Please check the examination details below before entering your candidate information

Candidate surname	Other names

Centre Number | Candidate Number

Pearson Edexcel Level 3 GCE

Tuesday 2 June 2026

Morning (Time: 1 hour 45 minutes)

Paper reference **9CH0/01**

Chemistr y

Advanced

PAPER 1: Advanced Inorganic and Physical Chemistry

You must have:
Scientific calculator, Data Booklet, ruler

Total Marks

I nstruc tions

- 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 questioncarefullybeforeyoustarttoanswerit.
- Show all yourworkingincalculationsandincludeunitswhereappropriate.
- Check your answersifyouhavetimeattheend.

Turn over ▶

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Pearson

Answer ALL questions.

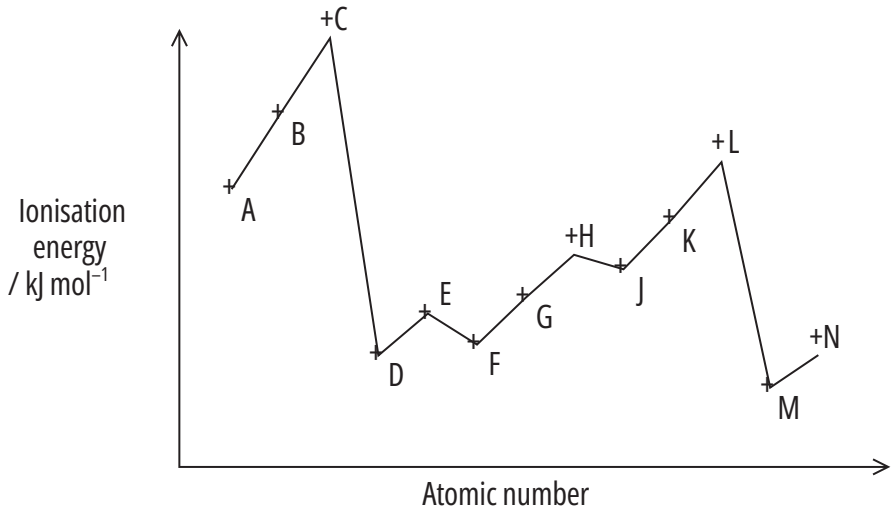
Some questions must be answered with a cross in a box ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

1 This question is about ionisation energy.

The graph shows the first ionisation energies of 13 successive elements in the Periodic Table in order of increasing atomic number.

Trends in first ionisation energies can be used to identify the group to which an element belongs.

The letters are **not** the symbols for the elements.



(a) (i) Which statement **best** describes the first ionisation energy of an element?

(1)

☒ **A** the energy released on removing 1 mol of electrons from 1 mol of atoms in the gaseous state

☒ **B** the energy required to form 1 mol of singly charged positive ions from 1 mol of atoms

☒ **C** the energy released when 1 mol of gaseous atoms forms 1 mol of gaseous singly charged positive ions

☒ **D** the energy required to remove 1 mol of electrons from 1 mol of gaseous atoms

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(ii) Explain why a general increase is shown in the graph for the first ionisation energies of the elements F to L.

(2)

(iii) Identify the reason why the first ionisation energy of element J is lower than for element H.

(1)

☒ **A** the electron is removed from a new shell

☒ **B** the electron is removed from a new sub-shell

☒ **C** the electron is removed from a fully occupied orbital

☒ **D** the electron is removed from a partially occupied orbital

(b) (i) Which pair of elements belong in Group 2?

(1)

☒ **A** elements B and K **B**

☒ elements C and L **C**

☒ elements D and M **D**

☒ elements E and N

(ii) Justify your answer in terms of ionisation energy.

(1)

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(c) Deduce the identity of element A.

Justify your answer, using the graph of first ionisation energies.

(3)

(Total for Question 1 = 9 marks)

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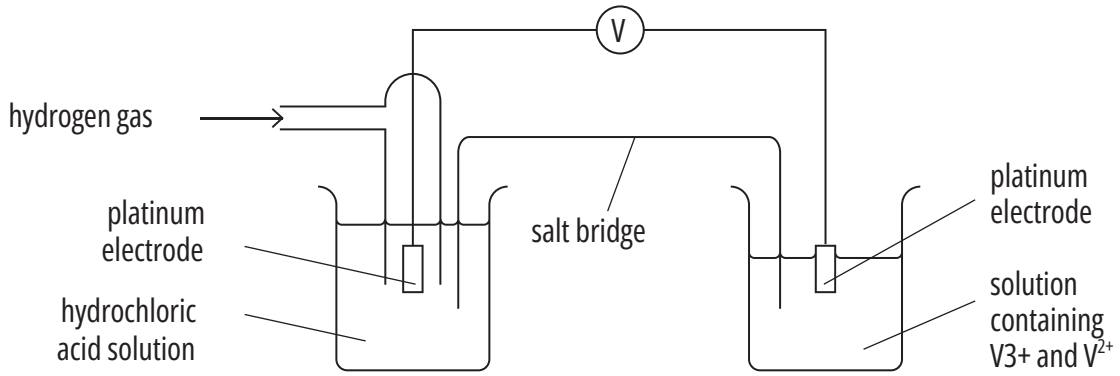
2 Vanadium exists in different oxidation states which can be interconverted using suitable oxidising and reducing agents.

(a) The standard electrode potential for the vanadium(III) / vanadium(II) half-cell is measured using the apparatus shown.



(i) Which is the **best** solution to use in a salt bridge?

(1)

- ☒ **A** 1 mol dm^{-3} potassium chloride solution
- ☒ **B** 1 mol dm^{-3} potassium iodide solution
- ☒ **C** saturated solution of potassium bromide
- ☒ **D** saturated solution of potassium nitrate

(ii) State the essential conditions for the cell in the diagram to give the standard electrode potential.
Assume that the solution you use for the salt bridge is correct.

(3)

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(b) Standard electrode potentials for some half-equations involving vanadium and sulfur are shown in the table.

Elec trode system	$E^{\ominus}$ / V –
$V2+(aq) + 2e^{-}$ V(s)	1.18 –
$V3+(aq) + e^{-}$ $V(aq)^{3+}$	0.26
$SO^{2-}_{4}(aq)+4H(aq)+2e$ $H_2SO_3(aq)^{-} + H_2O(l)$	+0.17
$VO^{2+}(aq) + 2H^{+}(aq) + e^{-}$ $V(aq)^{3+} + H_2O(l)$	+0.34
$S2O^{2}_{3}(aq) + 6H(aq) + 4e$ $2S(s) + 3H_2O(l)$	+0.47
$VO^{+}_{2}(aq)+ 2H(aq)+e$ $VO(aq)^{2+} + H_2O(l)$	+1.00

(i) Which of the sulfur-containing species in the table is the strongest reducing agent?

(1)

☒ **A** acidified thiosulfate ions

☒ **B** an aqueous solution of sulfuric(IV) acid an

☒ **C** aqueous solution of sulfuric(VI) acid

☒ **D** sulfur

(ii) What is the colour of a solution of vanadium(II) ions, V^{2+}?

(1)

☒ **A** blue

☒ **B** green

☒ **C** purple **D**

☒ yellow

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(c) A colourless solution containing acidified thiosulfate ions, SO^{2-}_{23}, was added to a solution containing vanadium(II) ions, V^{2+}, and stirred until no further change was observed.

(i) Predict the vanadium ion present when no further change was observed.

Justify your prediction by giving any relevant redox equations and calculating their $E^{\ominus}_{cell}$ values.

State symbols are not required.

(6)

(ii) Describe what would be observed when acidified thiosulfate ions are added to a solution containing vanadium(II) ions using your equation(s).

(2)

(TotalforQuestion 2 = 14 marks)

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3 Ethanoic acid, CH_3COOH, is the carboxylic acid found in vinegar.
Carboxylic acids are weak acids.

The table gives some data for four carboxylic acids.

Name	pK_a	K_a/mol dm^{-3}
butanoic acid	–	1.51×10^{-5}
ethanoic acid	–	1.74×10^{-5}
methanoic acid	3.75	–
propanoic acid	4.88	–

(a) (i) State what is meant by the term **weak acid**.

(2)

(ii) Explain which of these four compounds is the strongest acid, using the data in the table.

(3)

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(iii) Under certain conditions, ethanoic acid could react with propanoic acid in an acid-base reaction.

Complete the equation giving the products of this reaction and identifying the acid-base conjugate pairs in the spaces below the equation.

(2)

CH_3COOH + CH_3CH_2COOH → ..... + ...

....

(b) Calculate the pH of a solution of 0.100 mol dm^{-3} ethanoic acid.
You must include any assumptions you have made.

(5)

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(c) A solution containing ethanoic acid and sodium ethanoate, $CHCOO^{-}Na^{+}$, acts as a buffer solution.

Explain how this solution acts as a buffer on the addition of separate small amounts of acid and alkali.

You may include relevant equations in your answer.

(4)

(Total for Question 3 = 16 marks)

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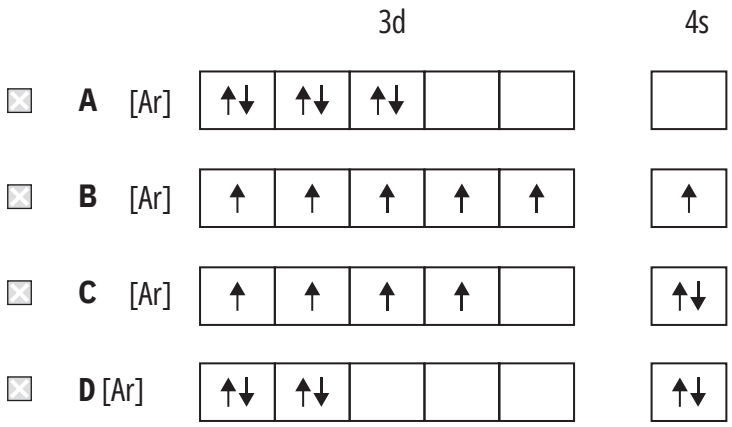
4 Chromium is a *d*-block element and a transition metal.

(a) Which electrons-in-boxes diagram shows the electronic configuration of a chromium atom?

(1)



(b) Explain why chromium is an electrical conductor.

(2)

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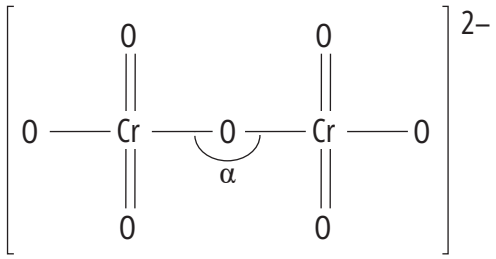
(c) The structure of the orange dichromate(VI) ion, CrO_{27}^{2-}, is shown.



Predict the value of the bond angle α shown in the diagram.
Justify your value using electron-pair repulsion theory.

(2)

(d) The green compound $[Cr(H_2O)_4Cl_2]Cl \cdot 2H_2O$ contains different types of bonding.

Identify the different types of bonding within this compound.

You must refer to the different species involved in each bond.

(3)

(Total for Question 4 = 8 marks)

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5 Manganese is a transition metal.

The most stable oxidation states of this element are manganese(II), manganese(IV) and manganese(VII).
These oxidation states are present in the complex ion $[Mn(H_2O)_6]^{2+}$, the compound MnO_2 and the ion MnO_4^- respectively.

Other oxidation states of manganese can also exist, which include manganese(I) and manganese(VI).

(a) Manganese(I) ions are not stable in aqueous solution, but can form stable complex ions such as the hexacyanomanganate(I) ion, $Mn(CN)_6^{5-}$.

(i) Draw a dot-and-cross diagram to show the electron arrangement in the cyanide ion, CN^-.
Use dots (●) for electrons from carbon, crosses (×) for electrons from nitrogen and a square ( ) to indicate the extra electron.

(2)

(ii) What shape is the hexacyanomanganate(I) ion?

(1)

☒ **A** hexagonal

☒ **B** octahedral

☒ **C** square planar

☒ **D** tetrahedral

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(b) Manganese(VI) in the ion MnO_4^{2-} can be made by reacting manganate(VII) ions in alkaline solution with manganese(IV) oxide.
The equation for the reaction is shown.

$$2MnO_4^-(aq) + MnO_2(s) + 4OH^-(aq) \rightarrow 3MnO_4^{2-}(aq) + 2H_2O(l) \quad E^{\ominus}_{cell} = -0.03\ V$$

(i) Explain, with reference to the half-equations shown, the effect of increasing the concentration of alkali on the value of $E^{\ominus}_{cell}$.

$$MnO_4^-(aq) + e^- \rightleftharpoons MnO_4^{2-}(aq) \quad E^{\ominus} = +0.56\ V$$

$$MnO_4^{2-}(aq) + 2H_2O(l) + 2e^- \rightleftharpoons MnO_2(s) + 4OH^-(aq) \quad E^{\ominus} = +0.59\ V$$

(3)

(ii) Explain why the preparation of manganate(VI) ions, MnO_4^{2-}, may be described as a **reverse** disproportionation reaction.

(2)

(Total for Question 5 = 8 marks)

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6 A white powder with the formula XCO_3 is a carbonate of an element (**X**) in Group 2.

The reaction of XCO_3 with an excess of dilute hydrochloric acid produces carbon dioxide.

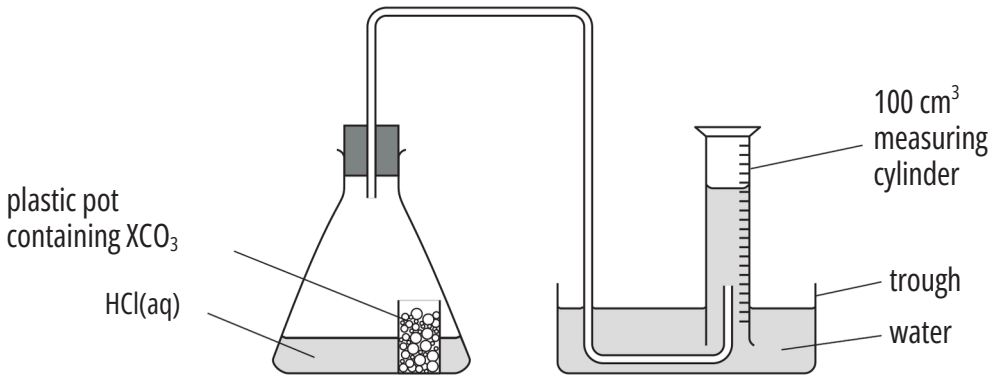
(a) Write the equation for this reaction between XCO_3 and hydrochloric acid.

Include state symbols.

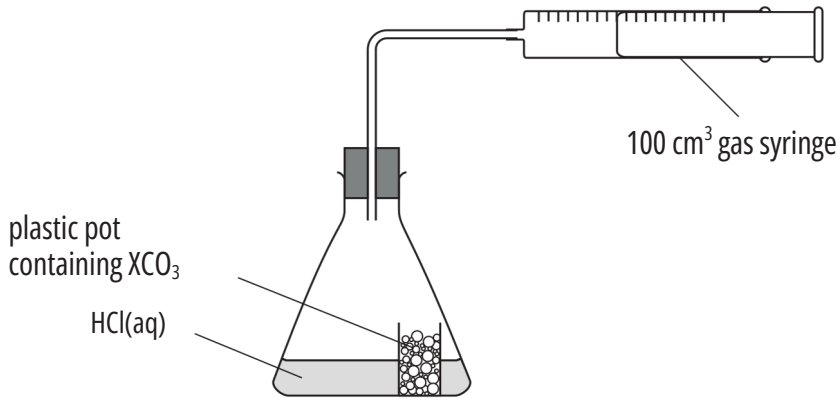
(2)

(b) Apparatus **1** and Apparatus **2** show two sets of apparatus that could be used to measure the volume of gas produced.

Apparatus **1**



Apparatus **2**



In an experiment, 0.320 g of XCOreactswith100cm^3 of HCl with a concentration of 0.200 mol dm^{-3}.

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(i) Give a reason why XCO_3 is placed in a plastic pot in Apparatus **1** and in Apparatus **2**.

(1)

(ii) Give a reason why the volume of gas obtained using Apparatus **1** would be lower than with Apparatus **2**.

(1)

(iii) Explain one possible improvement to the experiment using Apparatus **2**.

(2)

(iv) Using Apparatus **2**, the sample of 0.320 g of XCO produced 50 cm^3 of carbon dioxide.
Under the conditions of the reaction, 1 mol of gas occupies 24 000 cm^3.

Which of the following gives the suggested atomic mass, A_r, of **X**?

(1)

☒ **A** $A_r = \frac{50}{24000 \times 0.320} - 60$

☒ **B** $A_r = \frac{24000}{50} \times 0.320 - 60$

☒ **C** $A_r = \frac{50}{24000 \times 0.320} + 60$

☒ **D** $A_r = \frac{24000}{50} \times 0.320 + 60$

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(v) Identify the element which is **most** likely to be **X**.

(1)

- ☒ **A** magnesium
- ☒ **B** calcium
- ☒ **C** strontium
- ☒ **D** barium

(vi) A flame test was carried out to confirm the identity of **X**.

Explain whether or not the result of the flame test would confirm the identity of **X**, giving the expected flame colour.

(2)

(c) Explain why repeating the experiment with XCO_3 and other Group 2 carbonates using sulfuric acid in place of hydrochloric acid would give inaccurate results.

(2)

(Total for Question 6 = 12 marks)

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*** 7** The table gives the melting temperatures for the Period 3 elements silicon, phosphorus, sulfur and chlorine.

All four elements are covalently bonded.

Element	Si	P	S	Cl
Melting temperature / K	1680	317	392	172

Compare and contrast these melting temperatures in terms of structure and bonding of these elements.

(6)

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(Total for Question 7 = 6 marks)

8 This question is about the solubility of chloride salts.

The enthalpy change of solution may be found by dissolving a compound in deionised water and measuring the temperature change.

A student devised an experiment to measure the enthalpy change of solution for barium chloride, $BaCl_2$.

The method resulted in the formation of 50.0 cm^3 of solution containing 8.0 g of barium chloride.
The enthalpy change of solution was found to be –32 kJ mol^{-1}.

(a) Calculate the temperature increase obtained by the student in this experiment.

[M_r of BaCl = 208.3 specific heat capacity of the solution = 4.18 J g^{-1} $°C^{-1}$]

(3)

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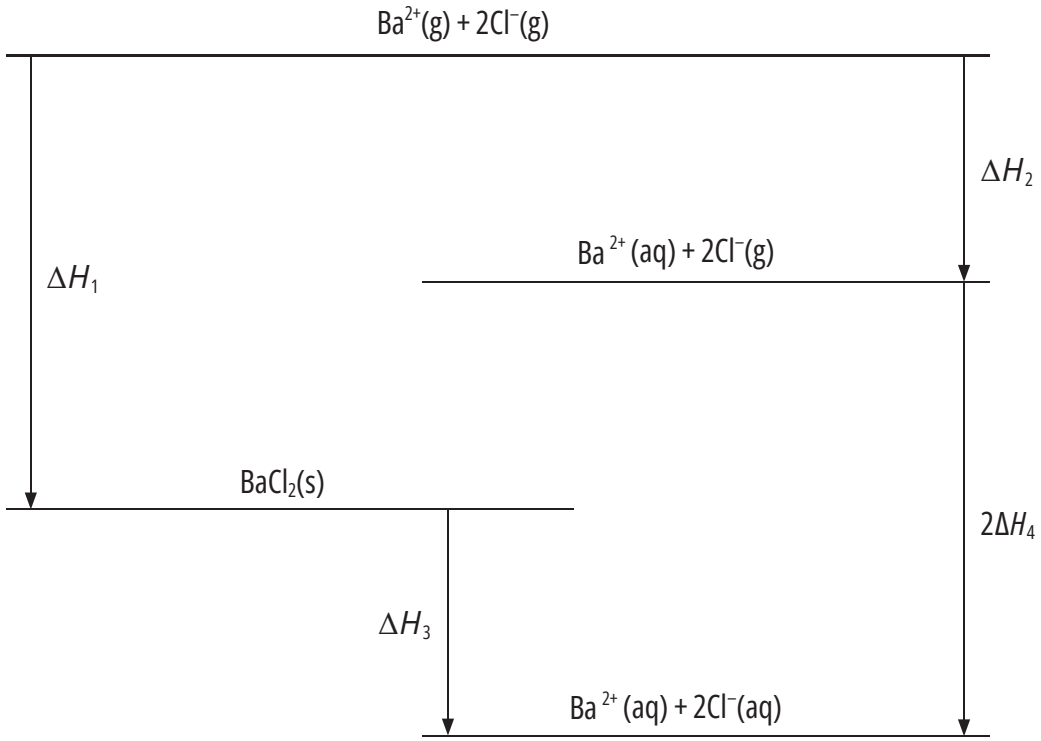
(b) The energy level diagram shows the enthalpy changes associated with the formation of barium chloride solution.



Some of the data for this energy level diagram is shown in the table.

Symbol	Enthalpy change	Value / kJ mol^{-1}
ΔH_1		–2056
ΔH_2	Enthalpy change of hydration of Ba^{2+}	–1360
ΔH_3	Enthalpy change of solution for $BaCl_2$	–32
ΔH_4		

(i) Complete the enthalpy change column of the table by giving the names of the enthalpy changes ΔH_1 and ΔH_4.

(2)

(ii) Calculate a value for the enthalpy change ΔH_4.

(2)

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(c) At 298 K, 0.270 g of calcium sulfate will dissolve in 100 cm^3 of water to form a saturated solution.
Adding more calcium sulfate results in an equilibrium between a saturated solution and undissolved calcium sulfate.

$$CaSO(s) \quad Ca^{2+}(aq) + SO^{2-}{}_4(aq)$$

The expression for the equilibrium constant for this equilibrium is shown.

$$K_{c1} = [Ca^{2+}(aq)][SO^{2-}{}_4(aq)]$$

(i) State why the concentration of calcium sulfate is not present in the K_c1 expression.

(1)

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(ii) Calculate the concentration, in mol dm^{-3}, of calcium sulfate solution when 0.270 g dissolves in water to produce 100 cm^3 of solution.

(1)

(iii) Calculate the value of K_{c1}

Give units with your answer.

(2)

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(d) Like most ionic compounds, the solubility of calcium sulfate changes with temperature and so the equilibrium constant also changes.
The equilibrium constants at 298 K and 350 K are related mathematically by the simplified equation shown.

$$\log_{10}K_{c2} - \log_{10}K_{c1} = \Delta H_{sol} \times 2.61 \times 10^{-5}$$

Data

K_{c1} is the equilibrium constant at 298 K K_{c2} is the

equilibrium constant at 350 K

ΔH_{sol} is the enthalpy change of solutionofCaSO=–17800Jmol^{-1} 4

and at T_1 = 298 K, K_{c1} is the answer to (c)(iii)

(i) Calculate a value for the equilibrium constant at 350 K, K_{c2}, using your answer to (c)(iii) and the simplified mathematical expression.

[If you have been unable to calculate a value for K_{c1} then you may use K_{c1} = 6.50 × 10^{-6} . This is not the correct value.]

(4)

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(ii) Deduce how the solubility of calcium sulfate changes as temperature is increased.

Justify your answer in terms of K_c values.

(2)

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(Total for Question 8 = 17 marks)

TOTAL FOR PAPER = 90 MARKS

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The Periodic Table of Elements

1	2											3	4	5	6	7	0 (8)
							1.0 H hydrogen 1										(18) 4.0 He helium 2
(1)	(2)		Key: relative atomic mass / atomic symbol / name / atomic (proton) number									(13)	(14)	(15)	(16)	(17)	
6.9 Li lithium 3	9.0 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
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

* Actinide 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
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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