Please check the examination details below before entering your candidate information

Candidate surname	Other names

Centre Number | Candidate Number

Pearson Edexcel Level 3 GCE

Monday 12 June 2023

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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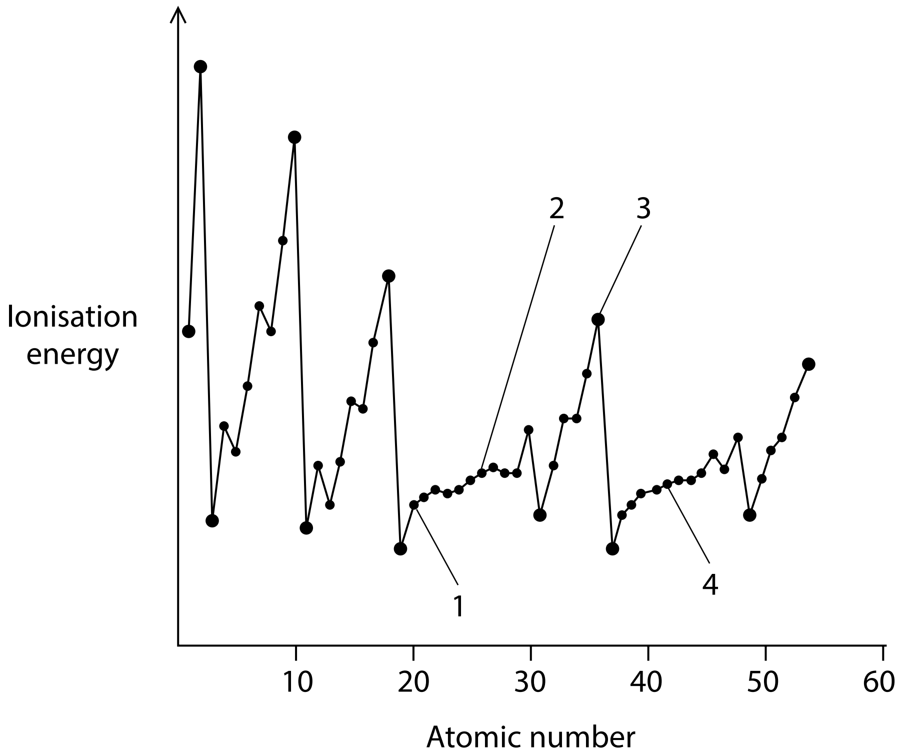
Answer ALL questions.

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 d-block elements.

(a) Which of the labels 1–4 identifies a d-block element in Period 4?



(1)

☐ **A** 1

☐ **B** 2

☐ **C** 3

☐ **D** 4

(b) State what is meant by the term d-block element.

(1)

(Total for Question 1 = 2 marks)

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2 Chemists often use the term 'orbital' when considering atomic structure.

(a) State what is meant by the term orbital.

(2)

(b) Draw diagrams to show the shape of an s and a p orbital.

(2)

s orbital	p orbital

(c) What is the electronic configuration of a copper atom?

(1)

☐ **A** $[Ar]4s^1 3d^{10}$

☐ **B** $[Ar]4s^2 3d^9$

☐ **C** $[Ar]4s^2 4p^1 3d^8$

☐ **D** $[Ar]4s^2 4p^2 3d^7$

(Total for Question 2 = 5 marks)

3 This question is about compounds containing elements from Group 7.

(a) Which change occurs when concentrated sulfuric acid is added to potassium bromide?

(1)

☐ **A** bromide ions oxidise sulfuric acid forming sulfur

☐ **B** bromide ions oxidise sulfuric acid forming sulfur dioxide

☐ **C** bromide ions reduce sulfuric acid forming sulfur

☐ **D** bromide ions reduce sulfuric acid forming sulfur dioxide

(b) Chemists can test for the presence of bromide ions in solution by adding a small amount of acidified silver nitrate solution.
The solubility of the precipitate in aqueous ammonia is then tested.

(i) Which statement is correct for bromide ions?

(1)

☐ **A** a white precipitate forms that dissolves in concentrated ammonia only

☐ **B** a white precipitate forms that dissolves in both dilute and concentrated ammonia

☐ **C** a cream precipitate forms that dissolves in concentrated ammonia only

☐ **D** a cream precipitate forms that dissolves in both dilute and concentrated ammonia

(ii) Give a reason why the silver nitrate must be acidified.

(1)

(iii) Explain which acid needs to be used to acidify the silver nitrate solution and why other acids are unsuitable.

(2)

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(c) Iodine trichloride forms a dimer, I_2Cl_6, in the solid state.
When molten, it is suggested that it breaks down as shown.

$$I_2Cl_6 \rightleftharpoons ICl_2^+ + ICl_4^-$$

(i) Draw a labelled diagram of a simple experiment to confirm this dissociation has occurred, stating the positive result.

(2)

Result

(ii) What is the shape of the ICl_4^- ion?

(1)

☐ **A** octahedral

☐ **B** square planar

☐ **C** tetrahedral

☐ **D** trigonal bipyramidal

(iii) The equilibrium position for the dissociation of molten I_2Cl_6 lies to the left.

$$I_2Cl_6 \rightleftharpoons ICl_2^+ + ICl_4^-$$

What is the most likely numerical value of K_c for this equilibrium?

(1)

☐ **A** 1.0×10^6

☐ **B** 5.0×10^3

☐ **C** 1.0

☐ **D** 5.0×10^{-3}

(Total for Question 3 = 9 marks)

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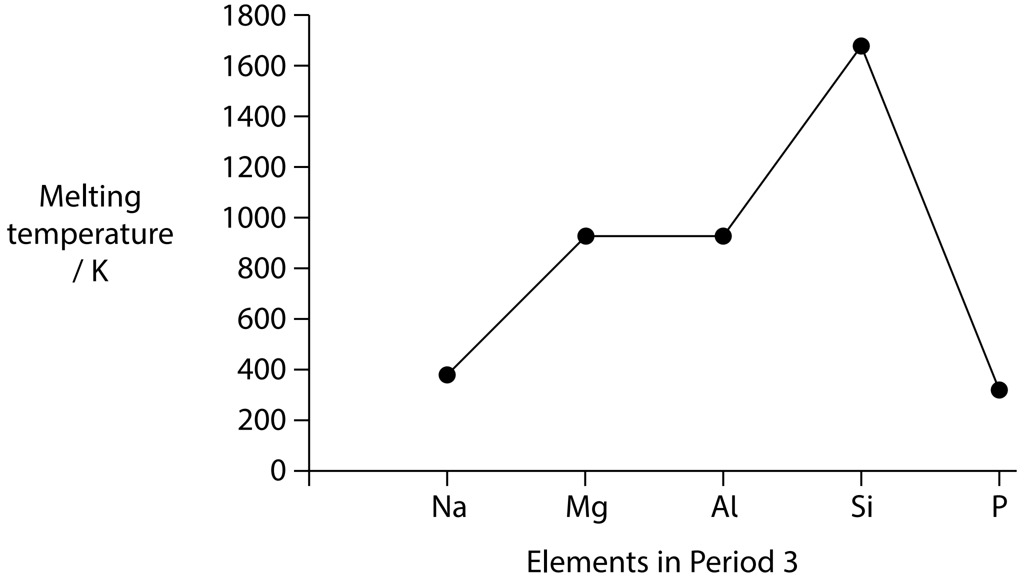
4 The graph shows the melting temperatures of some elements in Period 3.



Explain the variations in melting temperature across the period in terms of the structure and bonding in these elements.

(6)

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(Total for Question 4 = 6 marks)

5 This question is about the decomposition of dinitrogen tetroxide.
The reaction eventually reaches equilibrium.

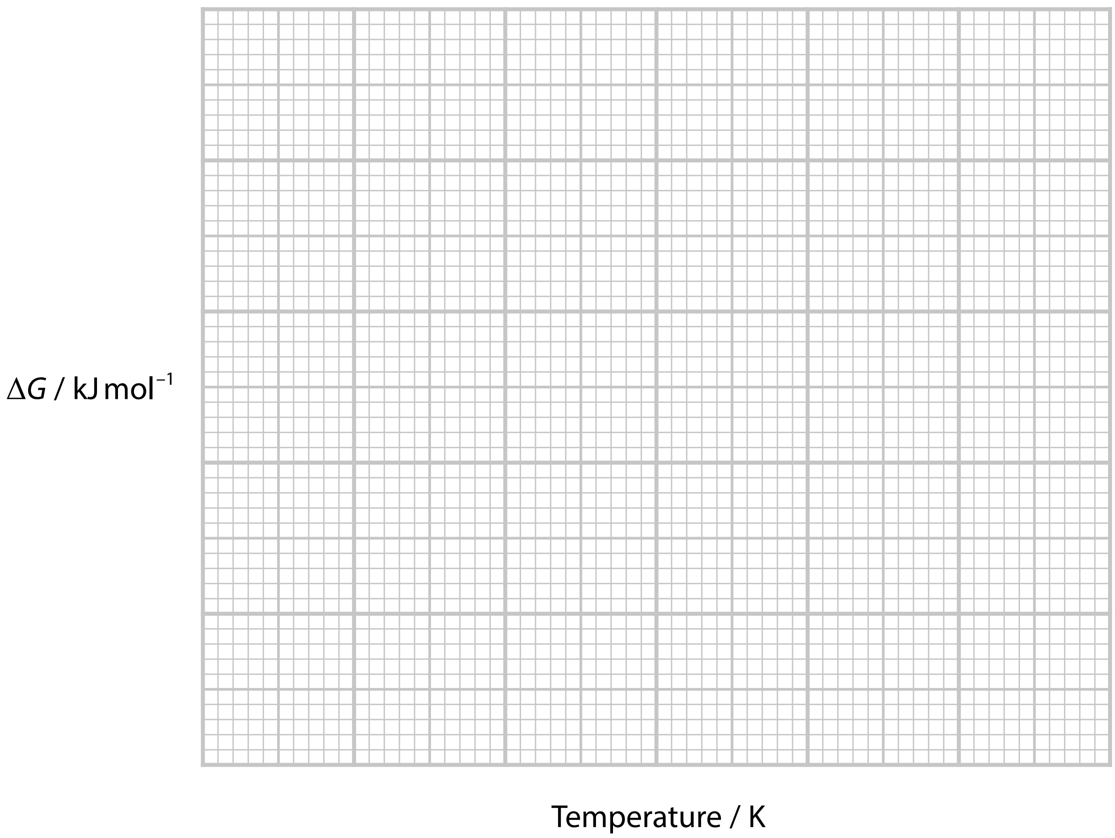
$$\underset{\text{colourless}}{N_2O_4(g)} \rightleftharpoons \underset{\text{brown}}{2NO_2(g)}$$

(a) The table shows values of ΔG at different temperatures for this reaction.

Temperature / K	ΔG / kJ mol^{-1}
350	–4.0
400	–13
450	–22
500	–31
550	–40

(i) Plot a graph of ΔG against temperature.

(2)



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(ii) Calculate the entropy change of the system, ΔS_{system}, in $J K^{-1} mol^{-1}$, using your straight line from the graph in (a)(i) and the equation shown.

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

(3)

(iii) What feature of the graph in (a)(i) gives the enthalpy change of the reaction?

(1)

- ☐ **A** intercept of the x-axis
- ☐ **B** (intercept of the x-axis) $\times -1$
- ☐ **C** intercept of the y-axis
- ☐ **D** (intercept of the y-axis) $\times -1$

(b) What happens to the position of the equilibrium and the colour of the mixture when the pressure is increased?

The volume of the system remains constant.

$$\underset{\text{colourless}}{N_2O_4(g)} \rightleftharpoons \underset{\text{brown}}{2NO_2(g)}$$

(1)

		Position of equilibrium	Change in colour
☐	**A**	moves to the right	mixture gets lighter
☐	**B**	moves to the right	mixture gets darker
☐	**C**	moves to the left	mixture gets lighter
☐	**D**	moves to the left	mixture gets darker

(Total for Question 5 = 7 marks)

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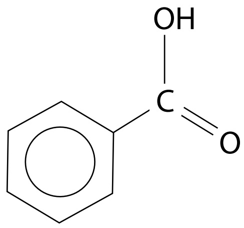
6 Benzoic acid is a weak acid found in cranberries.



C_6H_5COOH – benzoic acid

(a) Which of these answers identifies the types of species present when benzoic acid is mixed with nitric acid?

[K_a of benzoic acid = 6.3×10^{-5} mol dm^{-3}; K_a of nitric acid = 40 mol dm^{-3}]

(1)

		C_6H_5COOH	+ HNO_3	⇌ $C_6H_5COOH_2^+$	+ NO_3^-
☐	**A**	acid	base	acid	base
☐	**B**	acid	base	base	acid
☐	**C**	base	acid	base	acid
☐	**D**	base	acid	acid	base

(b) The ionic salts sodium benzoate and potassium benzoate are both used as food preservatives.

Explain why the melting temperature of sodium benzoate is higher than the melting temperature of potassium benzoate.

(2)

(c) The value of K_a for benzoic acid = 6.28×10^{-5} mol dm^{-3}.

(i) Write the expression for the acid dissociation constant, K_a, of benzoic acid.

(1)

(ii) Calculate the mass of benzoic acid needed to prepare 250 cm^3 of a solution with a pH = 3.51

(4)

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(d) Weak acids such as benzoic acid can be neutralised by sodium hydroxide solution.

$$C_6H_5COOH(aq) + NaOH(aq) \rightarrow C_6H_5CO_2Na(aq) + H_2O(l)$$

(i) Which of these could be used to show the end-point of a titration of benzoic acid with sodium hydroxide solution?

(1)

- ☐ **A** bromothymol blue
- ☐ **B** litmus
- ☐ **C** methyl orange
- ☐ **D** phenolphthalein

(ii) Another weak acid found in cranberries is quinic acid, $C_6H_7(OH)_4COOH$.
It is neutralised by sodium hydroxide solution in a similar way to benzoic acid.

A 25.0 cm^3 sample of 0.500 mol dm^{-3} quinic acid solution was neutralised under standard conditions in a polystyrene cup using 25.0 cm^3 of 0.800 mol dm^{-3} of sodium hydroxide solution.
This resulted in a temperature rise of 2.9 °C.

Calculate the standard enthalpy change of neutralisation, $\Delta_{neut}H^{\ominus}$, of quinic acid in kJ mol^{-1}.

[Assume the density of both solutions is 1.0 g cm^{-3}.

specific heat capacity of solution formed = 4.18 J g^{-1} °C^{-1}]

(3)

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(iii) The standard enthalpy change of neutralisation of the weak acid HCN by sodium hydroxide is –11.7 kJ mol^{-1} while that of the strong acid HCl is –57.9 kJ mol^{-1}.

Explain the difference between these values.

(2)

(Total for Question 6 = 14 marks)

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7 This question is about chromium and chromium compounds.

(a) Naturally occurring chromium has four isotopes, ^{50}Cr, ^{52}Cr, ^{53}Cr and ^{54}Cr.

State what is meant by the term isotopes.

(2)

(b) Both chromium and calcium can form ions with a +2 charge.

(i) Complete the electronic configuration of a Cr^{2+} ion.

(1)

$1s^2$

(ii) Explain which of chromium or calcium most easily forms a +2 ion using all of the data in the table.

Element	Atomic number	1st ionisation energy / $kJ\,mol^{-1}$	2nd ionisation energy / $kJ\,mol^{-1}$	Metallic radius / nm
Chromium	24	653	1592	0.129
Calcium	20	590	1145	0.197

(3)

(c) Chromium(III) sulfate, $Cr_2(SO_4)_3$, dissolves in water to form the complex ion $[Cr(H_2O)_6]^{3+}(aq)$.

(i) State the colour of this complex ion.

(1)

(ii) Explain why the aqueous solution of this complex ion has an acidic pH by considering the interaction between the metal ion and the ligands.

(2)

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(d) A student researching the role of dichromate(VI) ions, $Cr_2O_7^{2-}$, as an oxidising agent made the statement shown.

'Standard electrode potential data shows that it is never feasible for a 1.00 mol dm^{-3} solution of potassium dichromate(VI) to oxidise the chloride ions in hydrochloric acid.'

Comment on this statement using the data and equilibria shown.

Equilibrium 1

$Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^- \rightleftharpoons 2Cr^{3+}(aq) + 7H_2O(l)$ $\quad E^\ominus = +1.33\,V$

Equilibrium 2

$Cl_2(aq) + 2e^- \rightleftharpoons 2Cl^-(aq)$ $\quad E^\ominus = +1.36\,V$

(4)

(Total for Question 7 = 13 marks)

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***8** Transition metals and their compounds can act as catalysts in many reactions such as the ones shown:

- platinum, Pt, in the catalytic converters of vehicles
- manganese(II) ions, $Mn^{2+}(aq)$, in the oxidation of ethanedioate ions, $C_2O_4^{2-}(aq)$, by manganate(VII) ions, $MnO_4^-(aq)$.

Compare and contrast the role of the catalysts in these reactions.

(6)

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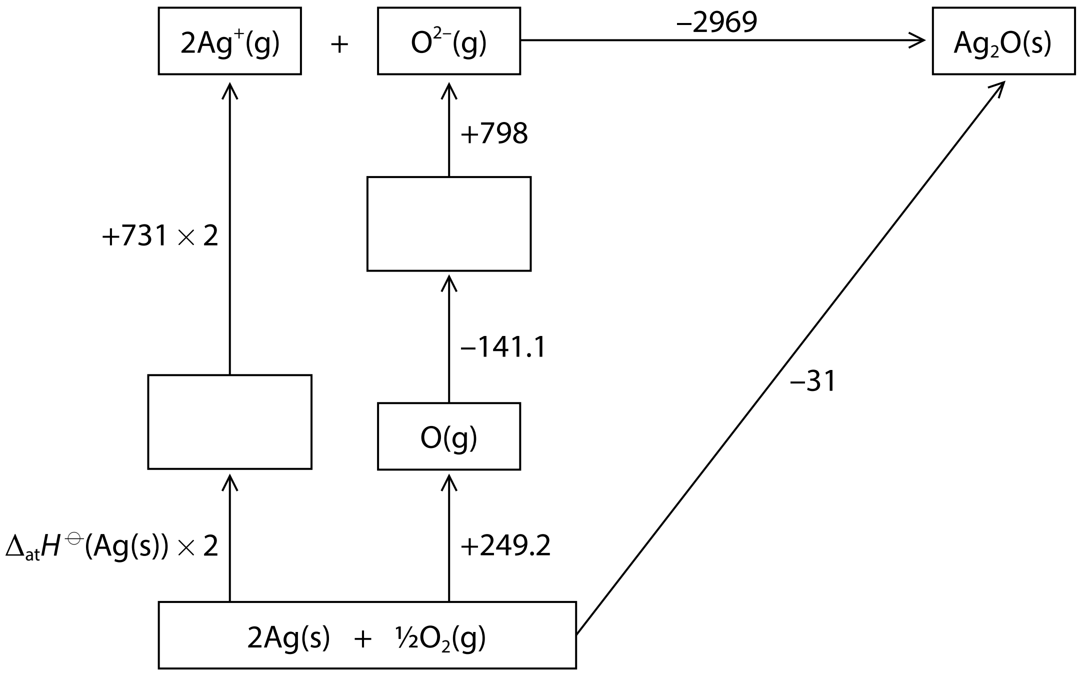
(Total for Question 8 = 6 marks)

9 This question is about silver compounds.

(a) The diagram shows a Born–Haber cycle for the formation of silver(I) oxide, Ag_2O. All quantities are measured in kJ mol^{-1}.



(i) Complete the diagram by adding appropriate species and state symbols to the empty boxes.

(2)

(ii) Explain why the value for the first electron affinity of oxygen is negative and the value for the second electron affinity is positive.

(3)

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(iii) Calculate a value for the standard enthalpy change of atomisation of silver, $\Delta_{at}H^{\ominus}$, using the Born–Haber cycle.

(3)

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(b) Another silver compound is silver chloride, AgCl. Values for its lattice energy can be found by experiment or by theoretical calculation.

Compound	Experimental lattice energy / $kJ\,mol^{-1}$	Theoretical lattice energy / $kJ\,mol^{-1}$
Silver chloride	−905	−833

(i) Give **two** assumptions used in the model to calculate the theoretical lattice energy.

(2)

(ii) Explain the difference in the two values for the lattice energy of silver chloride by considering the possible bonding models.

(3)

(Total for Question 9 = 13 marks)

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10 Manganese compounds can be used to determine the amounts of dissolved molecular oxygen in water samples.

(a) Draw the dot-and-cross diagram for an oxygen molecule, O_2.
Show outer shell electrons only.

(1)

(b) The solubility of oxygen in water under standard conditions is 1.22×10^{-3} mol dm^{-3}.

Comment on this value by considering the type and strength of the intermolecular forces in

- pure water
- pure oxygen
- a mixture of water and oxygen.

Detailed descriptions of the forces involved are not required.

(4)

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(c) The amount of dissolved oxygen in a sample of river water was found using the process outlined.

- excess alkaline manganese(II) sulfate, $MnSO_4$, was added to a 150 cm^3 sample of river water
- the Mn^{2+} ions reacted with the dissolved oxygen forming a precipitate of manganese(IV) oxide hydroxide

$$2Mn^{2+}(aq) + O_2(aq) + 4OH^-(aq) \rightarrow 2MnO(OH)_2(s)$$

- the precipitate was then dissolved using excess sulfuric acid, forming Mn^{4+}(aq) ions

$$MnO(OH)_2(s) + 4H^+(aq) \rightarrow Mn^{4+}(aq) + 3H_2O(l)$$

- excess potassium iodide solution was then added, forming iodine

$$Mn^{4+}(aq) + 2I^-(aq) \rightarrow Mn^{2+}(aq) + I_2(aq)$$

- the liberated iodine was then titrated with sodium thiosulfate solution, $Na_2S_2O_3$(aq), of concentration 0.00518 mol dm^{-3}

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

- the mean volume of the titre of $Na_2S_2O_3$(aq) was 34.20 cm^3.

(i) Calculate the concentration of dissolved oxygen in the sample of river water, in g dm^{-3}.

(5)

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You may use this space to continue your answer to 10(c)(i).

(ii) The concentration of oxygen in water is often expressed in parts per million (ppm), where 1 ppm equals 1 g of solute dissolved in 1×10^6 g of solvent.

Calculate the concentration of the oxygen in the sample of river water in ppm. Assume the density of the river water is 1.00 g cm^{-3}.

(1)

(d) Some data is shown for electrode systems involving the Mn^{3+}(aq) ion.

Half-cell	Electrode system	$E^{\ominus}$ / V
A	$MnO_2(s) + 4H^+(aq) + e^- \rightleftharpoons Mn^{3+}(aq) + 2H_2O(l)$	+0.95
B	$Mn^{3+}(aq) + e^- \rightleftharpoons Mn^{2+}(aq)$	+1.51

Explain why Mn^{3+} ions are unstable in aqueous solution.
Include an equation and the type of reaction that occurs.

(4)

(Total for Question 10 = 15 marks)

TOTAL FOR PAPER = 90 MARKS

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The Periodic Table of Elements

Key

relative atomic mass **atomic symbol** name atomic (proton) number

1	**2**											**3**	**4**	**5**	**6**	**7**	**0 (8)**
(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*	*(9)*	*(10)*	*(11)*	*(12)*	*(13)*	*(14)*	*(15)*	*(16)*	*(17)*	*(18)*
							1.0 **H** hydrogen 1										4.0 **He** helium 2
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											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