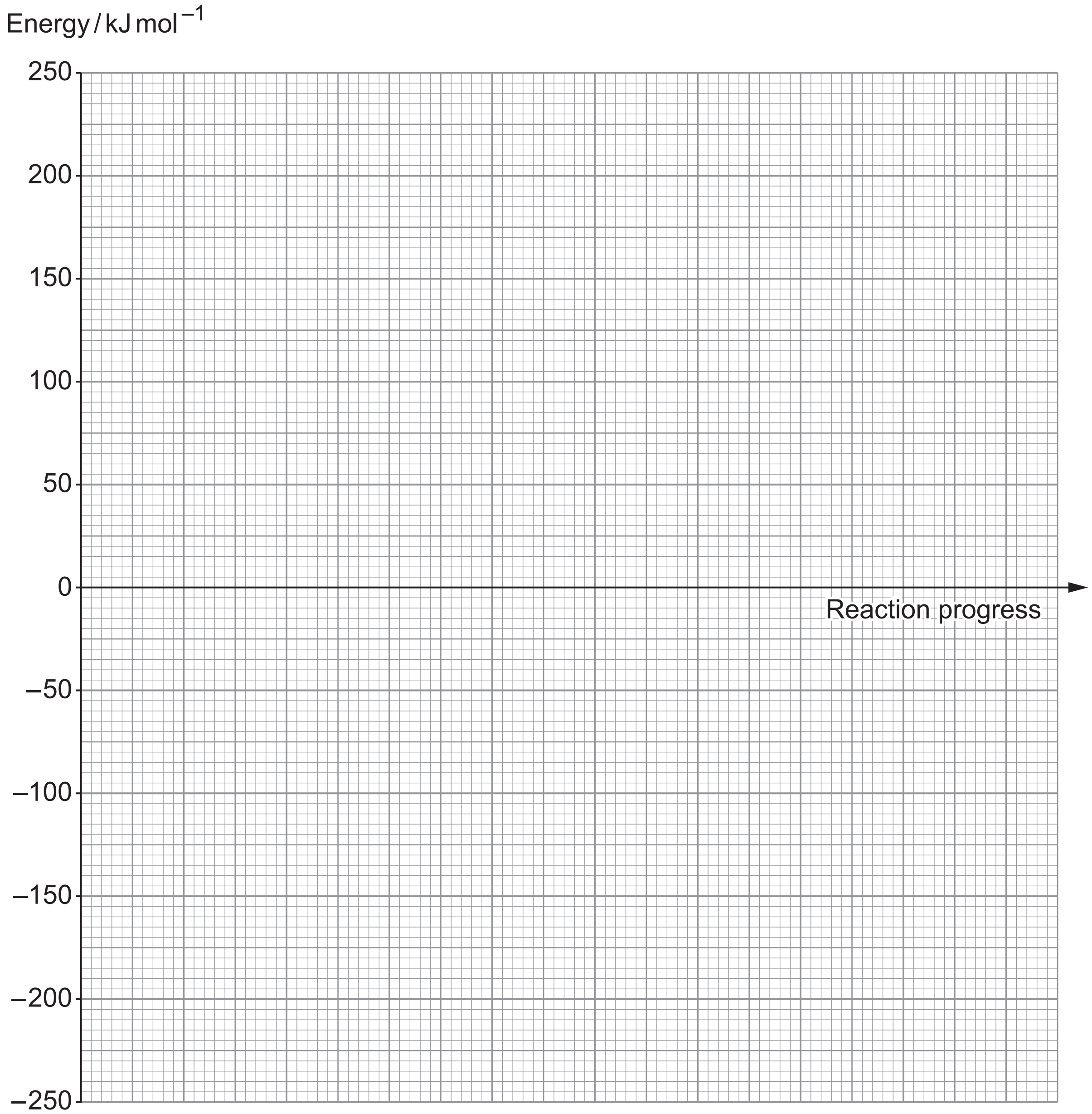
$$3Cl_2(g) \quad + \quad 7O_3(g) \longrightarrow 3Cl_2O_7(g) \qquad \Delta H^{\theta} = -199\,kJ\,mol^{-1}$$

Substance	Standard enthalpy change of formation, $\Delta_f H^{\theta}$ / $kJ\,mol^{-1}$
$Cl_2(g)$	0
$O_3(g)$	142

Examiner only

(i) The activation energy for this reaction is 18 kJ mol^{-1}.

Draw the energy profile for this reaction on the axes provided. [3]



Examiner only

(ii) The reaction is carried out at a temperature of 223 K and the rate constant is found to have a value of 2.24×10^3. The unit of the rate constant is not stated.

Calculate the temperature required to double the rate of reaction. [4]

T = ... K

(iii) The rate equation for this reaction is first order with respect to each reactant and the rate is measured in units of $mol\,dm^{-3}\,s^{-1}$.

I. Write the rate equation. [1]

....

II. Give the unit of the rate constant. [1]

....

(iv) Explain why the standard enthalpy of formation for chlorine gas is zero but that of ozone is not. [2]

....

....

....

Examiner only

(v) Dichlorine heptoxide decomposes readily to form Cl_2(g) and O_2(g).

$$2Cl_2O_7(g) \longrightarrow 2Cl_2(g) + 7O_2(g)$$

Calculate the volume of gas produced when 2.70 g of Cl_2O_7 decomposes at a temperature of –12°C and 1 atm pressure. [4]

Volume = ... dm^3

Examiner only

(b) Chlorine dioxide, ClO_2, is an unstable oxide of chlorine. It is often stored in aqueous solution and in some countries solutions can only be transported if the concentration is lower than 0.30 g in 100 cm^3 of water.

Calculate the concentration of this solution in $mol\,dm^{-3}$. [2]

Concentration = ………………………… $mol\,dm^{-3}$

(c) Chlorine perchlorate, $ClOClO_3$, is an oxide with the two chlorine atoms in different oxidation states.

(i) If one chlorine atom has an oxidation state of +1, find the oxidation state of the other. [1]

…………………………

(ii) Predict the appearance of the molecular ion peaks seen in the mass spectrum of chlorine perchlorate. Give reasons for your answer.

You should refer to both the positions and heights of the peaks. [4]

…………………………………………………………

…………………………………………………………

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Examiner only

(d) The chlorite ion, O$=$Cl$-$O$^-$, has a non-linear shape.

Explain why this ion is not linear. [2]

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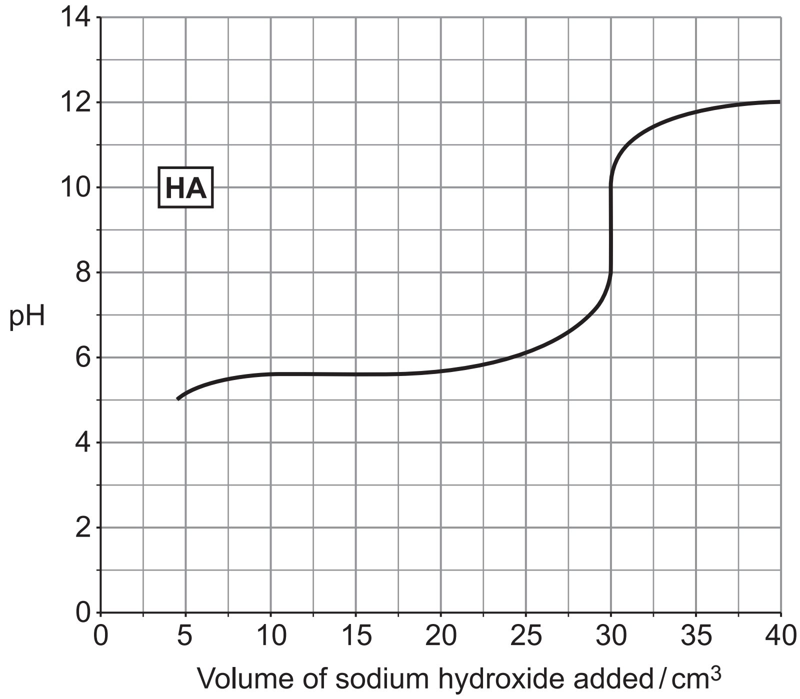
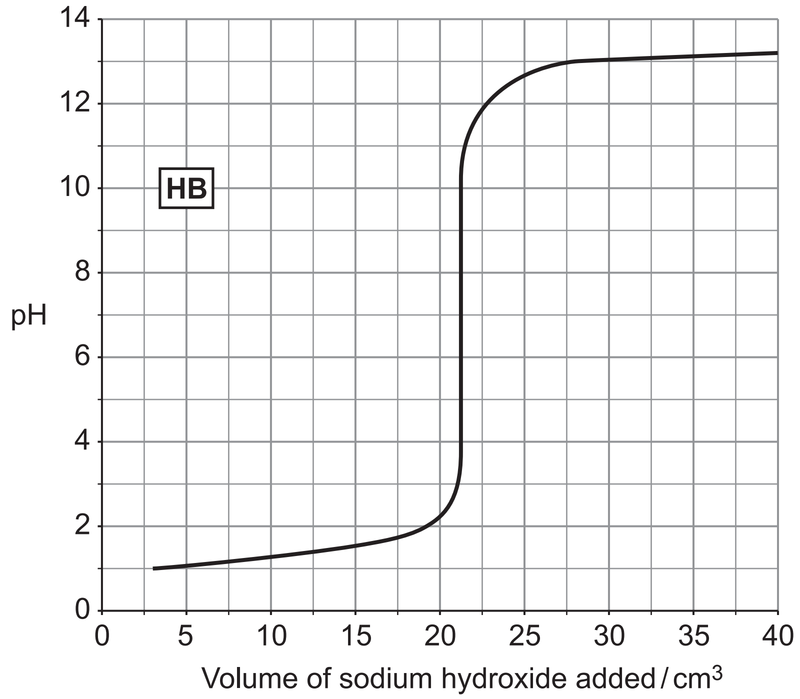
11. A student carried out two acid-base titrations using two acids, HA and HB.

A 25.0 cm^3 sample of each acid was titrated against a sodium hydroxide solution of concentration 0.150 mol dm^{-3} giving the titration curves shown. The initial pH values are missing from both graphs.

One acid is a strong acid and one is a weak acid.





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(a) Describe and explain the differences between the two curves.

- You should identify which acid is strong and which is weak, explaining fully how you have reached your conclusion.
- You should identify which acid is more concentrated and which is more dilute, explaining how you have reached your conclusion.

[6 QER]

(b) Calculate K_a for the weak acid. [2]

K_a = ... $mol\,dm^{-3}$

Examiner only

(c) Both these titrations can be performed using appropriate acid-base indicators, but similar experiments using a weak acid and a weak base cannot use acid-base indicators successfully. Explain this difference. [2]

....

....

....

(d) The students made 250 cm^3 of aqueous sodium hydroxide of concentration 0.150 mol dm^{-3} for these experiments.

(i) Calculate the mass of NaOH required to make this solution. [2]

Mass = ... g

(ii) Outline how this solution could be made. [3]

....

....

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....

Examiner only

(iii) Calculate the pH of this aqueous sodium hydroxide at 298 K. [3]

pH = ...

18

Turn over.

Examiner only

12. (a) Five ionisation energies are represented by the letters **A**–**E** as shown below.

A 1st ionisation energy of helium
B final ionisation energy of nitrogen
C final ionisation energy of oxygen
D 1st ionisation energy of sodium
E 2nd ionisation energy of magnesium

The values of these five ionisation energies are given in the table.

Value of ionisation energy / $kJ\,mol^{-1}$	Letter representing the ionisation energy
84 078	....
64 360	....
2372	....
1450	....
496	....

Complete the table using letters **A**–**E** to show which ionisation energy corresponds to each value.

Give reasons for your choices. [5]

....

....

....

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Examiner only

(b) Three boiling temperatures are listed below.

–33°C –111°C –132°C

These are the boiling temperatures of NH_3, PH_3 and AsH_3. Identify which value corresponds to each compound.

Give reasons for your choices. [3]

Boiling temperature of NH_3 .... °C

Boiling temperature of PH_3 .... °C

Boiling temperature of AsH_3 .... °C

....

....

....

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....

(c) A student is provided with four solutions labelled **W**, **X**, **Y** and **Z** and is told that these contain common cations and anions that they have studied.

He observes that one solution is pale blue and the others are colourless. Flame tests on the solutions give apple-green and golden yellow flames with two solutions and unfamiliar colours with the others.

The student mixes pairs of solutions together and obtains the following results. He did not complete all the experiments.

Solution 1	Solution 2	Observation(s)
W	**X**	white precipitate that dissolves when excess solution **W** is added
W	**Y**	mixture of pale blue precipitate and white precipitate in a colourless solution
W	**Z**	no visible change
X	**Y**	white precipitate in a pale blue solution
X	**Z**	
Y	**Z**	white precipitate in a brown solution

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Identify the **four** compounds and give reasons for your decisions. [6]

Compound **W** ....

Compound **X** ....

Compound **Y** ....

Compound **Z** ....

....

....

....

....

....

....

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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

A410U10-1A

S23-A410U10-1A

MONDAY, 12 JUNE 2023 – MORNING

CHEMISTRY – A level component 1
Data Booklet

Avogadro constant	N_A	$= 6.02 \times 10^{23}$ 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	$= 6.63 \times 10^{-34}$ J s
speed of light	c	$= 3.00 \times 10^{8}$ 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	$= 1.00 \times 10^{-14}$ mol^2 dm^{-6}
fundamental electronic charge	e	$= 1.60 \times 10^{-19}$ 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

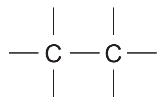
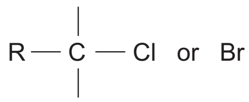
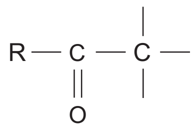
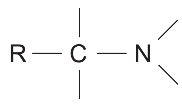
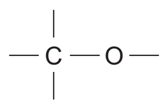
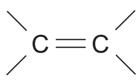
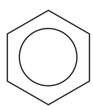
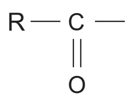
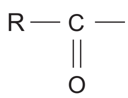
Multiple	Prefix	Symbol
10^{-9}	nano	n
10^{-6}	micro	μ
10^{-3}	milli	m

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

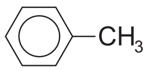
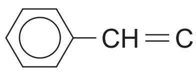
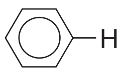
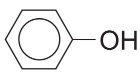
Infrared absorption values

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

Group

s block | d block | p block | 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

Key

A_r	relative atomic mass
Symbol	
Name	
Z	atomic number