Please check the examination details below before entering your candidate information

Candidate surname	Other names
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Centre Number | Candidate Number

Pearson Edexcel Level 3 GCE

Monday 10 June 2024

Morning (Time: 1 hour 45 minutes)

Paper reference **9CH0/01**

Chemistry

Advanced

PAPER 1: Advanced Inorganic and Physical Chemistry

You must have:
Scientific calculator, Data Booklet, ruler

Total Marks

Instructions

- Use **black** ink or ball-point pen.
- If pencil is used for diagrams/sketches/graphs it must be dark (HB or B).
- **Fill in the boxes** at the top of this page with your name, centre number and candidate number.
- Answer **all** questions.
- Answer the questions in the spaces provided
  – *there may be more space than you need.*

Information

- The total mark for this paper is 90.
- The marks for **each** question are shown in brackets
  – *use this as a guide as to how much time to spend on each question.*
- For the question marked with an **asterisk** (*), marks will be awarded for your ability to structure your answer logically, showing the points that you make are related or follow on from each other where appropriate.
- A Periodic Table is printed on the back cover of this paper.

Advice

- Read each question carefully before you start to answer it.
- Show all your working in calculations and include units where appropriate.
- Check your answers if you have time at the end.

Turn over ▶

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Answer ALL questions.

Some questions must be answered with a cross in a box ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

1 This question is about atomic structure.

(a) Complete the table.

(3)

Species	Number of protons	Number of neutrons	Number of electrons
^{32}S	16	16	16
^{33}S	16	17	16
$^{34}S^{2-}$	16	18	18

(b) A sample of sulfur was found to contain only four isotopes.

(i) Complete the table to show the percentage abundance of ^{34}S.

(1)

Isotope	^{32}S	^{33}S	^{34}S	^{36}S
Percentage abundance	95.02	0.75	4.21	0.02

(ii) Calculate the relative atomic mass (A_r) of the sulfur in this sample using the data in the table. Give your answer to **two** decimal places.

(2)

$$A_r = \frac{(95.02 \times 32) + (0.75 \times 33) + (4.21 \times 34) + (0.02 \times 36)}{100}$$

$A_r = 3209.25 \div 100 = 32.0925$

$A_r = 32.09$

(Total for Question 1 = 6 marks)

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2 This question is about the formation of ions.

(a) Explain the trend in the values of the first electron affinities of the elements shown.

(4)

Element	First electron affinity / kJ mol^{-1}
chlorine	–349
bromine	–325
iodine	–295

Going down the group from chlorine to iodine, the first electron affinity becomes less negative (less exothermic), so less energy is released when the electron is gained. This is because the atomic radius increases as there are more electron shells, so the distance between the nucleus and the incoming electron increases. There is also increased shielding from the inner electron shells, so there is less attraction between the nucleus and the incoming (added) electron. Although the nuclear charge increases, the increased shielding and distance outweigh the effect of the increasing nuclear charge.

(b) Which of these isoelectronic ions has the **smallest** ionic radius?

(1)

- ☒ **A** S^{2-}
- ☒ **B** Cl^{-}
- ☒ **C** K^{+}
- ☒ **D** Ca^{2+}

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(c) Some series of successive ionisation energies in kJ mol^{-1} are shown.
The letters do not refer to the symbols of the elements.

Element	Successive ionisation energies / kJ mol^{-1}				
A	578	1817	2745	11 578	14 831
B	653	1592	2987	4740	6686
C	738	1451	7733	10 541	13 629
D	1086	2353	4621	6223	37 832

(i) Which element in the table could be in Group 4?

(1)

- ☒ **A**
- ☒ **B**
- ☒ **C**
- ☒ **D**

(ii) Which element in the table could be described as an *s*-block element?

(1)

- ☒ **A**
- ☒ **B**
- ☒ **C**
- ☒ **D**

(Total for Question 2 = 7 marks)

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3 This question is about compounds and their chemical analysis.

Three containers of soluble white solids have lost their labels but are known to be calcium bromide, calcium iodide and potassium sulfate.

(a) (i) Describe how to carry out a flame test on these samples.

(3)

Dip a clean platinum (or nichrome) wire into concentrated hydrochloric acid, HCl(aq).

Then dip the wire into the solid sample so that some of the sample sticks to the wire.

Hold the wire with the sample in a hot, blue (non-luminous) Bunsen flame and observe the colour of the flame.

(ii) Give the expected observation for each of the flame tests.

(2)

calcium bromide

orange-red (brick-red)

calcium iodide

orange-red (brick-red)

potassium sulfate

lilac

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(b) Separate aqueous solutions of calcium bromide and of calcium iodide reacted with acidified silver nitrate to produce a precipitate.
Concentrated aqueous ammonia was added to each precipitate.

Complete the table.

(2)

Solution	Formula of precipitate with silver nitrate	Colour of precipitate with silver nitrate	Observation with concentrated aqueous ammonia
calcium bromide(aq)	*AgBr*	*cream*	*dissolves*
calcium iodide(aq)	*AgI*	*yellow*	*does not dissolve*

(c) Describe a chemical test for the sulfate ion giving the positive result.

(2)

Add dilute hydrochloric acid, HCl(aq), then barium chloride solution, $BaCl_2(aq)$, to a solution of the sample.

A white precipitate (of $BaSO_4$) forms if sulfate ions are present.

(d) What mass of potassium sulfate (K_2SO_4) would be needed to prepare 250 cm^3 of a solution of concentration 0.0450 mol dm^{-3}?

The molar mass of K_2SO_4 is 174.3 g mol^{-1}.

(1)

- ☒ **A** 1.96 g
- ☐ **B** 7.84 g
- ☐ **C** 19.6 g
- ☐ **D** 31.4 g

(Total for Question 3 = 10 marks)

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4 This question is about acids, bases and buffers.

(a) State what is meant by a Brønsted–Lowry acid.

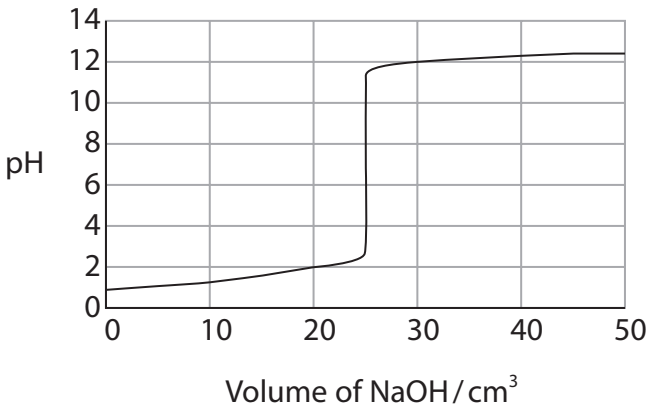
(1)

A Brønsted-Lowry acid is a proton (H^+ ion) donor.

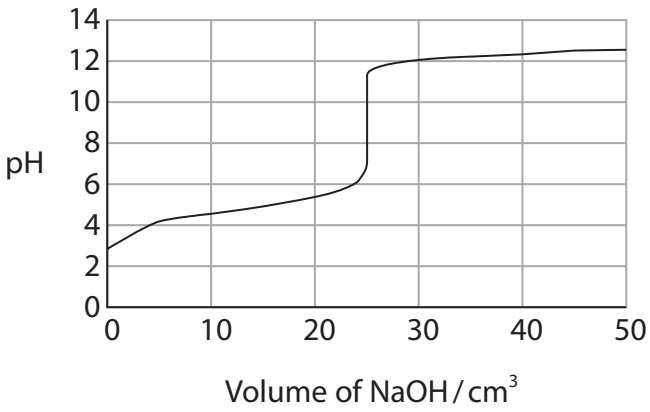
(b) Which could be the titration curve when 0.100 mol dm^{-3} NaOH(aq) is added to 25.0 cm^3 of 0.100 mol dm^{-3} CH_3COOH(aq)?

(1)

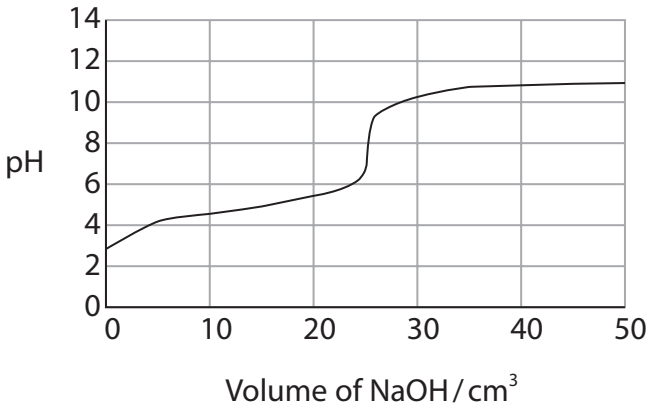
☒ **A**



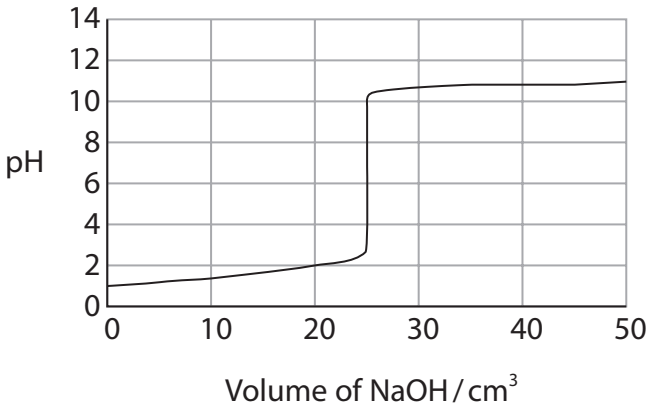
☒ **B**



☒ **C**



☒ **D**



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(c) Some information about acids in aqueous solution is given.

Comment on these pH values. No calculations are required.

(4)

Name of acid	Formula of acid	pH of a solution of 0.100 mol dm^{-3} acid
hydrochloric acid	HCl	1.00
sulfuric acid	H_2SO_4	0.98
propanoic acid	CH_3CH_2COOH	2.94

Hydrochloric acid is a strong acid, so it is fully dissociated (ionised) in solution: $HCl \rightarrow H^+ + Cl^-$, so $[H^+]$ equals the acid concentration and the pH is 1.00.

Sulfuric acid is diprotic, so each H_2SO_4 can donate two protons (H^+ ions): $H_2SO_4 \rightarrow H^+ + HSO_4^-$, then $HSO_4^- \rightleftharpoons H^+ + SO_4^{2-}$.

However, its pH is only slightly lower than that of HCl because the second ionisation is not complete: it is suppressed by the H^+ ions from the first ionisation, so $[H^+]$ is only slightly more than 0.100 mol dm^{-3}.

Propanoic acid is a weak acid, so it is only partially dissociated: $CH_3CH_2COOH \rightleftharpoons CH_3CH_2COO^- + H^+$. So $[H^+]$ is much lower than 0.100 mol dm^{-3} and the pH is higher.

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(d) One of the systems controlling the pH of blood is the carbonic acid–hydrogencarbonate buffer system.

$$H_2CO_3(aq) \rightleftharpoons H^+(aq) + HCO_3^-(aq)$$

(i) Write the expression for the acid dissociation constant, K_a, for carbonic acid. State symbols are not required.

(1)

$$K_a = \frac{[H^+][HCO_3^-]}{[H_2CO_3]}$$

(ii) A blood sample taken from an individual was analysed.

Calculate the pH of the blood sample.

Use your expression for K_a and the values shown.

K_a for carbonic acid = 4.50×10^{-7} mol dm^{-3}

$[HCO_3^-] = 0.0240$ mol dm^{-3} $[H_2CO_3] = 0.00200$ mol dm^{-3}

(3)

$[H^+] = K_a \times [H_2CO_3] \div [HCO_3^-]$

$[H^+] = (4.50 \times 10^{-7} \times 0.00200) \div 0.0240$

$[H^+] = 3.75 \times 10^{-8}$ mol dm^{-3}

$pH = -\log_{10}[H^+] = -\log_{10}(3.75 \times 10^{-8})$

$pH = 7.43$

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(e) The relevant equilibria that maintain the pH of blood are shown.

Equilibrium **1** $CO_2(aq) + H_2O(l) \rightleftharpoons H_2CO_3(aq)$

Equilibrium **2** $H_2CO_3(aq) \rightleftharpoons H^+(aq) + HCO_3^-(aq)$

(i) When a person exercises vigorously the concentration of carbon dioxide (aq) in the blood increases.

Explain how this increase in the concentration of carbon dioxide affects the pH of the blood.
Refer to the equilibria in your answer. No calculation is required.

(2)

The increase in $[CO_2(aq)]$ shifts the position of Equilibrium 1 to the right, to use up the extra CO_2, so more H_2CO_3 forms.

This shifts the position of Equilibrium 2 to the right, so the concentration of H^+ ions, $[H^+]$, increases.

Therefore the pH of the blood decreases (becomes lower).

(ii) Explain how the carbonic acid–hydrogencarbonate buffer system in Equilibrium **2** acts to restore the pH of the blood after a person has exercised.

(2)

There is a large reservoir (high concentration) of HCO_3^- ions (and H_2CO_3) in the blood.

The extra H^+ ions react with HCO_3^- ions to form H_2CO_3: $H^+ + HCO_3^- \rightarrow H_2CO_3$, so Equilibrium 2 shifts to the left.

This removes the extra H^+ ions, so $[H^+]$ falls and the pH is restored.

(Total for Question 4 = 14 marks)

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5 This question is about 'Direct Ethanol Fuel Cells' which are being developed to power small electronic devices.

The overall reaction in these fuel cells is shown.

$$C_2H_5OH(l) + 3O_2(g) \rightarrow 3H_2O(l) + 2CO_2(g)$$

(a) Calculate the enthalpy change for the reaction using the mean bond enthalpy data.

(3)

Bond	Mean bond enthalpy / kJ mol^{-1}
C—C	347
C—H	413
C—O	358
O—H	464
O═O	498
C═O	805

Bonds broken: 5(C–H) + (C–C) + (C–O) + (O–H) + 3(O=O)

= (5 × 413) + 347 + 358 + 464 + (3 × 498) = +4728 kJ mol^{-1}

Bonds made: 6(O–H) + 4(C=O)

= (6 × 464) + (4 × 805) = 6004 kJ mol^{-1} released

ΔH = 4728 – 6004 = –1276 kJ mol^{-1}

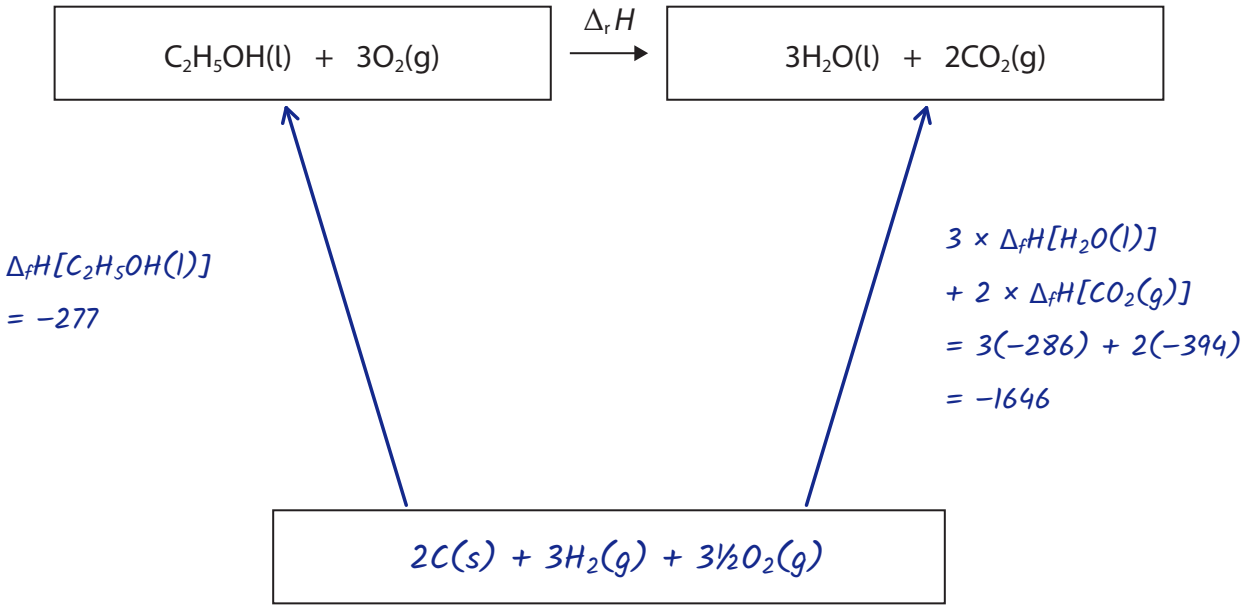
Enthalpy change = *–1276* kJ mol^{-1}

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(b) (i) Complete the enthalpy cycle for the overall reaction in the Direct Ethanol Fuel Cell. Include labels.

(2)

Substance	$\Delta_f H^{\ominus}$ / kJ mol^{-1}
$C_2H_5OH(l)$	−277
$CO_2(g)$	−394
$H_2O(l)$	−286



(ii) Calculate a value for the enthalpy change of the Direct Ethanol Fuel Cell reaction, using your cycle.

(1)

$\Delta_r H = [3 \times (-286) + 2 \times (-394)] - (-277)$

$\Delta_r H = -1646 + 277 = -1369$ kJ mol^{-1}

Enthalpy change = ... −1369 ..... kJ mol^{-1}

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(c) Give **two** reasons for the difference between your calculated values in (a) and (b).

(2)

Mean bond enthalpies are used in (a); these are averages over many different compounds, so they are not the actual values for the bonds in these molecules.

Bond enthalpies are for substances in the gaseous state, but ethanol and water are liquids in this reaction.

(d) In the Direct Ethanol Fuel Cell under acidic conditions, at one electrode the ethanol is oxidised in the presence of water to produce carbon dioxide, hydrogen ions and electrons.

At the other electrode, the hydrogen ions and electrons combine with oxygen to form water.

Write the two ionic half-equations for this process.
State symbols are not required.

(2)

Oxidation half-equation

$C_2H_5OH + 3H_2O \rightarrow 2CO_2 + 12H^+ + 12e^-$

Reduction half-equation

$O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$

(Total for Question 5 = 10 marks)

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***6** Explain why aqueous solutions of Cu^{2+} ions and Fe^{2+} ions are coloured but have different colours, whereas aqueous solutions of Zn^{2+} ions are colourless. Include any relevant electronic configurations.

(6)

Cu^{2+} is $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^9$, i.e. $[Ar]3d^9$

Fe^{2+} is $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^6$, i.e. $[Ar]3d^6$

Zn^{2+} is $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}$, i.e. $[Ar]3d^{10}$

In aqueous solution each ion is surrounded by water ligands, which form dative covalent bonds to the metal ion. The ligands cause the 3d-orbitals to split into two groups at different energy levels, with an energy gap, ΔE, between them.

Cu^{2+} and Fe^{2+} both have partially filled 3d-subshells, so an electron can be promoted (excited) from a lower energy d-orbital to a higher energy d-orbital, a d-d transition.

To do this the electron absorbs a photon of visible light whose energy matches the energy gap ($\Delta E = hf$). The remaining frequencies of light, the complementary colour, are transmitted (or reflected), and this is the colour we see.

The size of the energy gap is different for Cu^{2+} and Fe^{2+} ions, because they are different metal ions with different numbers of d-electrons. So light of different frequencies (wavelengths) is absorbed and different complementary colours are seen:

$[Cu(H_2O)_6]^{2+}$ is blue but $[Fe(H_2O)_6]^{2+}$ is pale green.

Zn^{2+} has a full 3d-subshell ($3d^{10}$), so there is no space in the higher energy d-orbitals for an electron to be promoted.

Therefore no d-d transitions can occur, no visible light is absorbed, and so solutions of Zn^{2+} ions are colourless.

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(Total for Question 6 = 6 marks)

7 This question is about vanadium.

The contact process is used in the manufacture of sulfuric acid. In the second stage, sulfur dioxide is converted into sulfur trioxide by passing sulfur dioxide and air over a solid V_2O_5 catalyst.

The equation for the second stage is shown.

$$SO_2(g) + \tfrac{1}{2}O_2(g) \rightleftharpoons SO_3(g) \qquad \Delta H = -196\,kJ\,mol^{-1}$$

(a) (i) What are the expression and the units for the equilibrium constant (K_p) for this reaction?

(1)

		Expression	Units
☒	**A**	$\frac{p(SO_3)}{p(SO_2)\,p(O_2)^{\frac{1}{2}}}$	atm^2
☒	**B**	$\frac{p(SO_2)\,p(O_2)^{\frac{1}{2}}}{p(SO_3)}$	$atm^{\frac{1}{2}}$
☒	**C**	$\frac{p(SO_2)\,p(O_2)^{\frac{1}{2}}}{p(SO_3)}$	$atm^{-\frac{1}{2}}$
☒	**D**	$\frac{p(SO_3)}{p(SO_2)\,p(O_2)^{\frac{1}{2}}}$	$atm^{-\frac{1}{2}}$

(ii) Which variable affects the value of K_p?

(1)

☒ **A** pressure

☒ **B** temperature

☒ **C** surface area of the catalyst

☒ **D** concentration of $O_2(g)$

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(b) Write **two** equations that show the conversion of SO_2 and O_2 into SO_3 by using V_2O_5 as the catalyst.
State symbols are not required.

(2)

$SO_2 + V_2O_5 \rightarrow SO_3 + V_2O_4$

$V_2O_4 + \frac{1}{2}O_2 \rightarrow V_2O_5$

(c) Which row of the table shows the correct colour of the solution and oxidation number of vanadium in the aqueous ions shown?

(1)

	Aqueous ion	Colour of solution	Oxidation number of vanadium
☐ **A**	VO_2^+	yellow	+3
☐ **B**	VO^{2+}	green	+4
☒ **C**	VO_2^+	yellow	+5
☐ **D**	VO^{2+}	blue	+5

(d) What is the value of the cell potential for the reaction of Zn and VO_2^+?
Use your Data Booklet.

$$2VO_2^+(aq) + 4H^+(aq) + Zn(s) \rightarrow 2VO^{2+}(aq) + 2H_2O(l) + Zn^{2+}(aq)$$

(1)

☒ **A** +1.76V

☐ **B** +0.24V

☐ **C** −0.24V

☐ **D** −1.76V

(Total for Question 7 = 6 marks)

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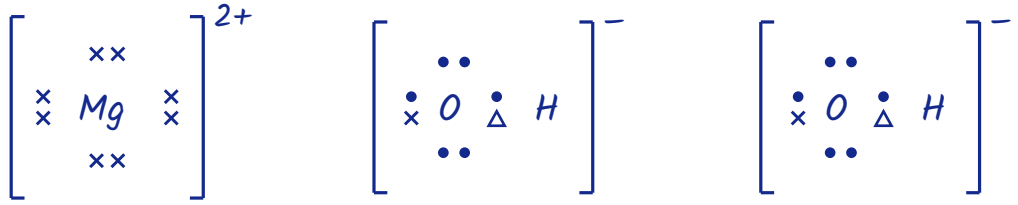
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8 This question is about ionic compounds.

(a) Draw dot-and-cross diagrams of the ions in magnesium hydroxide, showing the outer shell electrons only.

Use × for magnesium electrons, ● for oxygen electrons and △ for each hydrogen electron.

(2)



(b) Which definition correctly describes the enthalpy change of solution, $\Delta_{sol}H$?

(1)

		Enthalpy change of solution, $\Delta_{sol}H$
☐	**A**	The enthalpy change when 1 mol of gaseous ions dissolves in sufficient water to give an infinitely dilute solution.
☒	**B**	The enthalpy change when 1 mol of an ionic substance dissolves in water to give an infinitely dilute solution.
☐	**C**	The enthalpy change when 1 mol of gaseous ions dissolves in sufficient water to give a solution of concentration 1 mol dm^{-3}.
☐	**D**	The enthalpy change when 1 mol of an ionic substance dissolves in water to give a solution of concentration 1 mol dm^{-3}.

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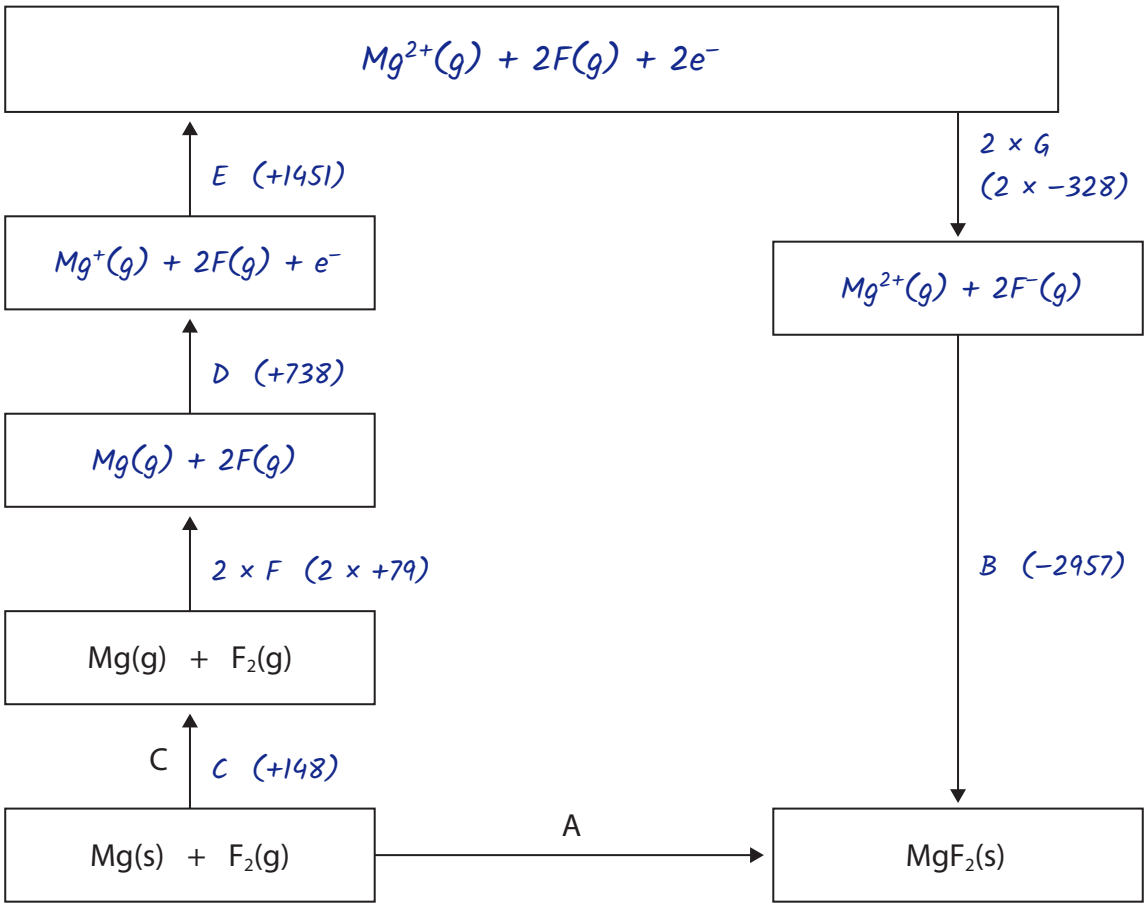
(c) The table shows the information needed to calculate the standard enthalpy change of formation of magnesium fluoride.

Label	Description	Value / kJ mol^{-1}
A	enthalpy change of formation of magnesium fluoride	
B	lattice energy of magnesium fluoride	−2957
C	enthalpy change of atomisation of magnesium	+148
D	1st ionisation energy of magnesium	+738
E	2nd ionisation energy of magnesium	+1451
F	enthalpy change of atomisation of fluorine	+79
G	1st electron affinity of fluorine	−328

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(i) Complete the Born–Haber cycle for magnesium fluoride with formulae, state symbols, electrons and correctly labelled arrows.
The cycle is not drawn to scale.

(4)



(ii) Calculate the value of $\Delta_f H^{\ominus}[MgF_2(s)]$.

(1)

$\Delta_f H = 148 + 2(79) + 738 + 1451 + 2(-328) + (-2957)$

$\Delta_f H[MgF_2(s)] = -1118 \text{ kJ mol}^{-1}$

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(iii) The experimental and theoretical values of the lattice energy for MgF_2 and MgI_2 are given in the table.

Explain the differences in these values.

(4)

Compound	Experimental lattice energy / kJ mol^{-1}	Theoretical lattice energy / kJ mol^{-1}
MgF_2	−2957	−2913
MgI_2	−2327	−1944

The values for MgF_2 are very close because MgF_2 is (almost) 100% ionic, so the ionic model fits well.

For MgI_2 the experimental value is much more negative than the theoretical value because MgI_2 has some covalent character (more than MgF_2).

This is because the I^- ion is larger than the F^- ion, so the I^- ion is more polarisable and is distorted by the Mg^{2+} ion.

Both values for MgF_2 are more negative than for MgI_2 because the F^- ion is smaller than the I^- ion, so the ionic bonding is stronger in MgF_2.

(Total for Question 8 = 12 marks)

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9 Sodium hydrogencarbonate is used as a raising agent in baking as carbon dioxide gas is released when it undergoes thermal decomposition.

(a) Show that this reaction is **not** feasible at 298 K by calculating ΔG.

$$2NaHCO_3(s) \rightarrow Na_2CO_3(s) + CO_2(g) + H_2O(l) \qquad \Delta_r H = +91.6\,kJ\,mol^{-1}$$

(3)

Compound	$NaHCO_3(s)$	$Na_2CO_3(s)$	$CO_2(g)$	$H_2O(l)$
Standard molar entropy / $J\,K^{-1}\,mol^{-1}$	101.7	135.0	213.6	69.9

$\Delta S_{system} = (135.0 + 213.6 + 69.9) - (2 \times 101.7)$

$\Delta S_{system} = +215.1\ J\ K^{-1}\ mol^{-1} = +0.2151\ kJ\ K^{-1}\ mol^{-1}$

$\Delta G = \Delta H - T\Delta S_{system}$

$\Delta G = 91.6 - (298 \times 0.2151) = +27.5\ kJ\ mol^{-1}$

ΔG is positive ($\Delta G > 0$), so the reaction is not feasible at 298 K.

(b) Calculate the minimum temperature, in degrees Celsius (°C), at which an oven should be set for this reaction to be thermodynamically feasible.

(2)

Feasible when $\Delta G \leq 0$, so $T = \Delta H \div \Delta S_{system}$

$T = 91.6 \div 0.2151 = 425.8$ K

$425.8 - 273 = 152.8$ °C

Minimum temperature = 153 °C

(Total for Question 9 = 5 marks)

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10 Vitamin C has the molecular formula $C_6H_8O_6$.

The label on a bottle of vitamin C tablets stated that a 2.50 g tablet contained 6% of vitamin C by mass. The tablet was analysed to check the accuracy of the label. The procedure involved a series of steps.

(a) Step **1** Dissolving the tablet.

A 2.50 g vitamin C tablet was crushed and dissolved to make an aqueous solution of volume 250.0 cm^3.

Describe how to make this solution from the crushed tablet.

(3)

Transfer the crushed tablet to a beaker and dissolve it in some deionised (distilled) water, stirring with a glass rod.

Transfer the solution to a 250.0 cm^3 volumetric flask using a funnel.

Rinse the beaker, rod and funnel with deionised water and transfer all the washings into the flask.

Make up to the mark with deionised water (bottom of the meniscus on the line), then stopper and invert the flask several times to mix.

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(b) Step **2** Producing a known amount of iodine.

Iodine was produced by reacting 25.0 cm^3 of 0.0100 mol dm^{-3} potassium iodate with excess potassium iodide and hydrochloric acid in a conical flask.

(i) Complete the ionic equation for the formation of the iodine from 1 mol of IO_3^- ions.

(1)

$$IO_3^- + \underline{5}\ I^- + \underline{6}\ H^+ \rightarrow 3I_2 + \underline{3H_2O}$$

(ii) Show, by calculation, that 7.50×10^{-4} moles of iodine were produced in the flask.

(2)

$n(IO_3^-) = (25.0 \div 1000) \times 0.0100 = 2.50 \times 10^{-4}$ mol

1 mol IO_3^- forms 3 mol I_2

$n(I_2) = 3 \times 2.50 \times 10^{-4} = 7.50 \times 10^{-4}$ mol

(c) Step **3** Titrating with sodium thiosulfate solution.

10.0 cm^3 of the vitamin C tablet solution from Step **1** was added to the conical flask from Step **2** to react with the iodine produced, as shown in the equation.

$$C_6H_8O_6(aq) + I_2(aq) \rightarrow C_6H_6O_6(aq) + 2HI(aq)$$

The unreacted iodine in the conical flask was titrated with a solution of 0.100 mol dm^{-3} sodium thiosulfate, $Na_2S_2O_3(aq)$.

The mean titre was 14.40 cm^3.

$$2S_2O_3^{2-}(aq) + I_2(aq) \rightarrow 2I^-(aq) + S_4O_6^{2-}(aq)$$

(i) State the indicator used in this titration, giving the colour change that would be observed at the end-point.

(2)

Starch (added near the end-point).

Colour change: blue-black to colourless.

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(ii) Deduce, by calculation, whether the label on the bottle of vitamin C tablets is correct.

(6)

$n(S_2O_3^{2-}) = (14.40 \div 1000) \times 0.100 = 1.44 \times 10^{-3}$ mol

unreacted $n(I_2) = 1.44 \times 10^{-3} \div 2 = 7.20 \times 10^{-4}$ mol

$n(I_2)$ reacting with vitamin C $= 7.50 \times 10^{-4} - 7.20 \times 10^{-4}$

$= 3.00 \times 10^{-5}$ mol

1 : 1 ratio, so $n(C_6H_8O_6)$ in 10.0 $cm^3 = 3.00 \times 10^{-5}$ mol

$n(C_6H_8O_6)$ in 250.0 cm^3 (one tablet) $= 3.00 \times 10^{-5} \times 25$

$= 7.50 \times 10^{-4}$ mol

$M(C_6H_8O_6) = (6 \times 12.0) + (8 \times 1.0) + (6 \times 16.0) = 176.0$ g mol^{-1}

mass of vitamin C in tablet $= 7.50 \times 10^{-4} \times 176.0 = 0.132$ g

expected mass $= (6 \div 100) \times 2.50 = 0.150$ g

percentage by mass $= (0.132 \div 2.50) \times 100 = 5.28\%$

0.132 g is less than 0.150 g (5.28% is less than 6%),

so the label is not correct: there is less vitamin C

in each tablet than the label states.

(Total for Question 10 = 14 marks)

TOTAL FOR PAPER = 90 MARKS

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The Periodic Table of Elements

1	2											3	4	5	6	7	0 (8)
																	(18)
							1.0 H hydrogen 1										4.0 He helium 2
(1)	(2)		Key									(13)	(14)	(15)	(16)	(17)	
6.9 Li lithium 3	9.0 Be beryllium 4		relative atomic mass atomic symbol name atomic (proton) number									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
23.0 Na sodium 11	24.3 Mg magnesium 12	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(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	39.9 Ar argon 18
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
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] Tc technetium 43	101.1 Ru ruthenium 44	102.9 Rh rhodium 45	106.4 Pd palladium 46	107.9 Ag silver 47	112.4 Cd cadmium 48	114.8 In indium 49	118.7 Sn tin 50	121.8 Sb antimony 51	127.6 Te tellurium 52	126.9 I iodine 53	131.3 Xe xenon 54
132.9 Cs caesium 55	137.3 Ba barium 56	138.9 La* lanthanum 57	178.5 Hf hafnium 72	180.9 Ta tantalum 73	183.8 W tungsten 74	186.2 Re rhenium 75	190.2 Os osmium 76	192.2 Ir iridium 77	195.1 Pt platinum 78	197.0 Au gold 79	200.6 Hg mercury 80	204.4 Tl thallium 81	207.2 Pb lead 82	209.0 Bi bismuth 83	[209] Po polonium 84	[210] At astatine 85	[222] Rn radon 86
[223] Fr francium 87	[226] Ra radium 88	[227] Ac* actinium 89	[261] Rf rutherfordium 104	[262] Db dubnium 105	[266] Sg seaborgium 106	[264] Bh bohrium 107	[277] Hs hassium 108	[268] Mt meitnerium 109	[271] Ds darmstadtium 110	[272] Rg roentgenium 111							

Elements with atomic numbers 112-116 have been reported but not fully authenticated

* Lanthanide series	140 Ce cerium 58	141 Pr praseodymium 59	144 Nd neodymium 60	[147] Pm promethium 61	150 Sm samarium 62	152 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
* Actinide series	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

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