Please check the examination details below before entering your candidate information

Candidate surname	Other names

Centre Number | Candidate Number

Pearson Edexcel International Advanced Level

Tuesday 2 June 2026

Afternoon (Time: 1 hour 45 minutes)

Paper reference **WCH15/01**

Chemistry

International Advanced Level
UNIT 5: Transition Metals and Organic Nitrogen 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.*
- In the question marked with an **asterisk (*)**, marks will be awarded for your ability to structure your answer logically, showing how 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.
- Try to answer every question.
- Check your answers if you have time at the end.

Turn over ▶

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SECTION A

Answer ALL the questions in this section.

You should aim to spend no more than 20 minutes on this section.

For each question, select one answer from A to D and put a cross in the box ☒. If you change your mind, put a line through the box ☒ and then mark your new answer with a cross ☒.

1 In a methanol/oxygen fuel cell, the methanol is

☒ **A** oxidised at the negative electrode

☒ **B** oxidised at the positive electrode

☒ **C** reduced at the negative electrode

☒ **D** reduced at the positive electrode

(Total for Question 1 = 1 mark)

2 Which statement(s) about haemoglobin and carbon monoxide poisoning is/are correct?

1 Haemoglobin is an iron(III) complex.

2 Haemoglobin contains a polydentate ligand.

3 Carbon monoxide replaces an oxygen molecule bound to haemoglobin by ligand exchange.

☒ **A** **1**, **2** and **3** are correct

☒ **B** only **1** and **2** are correct

☒ **C** only **2** and **3** are correct

☒ **D** only **3** is correct

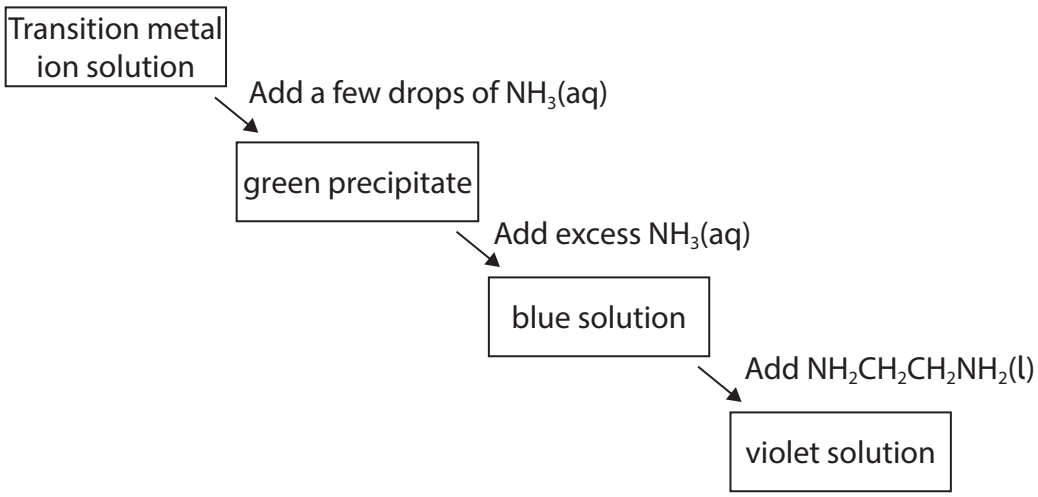
(Total for Question 2 = 1 mark)

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3 A transition metal ion solution was tested as shown.



(a) Which transition metal ion is present?

(1)

- ☒ **A** Cr^{3+}
- ☒ **B** Cu^{2+}
- ☒ **C** Fe^{2+}
- ☒ **D** Ni^{2+}

(b) Which is the **best** explanation for the reaction that occurs when ethane-1,2-diamine is added to the blue solution?

(1)

- ☒ **A** the bonds between the ligands and the transition metal ion are stronger in the product than in the reactant
- ☒ **B** the reaction is extremely exothermic
- ☒ **C** the reaction has a low activation energy
- ☒ **D** the total number of particles on the right-hand side of the equation is greater than on the left

(c) What is the bond angle between dative covalent bonds of the ligand and the transition metal ion in the violet solution?

(1)

- ☒ **A** 90°
- ☒ **B** 107°
- ☒ **C** 109.5°
- ☒ **D** 120°

(Total for Question 3 = 3 marks)

4 Copper(II) ions form a number of complexes.

(a) What are the coordination numbers of the two complex ions?

(1)

		$[Cu(H_2O)_6]^{2+}$	$[Cu(OOCCOO)_3]^{4-}$
☒	**A**	2	2
☒	**B**	2	4
☒	**C**	6	3
☒	**D**	6	6

(b) What are the shapes of the two complex ions?

(1)

		$[Cu(H_2O)_6]^{2+}$	$[CuCl_4]^{2-}$
☒	**A**	hexagonal	square planar
☒	**B**	hexagonal	tetrahedral
☒	**C**	octahedral	square planar
☒	**D**	octahedral	tetrahedral

(Total for Question 4 = 2 marks)

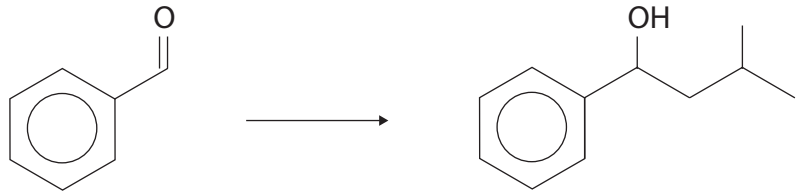
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5 Grignard reagents can be used to increase the length of the carbon chain in organic molecules.

Benzaldehyde reacts with a Grignard reagent, followed by hydrolysis to form 3-methyl-1-phenylbutan-1-ol.



benzaldehyde 3-methyl-1-phenylbutan-1-ol

(a) What is the formula of the Grignard reagent in this reaction?

(1)

- ☒ **A** $CH_3CH_2CH_2CH_2MgBr$
- ☒ **B** $(CH_3)_2CHCH_2MgBr$
- ☒ **C** $CH_3CH_2CH(CH_3)MgBr$
- ☒ **D** $(CH_3)_3CMgBr$

(b) What type of reaction does benzaldehyde undergo with the Grignard reagent?

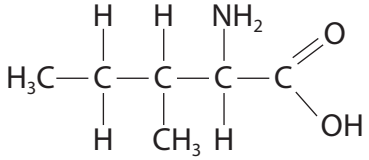
(1)

- ☒ **A** electrophilic addition
- ☒ **B** nucleophilic addition
- ☒ **C** electrophilic substitution
- ☒ **D** nucleophilic substitution

(Total for Question 5 = 2 marks)

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6 The structure of isoleucine is shown.



(a) Which absorptions would you **not** expect in the infrared spectrum of isoleucine? Use your Data Booklet.

(1)

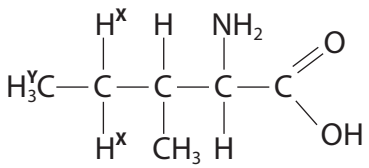
☒ **A** 3500 – 3300 cm^{-1}

☒ **B** 2962 – 2853 cm^{-1}

☒ **C** 1725 – 1700 cm^{-1}

☒ **D** 1700 – 1630 cm^{-1}

(b) The structure of isoleucine with two types of protons labelled **X** and **Y** is shown.



What are the expected splitting patterns of the peaks for these hydrogen atoms in the high resolution proton NMR spectrum of isoleucine?

(1)

		Splitting pattern of the peak for the two hydrogen atoms labelled H^X	Splitting pattern of the peak for the three hydrogen atoms labelled H_3^Y
☒	**A**	doublet	doublet
☒	**B**	doublet	triplet
☒	**C**	quintet (multiplet of five)	doublet
☒	**D**	quintet (multiplet of five)	triplet

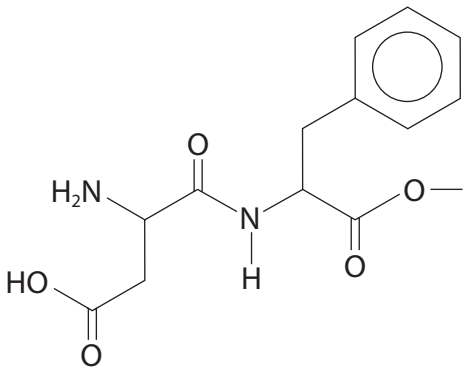
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7 Aspartame is an artificial sweetener with a number of functional groups.



(a) Which functional group is **not** present in this molecule?

(1)

- ☒ **A** amine
- ☒ **B** ester
- ☒ **C** ketone
- ☒ **D** phenyl

(b) How many chiral carbon atoms are present in this molecule?

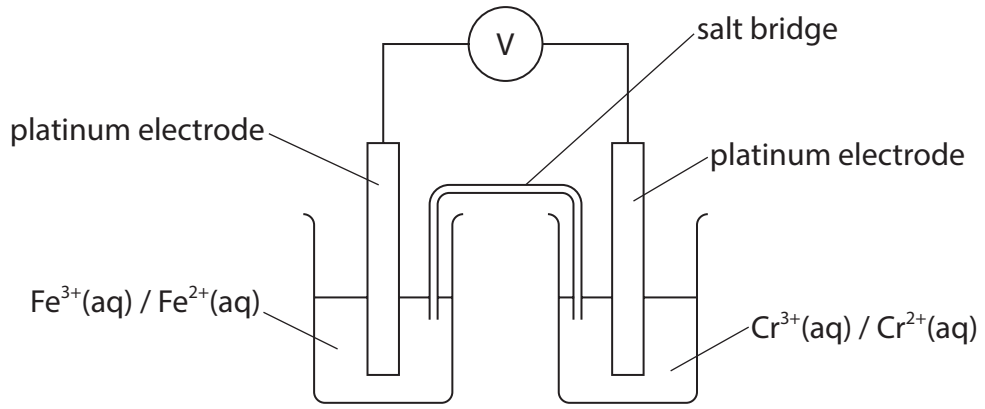
(1)

- ☒ **A** none
- ☒ **B** one
- ☒ **C** two
- ☒ **D** three

(Total for Question 7 = 2 marks)

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8 A student set up an electrochemical cell to measure the standard emf, $E^{\ominus}_{cell}$, of the reaction between iron(III) ions and chromium(II) ions.



(a) The student measured 250 cm^3 of solution into each beaker.

What mass of iron(III) sulfate, $Fe_2(SO_4)_3$, would be needed to make the solution for the iron(III) half-cell?

[Data: Molar mass of $Fe_2(SO_4)_3$ = 399.9 g mol^{-1}]

(1)

- ☒ **A** 49.99 g
- ☒ **B** 99.98 g
- ☒ **C** 199.95 g
- ☒ **D** 399.90 g

(b) The equation for the reaction is shown.

$$Fe^{3+}(aq) + Cr^{2+}(aq) \rightarrow Fe^{2+}(aq) + Cr^{3+}(aq)$$

What is taking place in this reaction?

(1)

- ☒ **A** chromium(II) ions act as an oxidising agent and iron(III) ions are oxidised
- ☒ **B** chromium(II) ions act as a reducing agent and iron(III) ions are oxidised
- ☒ **C** chromium(II) ions act as an oxidising agent and iron(III) ions are reduced
- ☒ **D** chromium(II) ions act as a reducing agent and iron(III) ions are reduced

(Total for Question 8 = 2 marks)

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9 Which does **not** provide evidence for the delocalised model for the structure of benzene?

- ☒ **A** infrared spectroscopy
- ☒ **B** mass spectrometry
- ☒ **C** thermochemistry
- ☒ **D** X-ray diffraction

(Total for Question 9 = 1 mark)

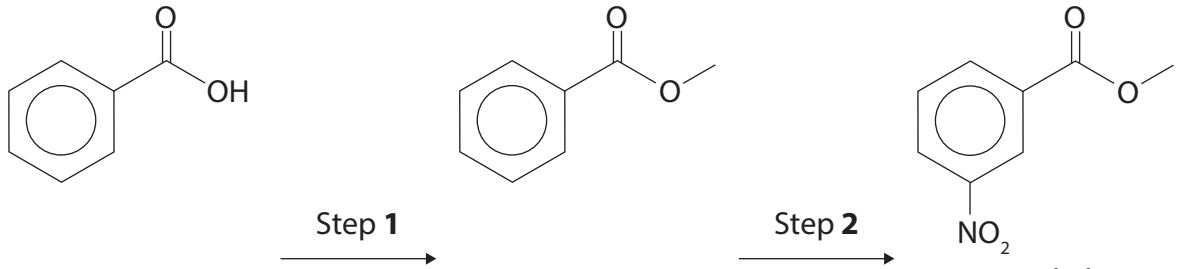
10 Which is correct for the formation of the delocalised ring of electrons in benzene?

	Orbital overlap	Bond formed
☒ **A**	p – p	σ
☒ **B**	p – p	π
☒ **C**	s – s	σ
☒ **D**	s – s	π

(Total for Question 10 = 1 mark)

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11 During a two-step laboratory synthesis, 11.9 g of benzoic acid was converted into 10.0 g of methyl 3-nitrobenzoate.



Step **1** → (66% yield) Step **2** →

benzoic acid — methyl benzoate — methyl 3-nitrobenzoate

[Data: M_r = 122 M_r = 136 M_r = 181]

(a) What is the mass of methyl benzoate formed in Step **1**?

(1)

- ☒ **A** 7.0 g
- ☒ **B** 8.8 g
- ☒ **C** 10.7 g
- ☒ **D** 13.3 g

(b) What is the **overall** yield for the formation of methyl 3-nitrobenzoate from benzoic acid?

(1)

- ☒ **A** 22%
- ☒ **B** 44%
- ☒ **C** 57%
- ☒ **D** 66%

(c) What reagent(s) is/are required for the conversion of methyl benzoate to methyl 3-nitrobenzoate?

(1)

- ☒ **A** concentrated H_2SO_4 and concentrated HNO_3
- ☒ **B** concentrated HCl and concentrated HNO_3
- ☒ **C** $NaNO_2$
- ☒ **D** $NaNO_2$ and concentrated HCl

(Total for Question 11 = 3 marks)

TOTAL FOR SECTION A = 20 MARKS

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SECTION B

Answer ALL the questions. Write your answers in the spaces provided.

12 This question is about some of the chemistry of the d-block elements vanadium and zinc.

(a) Complete the electronic configurations of a vanadium(II) ion and a zinc atom.

(2)

Vanadium(II) ion $1s^2\ 2s^2\ 2p^6$

Zinc atom $1s^2\ 2s^2\ 2p^6$

(b) The first **five** ionisation energies of vanadium, in kJ mol^{-1}, are shown.

	1st	2nd	3rd	4th	5th
Vanadium	650	1414	2828	4507	6294

(i) Explain why vanadium is able to form stable ions with different oxidation numbers.
Refer to the ionisation energies in your answer.

(2)

(ii) Four different oxidation states of vanadium are given in the table. Complete the table.

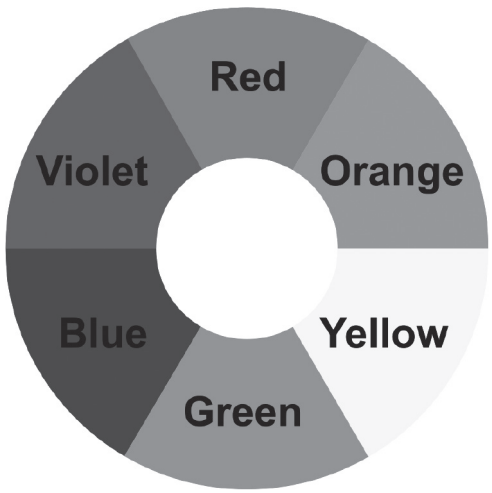
(2)

Oxidation number of vanadium	Formula of the ion	Colour of the ion
+5	VO_2^+	yellow
+4		
+3		
+2		

(iii) Explain why aqueous solutions containing V^{2+} ions are coloured.

(3)

(iv) The colours in the visible spectrum are shown in the diagram.



(Source: PAL)

State why aqueous solutions of V^{2+} ions are violet in colour.
Refer to the diagram in your answer.

(1)

(c) State and justify the colour, if any, of an aqueous solution containing Zn^{2+} ions.

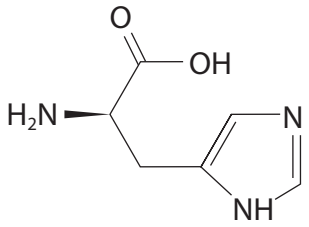
(2)

(Total for Question 12 = 12 marks)

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13 Histidine is an essential amino acid. It cannot be produced in sufficient quantities by chemical reactions in the human body, and so must be obtained from food.



(a) (i) Give the molecular formula of histidine.

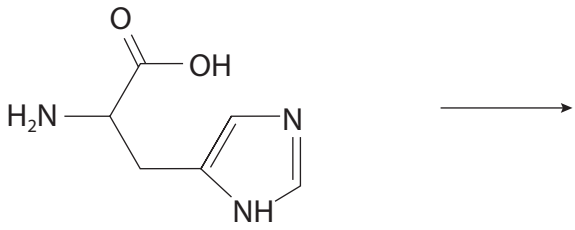
(1)

(ii) Calculate the percentage composition by mass of the elements in histidine.

(3)

(b) Histidine is protonated by acids.
Complete the equation to show the protonation of a molecule of histidine.

(1)



(c) Histidine melts and decomposes at above 250 °C, well above the melting temperature of octanoic acid which has a similar molar mass.

Explain why histidine has the much higher melting temperature.

(2)

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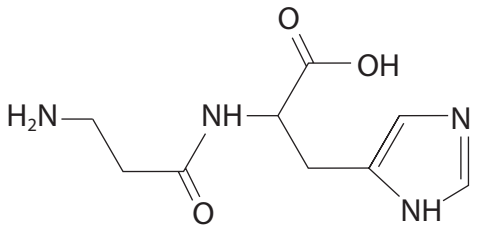
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(d) Dipeptides are molecules formed when two amino acids combine.
Carnosine is a dipeptide produced in the human body and found in muscle and brain tissues. The structure of carnosine is shown.



(i) Draw the **skeletal** formula of the amino acid which would react with histidine to make carnosine.

(1)

(ii) The concentration of carnosine in the blood should not exceed 6.3×10^{-6} mol dm^{-3}.

Convert this concentration to parts per million (ppm) by mass.

[Data: Molar mass of carnosine = 226 g mol^{-1}, density of blood = 1.06 g cm^{-3}]

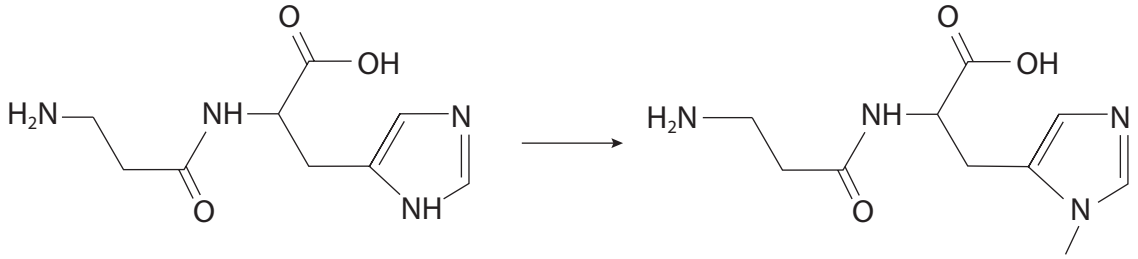
(3)

(e) Cobalt poisoning is due to the presence of $[Co(H_2O)_6]^{2+}$ ions in the bloodstream.
Carnosine is a possible treatment for cobalt poisoning.

Suggest how carnosine would interact with $[Co(H_2O)_6]^{2+}$ ions to reduce cobalt poisoning.
Refer to the structure of carnosine in your answer.

(3)

(f) Carnosine can be converted in a laboratory into anserine, which plays a similar role in birds to carnosine in humans.



carnosine anserine

Suggest a reagent that could be used to convert carnosine into anserine.

(1)

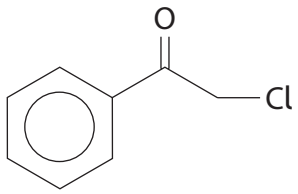
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14 This question is about compounds with the molecular formula C_8H_7ClO.

(a) The skeletal formula of one of these compounds, **A**, is shown.



Compound **A** can be made by reacting chloroethanoyl chloride, $CH_2ClCOCl$, with benzene.
This is an electrophilic substitution reaction which requires a catalyst.

(i) Give the formula of both the catalyst **and** the electrophile in this reaction.

(2)

.....

.....

(ii) Draw the mechanism for this reaction.

(3)

(b) A student carried out three tests on three **different** compounds, **B**, **C** and **D**, with molecular formula C_8H_7ClO. Each compound contained a benzene ring.

Test **1** was carried out on **B**, **C** and **D**.

Addition of a few drops of water gave white, misty fumes only with **B**.

Test **2** was carried out on **C** and **D** only.

Addition of ammoniacal silver nitrate gave a silver mirror on warming only with **C**.

Test **3** was carried out on **D** only.

Addition of iodine in sodium hydroxide solution gave a precipitate on warming with **D**.

(i) Identify, by name or formula, the white, misty fumes produced by **B** in Test **1**.

(1)

.....

(ii) State the type of reaction which the silver ions undergo in Test **2**.

(1)

.....

(iii) Give the formula of the precipitate produced by **D** in Test **3**.
Include the colour of the precipitate.

(2)

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(iv) The student used the results of the three tests and the molecular formula to identify the functional groups present in **B**, **C** and **D**.

Give **one** possible structure for each of **B**, **C** and **D**.

(3)

Compound **B**	
Compound **C**	
Compound **D**	

(c) Compounds **C** and **D** form precipitates with 2,4-dinitrophenylhydrazine.

(i) **Name** the functional group present in **C** and **D**.

(1)

(ii) Describe how the precipitate formed from the reaction of **D** can be collected, purified and used to determine the identity of **D**.
Detailed descriptions of the practical procedures are **not** required.

(5)

(Total for Question 14 = 18 marks)

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***15** Compare and contrast the reaction of phenol with bromine and the reaction of hex-1-ene with bromine.

Include in your answer:

- any reaction conditions
- an equation for each reaction
- reasons for any differences

Detailed mechanisms for these reactions are not required.

(6)

(Total for Question 15 = 6 marks)

TOTAL FOR SECTION B = 51 MARKS

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SECTION C

Answer ALL the questions. Write your answers in the spaces provided.

16 The manganate(VII) ion is a strong oxidising agent. It is used widely in the chemical industry and in laboratories, usually in the form of the potassium salt, $KMnO_4$, or the sodium salt, $NaMnO_4$.
One of its uses is in redox titrations, but it is also used in organic synthesis.

(a) Compounds containing the manganate(VII) ion can be prepared by the reaction of manganese(II) chloride with sodium chlorate(I).

(i) Complete the equation for the reaction shown.

(2)

.....$MnCl_2$ + ...NaClO + ...NaOH → .....$NaMnO_4$ + ...NaCl + ...H_2O

(ii) Explain why this is a redox reaction by quoting relevant oxidation numbers.

(2)

.....

.....

.....

.....

(b) Compounds containing the manganate(VII) ion can also be prepared by disproportionation reactions.
Standard electrode potentials for the relevant half-equations are shown.

$MnO_2 + 2e^- + 2H_2O \rightarrow Mn(OH)_2 + 2OH^-$ −0.05 V

$2MnO_2 + 2e^- + H_2O \rightarrow Mn_2O_3 + 2OH^-$ +0.15 V

$MnO_4^- + 2e^- \rightarrow MnO_4^{3-}$ +0.27 V

$MnO_4^- + e^- \rightarrow MnO_4^{2-}$ +0.56 V

$MnO_4^{2-} + 2H_2O + 2e^- \rightarrow MnO_2 + 4OH^-$ +0.60 V

$MnO_4^{3-} + e^- + 2H_2O \rightarrow MnO_2 + 4OH^-$ +0.93 V

Manganate(VI) ions and manganate(V) ions can both undergo disproportionation reactions to produce manganate(VII) ions and manganese dioxide.

(i) Deduce the equations for these two disproportionation reactions.

(2)

(ii) Compare the feasibility of these two disproportionation reactions by using the $E^{\ominus}_{cell}$ values.

(2)

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(c) In aqueous solution, $KMnO_4$ slowly oxidises water molecules. As a result, the concentration of $KMnO_4$ changes over time and the solutions need to be standardised before use.
Solutions of arsenic(III) oxide, As_2O_3, may be used for this standardisation.
As_2O_3 reacts with $KMnO_4$ in a 5 : 4 mole ratio and arsenic(V) is formed.

(i) Determine the final oxidation state of manganese in this reaction.
You **must** show your working.

(3)

(ii) A solution of $KMnO_4$ was stored for two weeks.

A standard solution of As_2O_3 was prepared by dissolving 1.05 g in deionised water to give a total volume of 250.0 cm^3.
25.0 cm^3 samples of this standard solution were titrated with the stored $KMnO_4$ solution.
The mean titre was 23.65 cm^3.

Calculate the concentration of the stored $KMnO_4$ solution.

(4)

(d) In organic chemistry, alkaline solutions of potassium manganate(VII) oxidise hydrocarbon side chains attached to the benzene ring. In an experiment using methylbenzene, the methyl side chain is converted to the carboxylate group.

An alkaline solution containing 10.0 g of potassium manganate(VII) was heated under reflux with 2.50 g of methylbenzene.
The equation for the reaction is shown.

$$C_6H_5CH_3 + 2MnO_4^- \rightarrow 2MnO_2 + C_6H_5COO^- + OH^- + H_2O$$

(i) Calculate which reactant is in excess.

[Data: M_r values $KMnO_4 = 158$ $C_6H_5CH_3 = 92$]

(3)

(ii) State how the benzoate ion, $C_6H_5COO^-$, can be converted into benzoic acid.

(1)

.....

.....

(Total for Question 16 = 19 marks)

TOTAL FOR SECTION C = 19 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)						(8)					(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)		(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							

Key

relative atomic mass
atomic symbol
name
atomic (proton) number

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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GradeMax