

Please check the examination details below before entering your candidate information

Candidate surname

Other names

**Pearson Edexcel**  
**International**  
**Advanced Level**

Centre Number

Candidate Number

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**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**

Total Marks

### Instructions

- Use **black** ink or **black** ball-point pen.
- **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.*
- The question labelled with an **asterisk** (\*) is one where the quality of your written communication will be assessed – *you should take particular care with your spelling, punctuation and grammar, as well as the clarity of expression, on this question.*
- 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.
- Good luck with your examination.

Turn over ►

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## SECTION A

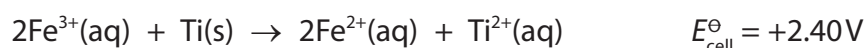
Answer ALL the questions in this section. You should aim to spend no more than 20 minutes on this section. For each question, select one answer from A to D and put a cross in the box . If you change your mind, put a line through the box  and then mark your new answer with a cross .

1 In which of the following pairs does the metal have **different** oxidation numbers?

- A  $\text{CrO}_4^{2-}$  and  $\text{Cr}_2\text{O}_7^{2-}$
- B  $\text{CrO}_4^{2-}$  and  $\text{CrO}_3\text{Cl}^-$
- C  $\text{V}_2\text{O}_5$  and  $\text{VO}_4^{3-}$
- D  $\text{VO}_2^+$  and  $\text{VO}^{2+}$

(Total for Question 1 = 1 mark)

2 This question is about the reaction



(a) The electrode potential for the  $\text{Fe}^{3+}/\text{Fe}^{2+}$  electrode system is +0.77V.

What is the electrode potential for the  $\text{Ti}^{2+}/\text{Ti}$  electrode system?

(1)

- A -3.17V
- B -1.63V
- C +1.63V
- D +3.17V



(b) What metals should be used for the electrodes in the cell for this reaction?

(1)

Metals used for the electrode		
	Fe <sup>3+</sup> / Fe <sup>2+</sup> electrode system	Ti <sup>2+</sup> / Ti electrode system
<input type="checkbox"/> A	iron	titanium
<input type="checkbox"/> B	iron	platinum
<input type="checkbox"/> C	platinum	titanium
<input type="checkbox"/> D	platinum	platinum

(c) The half-cell for the Fe<sup>3+</sup>/ Fe<sup>2+</sup> electrode system is prepared by mixing **equal** volumes of solutions of iron(II) sulfate, FeSO<sub>4</sub>, and iron(III) sulfate, Fe<sub>2</sub>(SO<sub>4</sub>)<sub>3</sub>.

What concentrations of the **original** solutions are needed for the resulting mixture to be standard?

(1)

Concentration of the original solution		
	FeSO <sub>4</sub>	Fe <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub>
<input type="checkbox"/> A	1 mol dm <sup>-3</sup>	0.5 mol dm <sup>-3</sup>
<input type="checkbox"/> B	1 mol dm <sup>-3</sup>	1 mol dm <sup>-3</sup>
<input type="checkbox"/> C	2 mol dm <sup>-3</sup>	1 mol dm <sup>-3</sup>
<input type="checkbox"/> D	2 mol dm <sup>-3</sup>	2 mol dm <sup>-3</sup>

(Total for Question 2 = 3 marks)

Use this space for any rough working. Anything you write in this space will gain no credit.



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3 What is the electronic configuration of a chromium atom?

- |                          |        | 3d |    |   |   |   | 4s |
|--------------------------|--------|----|----|---|---|---|----|
| <input type="checkbox"/> | A (Ar) | ↑  | ↑  | ↑ | ↑ | ↑ | ↑  |
| <input type="checkbox"/> | B (Ar) | ↑  | ↑  | ↑ | ↑ |   | ↑↓ |
| <input type="checkbox"/> | C (Ar) | ↑↓ | ↑↓ | ↑ |   |   | ↑  |
| <input type="checkbox"/> | D (Ar) | ↑↓ | ↑  | ↑ |   |   | ↑↓ |

(Total for Question 3 = 1 mark)

4 A ligand must be an

- A electron-pair donor
- B electron-pair donor and negatively charged
- C electron-pair acceptor
- D electron-pair acceptor and negatively charged

(Total for Question 4 = 1 mark)

5 Diamminecopper(I) ions are **not** coloured because

- A the d orbitals in copper(I) cannot be split
- B the energy difference between the split d orbitals is outside the visible region of the spectrum
- C d—d transitions are not possible because the d orbitals are fully occupied
- D copper(I) complexes are readily oxidised

(Total for Question 5 = 1 mark)

Use this space for any rough working. Anything you write in this space will gain no credit.



6 Copper(II) ions form a complex with 1,2-diaminoethane (symbol 'en') with the formula  $\text{Cu(en)}_3^{2+}$ .

What type of ligand is 1,2-diaminoethane, and what is the coordination number of copper(II) in the complex?

	Type of ligand	Coordination number
<input type="checkbox"/> A	bidentate	3
<input type="checkbox"/> B	bidentate	6
<input type="checkbox"/> C	tridentate	3
<input type="checkbox"/> D	tridentate	6

(Total for Question 6 = 1 mark)

7 Aqueous sodium hydroxide was added to aqueous iron(II) sulfate and the mixture allowed to stand.

What would be observed?

	Observations	
	Immediately after adding sodium hydroxide	After standing
<input type="checkbox"/> A	brown precipitate	no change
<input type="checkbox"/> B	green precipitate	no change
<input type="checkbox"/> C	brown precipitate	precipitate turns green
<input type="checkbox"/> D	green precipitate	precipitate turns brown

(Total for Question 7 = 1 mark)

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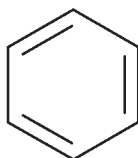
- 8 When aqueous ammonia is added to an aqueous solution of zinc sulfate, a white precipitate forms which dissolves in excess ammonia to give a colourless solution.

What types of reaction are occurring?

		Type of reaction	
		Formation of white precipitate	Formation of colourless solution
<input type="checkbox"/>	A	deprotonation	ligand exchange
<input type="checkbox"/>	B	deprotonation	deprotonation
<input type="checkbox"/>	C	ligand exchange	deprotonation
<input type="checkbox"/>	D	ligand exchange	ligand exchange

(Total for Question 8 = 1 mark)

- 9 Benzene is sometimes represented by a Kekulé structure.



Kekulé structure of benzene

If this were the **only** structure of benzene, what would be the total number of isomers of dichlorobenzene?

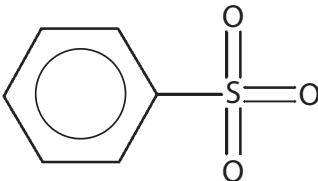
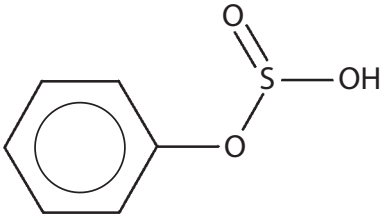
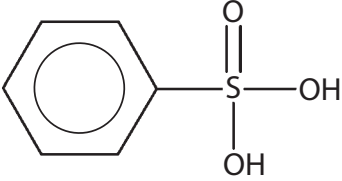
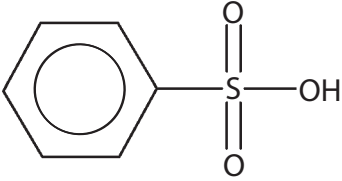
- A two  
 B three  
 C four  
 D five

(Total for Question 9 = 1 mark)

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10 What is the product when benzene reacts with fuming sulfuric acid?

- A 
- B 
- C 
- D 

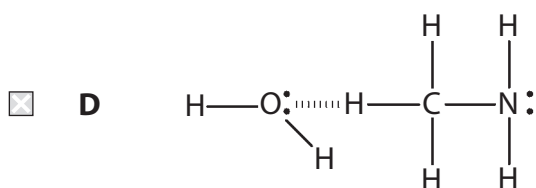
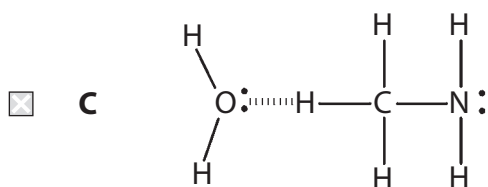
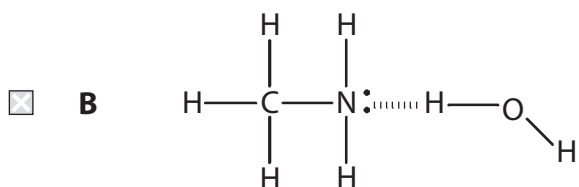
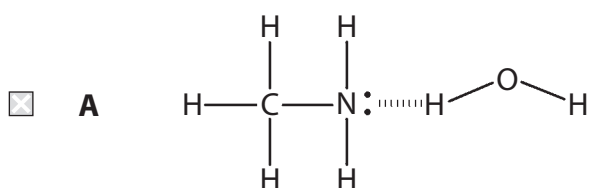
(Total for Question 10 = 1 mark)

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11 Hydrogen bonds are formed when methylamine dissolves in water.

Which structure best represents a hydrogen bond between methylamine and water?



(Total for Question 11 = 1 mark)

12 Which type of compound **cannot** be a monomer in the formation of polyamides?

- A amides
- B amino acids
- C diacyl chlorides
- D diamines

(Total for Question 12 = 1 mark)

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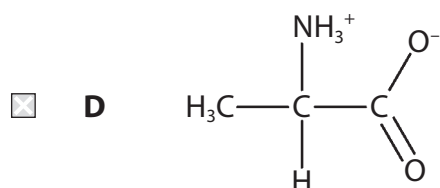
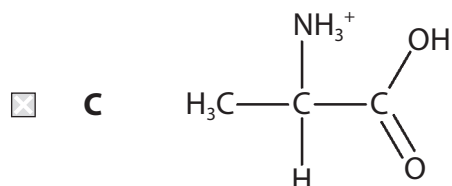
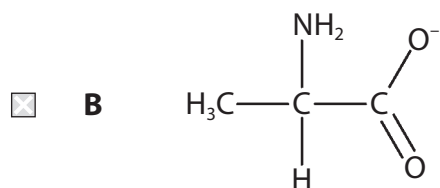
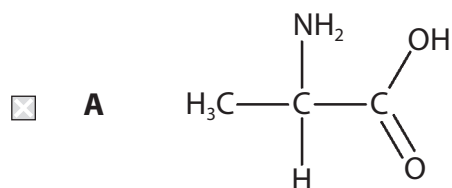
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13 Alanine is an amino acid.

(a) Which structure best represents alanine at **high** pH?

(1)



(b) Alanine is a crystalline solid at room temperature.

What are the main forces broken when alanine melts?

(1)

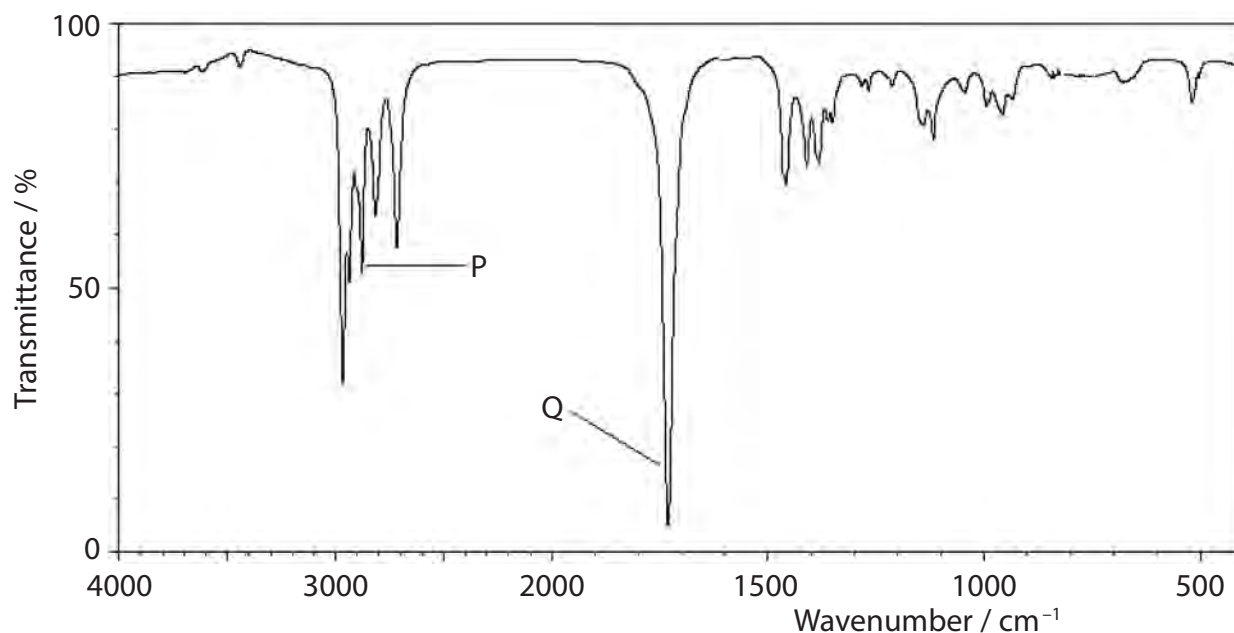
- A** London forces
- B** hydrogen bonds
- C** covalent bonds
- D** ionic bonds

(Total for Question 13 = 2 marks)



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14 An aliphatic organic compound has the infrared spectrum shown.



What are the bond stretches responsible for the peaks **P** and **Q** in the spectrum?

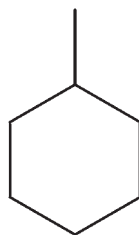
	<b>P</b>	<b>Q</b>
<input type="checkbox"/> <b>A</b>	O—H carboxylic acid	C=O carboxylic acid
<input type="checkbox"/> <b>B</b>	O—H carboxylic acid	C=O aldehyde
<input type="checkbox"/> <b>C</b>	C—H aldehyde	C=O carboxylic acid
<input type="checkbox"/> <b>D</b>	C—H aldehyde	C=O aldehyde

(Total for Question 14 = 1 mark)

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15 How many peaks are there in the carbon-13 ( $^{13}\text{C}$ ) NMR spectrum of methylcyclohexane?



methylcyclohexane

- A one
- B three
- C five
- D seven

(Total for Question 15 = 1 mark)

16 In the **high** resolution proton NMR spectrum of propan-2-ol,  $\text{CH}_3\text{CHOHCH}_3$ , there are

- A one singlet, one doublet and a heptet
- B one singlet, two doublets and a heptet
- C two singlets and two triplets
- D three singlets and a quartet

(Total for Question 16 = 1 mark)

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17 What is the minimum volume of oxygen gas, measured at room temperature and pressure, required for the complete combustion of 9.2 g of  $C_3H_8O_3$  ( $M_r = 92$ )?

[Molar volume of gas at room temperature and pressure =  $24.0 \text{ dm}^3 \text{ mol}^{-1}$ ]

- A  $4.8 \text{ dm}^3$
- B  $8.4 \text{ dm}^3$
- C  $12.0 \text{ dm}^3$
- D  $16.8 \text{ dm}^3$

(Total for Question 17 = 1 mark)

TOTAL FOR SECTION A = 20 MARKS

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## SECTION B

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

**18** This question is about manganese compounds. Some data are given below.

	Electrode reaction	$E^\ominus / \text{V}$
1	$\text{MnO}_4^- + \text{e}^- \rightleftharpoons \text{MnO}_4^{2-}$	+0.56
2	$\text{MnO}_4^{2-} + 2\text{H}_2\text{O} + 2\text{e}^- \rightleftharpoons \text{MnO}_2 + 4\text{OH}^-$	+0.59
3	$\text{Fe}^{3+} + \text{e}^- \rightleftharpoons \text{Fe}^{2+}$	+0.77
4	$\text{MnO}_2 + 4\text{H}^+ + 2\text{e}^- \rightleftharpoons \text{Mn}^{2+} + 2\text{H}_2\text{O}$	+1.23
5	$\text{MnO}_4^- + 8\text{H}^+ + 5\text{e}^- \rightleftharpoons \text{Mn}^{2+} + 4\text{H}_2\text{O}$	+1.51
6	$\text{MnO}_4^- + 4\text{H}^+ + 3\text{e}^- \rightleftharpoons \text{MnO}_2 + 2\text{H}_2\text{O}$	+1.70
7	$\text{MnO}_4^{2-} + 4\text{H}^+ + 2\text{e}^- \rightleftharpoons \text{MnO}_2 + 2\text{H}_2\text{O}$	+2.26

- (a) (i) Write the ionic equation for the disproportionation of manganate(VI) ions,  $\text{MnO}_4^{2-}$ , in **acidic** conditions, using relevant half-equations from the table. State symbols are not required.

(2)

- (ii) Calculate  $E_{\text{cell}}^\ominus$  for the disproportionation of manganate(VI) ions in **acidic** conditions, stating whether or not the reaction is thermodynamically feasible.

(2)

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(iii) Using the standard electrode potentials in the table, assess the thermodynamic feasibility of preparing manganate(VI) by reacting manganate(VII) and manganese(IV) oxide in **alkaline** conditions.

(4)

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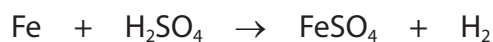
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- (b) Steel is an alloy of iron and carbon. A group of students determined the iron content of a sample of steel wire by a titration method.

A known mass of the wire was dissolved in dilute sulfuric acid and the resulting solution made up to  $250.0\text{ cm}^3$  with more dilute sulfuric acid and mixed thoroughly.



$25.0\text{ cm}^3$  samples of the resulting solution were titrated with  $0.0195\text{ mol dm}^{-3}$  potassium manganate(VII) solution.

- (i) State the colour change at the end-point of the titration.

(1)

- (ii) One student used  $1.53\text{ g}$  of the wire (weighed directly on the balance pan) and obtained a mean titre of  $27.35\text{ cm}^3$ .

Using half-equations 3 and 5 from the table, calculate the percentage of iron in the steel wire. Give your answer to **three** significant figures.

(5)





- (iii) A second student carried out the same experiment but used distilled water to make up the solution in the volumetric flask.  
A brown suspension formed during the titration.  
Explain how, if at all, the titre value would be affected by this student's error.

(3)

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- (c) The uncertainties of the apparatus used in the experiment in (b) are shown.

Apparatus	Value measured	Uncertainty on each reading	Percentage uncertainty on value measured / %
Balance	1.53 g	$\pm 0.005$ g	0.65
Burette	27.35 cm <sup>3</sup>	$\pm 0.05$ cm <sup>3</sup>	
Pipette	25.0 cm <sup>3</sup>	$\pm 0.06$ cm <sup>3</sup>	
Volumetric flask	250.0 cm <sup>3</sup>	$\pm 0.3$ cm <sup>3</sup>	

- (i) Complete the table. (2)

- (ii) A third student obtained a value of 95.863% for the proportion of iron in the wire. State whether or not this student has given their answer to an appropriate number of significant figures. Justify your answer in terms of the **total** percentage uncertainty of the experiment. (2)

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(Total for Question 18 = 21 marks)



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**19** This question is about the investigation of an organic compound **X**.  
**X** is a liquid at room temperature and pressure, which turns damp red litmus paper blue.

(a) (i) Name the functional group present in **X**. (1)

(ii) When 0.493 g of **X** was vaporised, 157 cm<sup>3</sup> of dry air was displaced, measured at 15°C and 103 000 Pa.

Calculate the molar mass of **X**, using the ideal gas equation.  
You **must** show your working. (4)

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(b) **X** reacted vigorously with ethanoyl chloride forming steamy fumes and a white solid **Y**.

(i) Identify the steamy fumes, by name or formula.

(1)

(ii) Suggest the functional group present in **Y**.

(1)

(iii) Analysis of **Y** showed that its composition by mass was 62.6% carbon; 11.3% hydrogen; 12.2% nitrogen; 13.9% oxygen.

Determine the empirical formula of **Y**. You **must** show your working.

(3)

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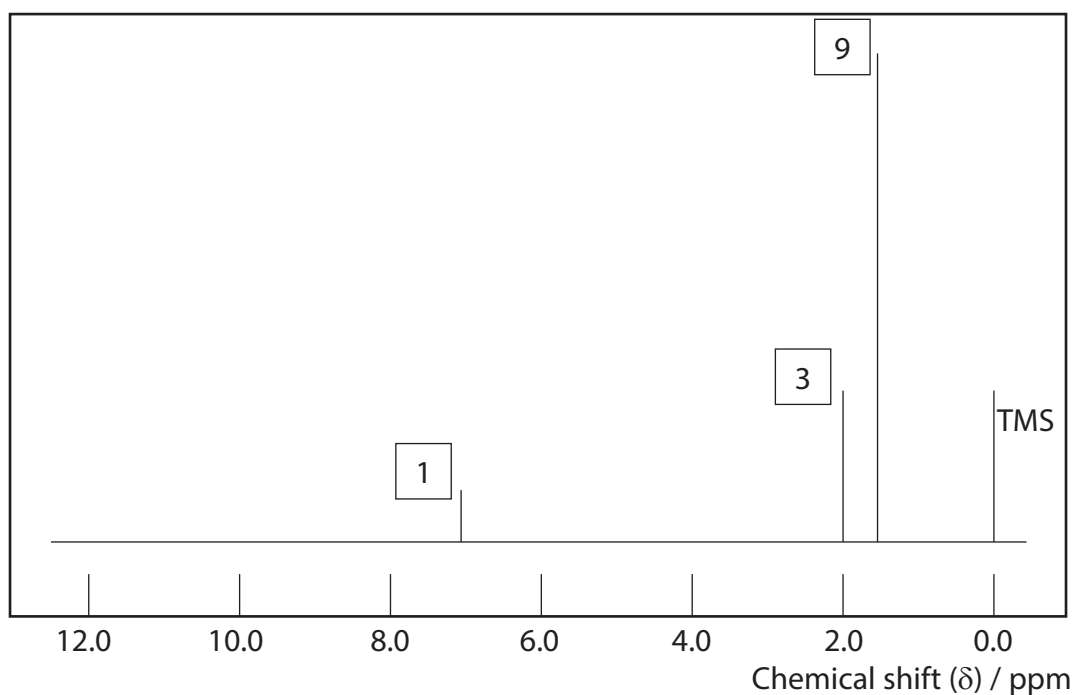


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\* (c) A simplified **high** resolution proton NMR spectrum of **Y** is shown.  
The relative peak areas are given near each peak.



Deduce the structure of **Y**, using the NMR spectrum and the other information in the question.

(6)



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Handwriting practice area with 20 sets of horizontal lines. Each set consists of a solid top line, a dashed middle line, and a solid bottom line.



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(d) Draw the structure of compound **X**.

(1)

(Total for Question 19 = 17 marks)

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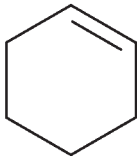
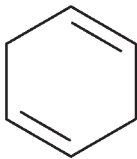
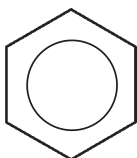
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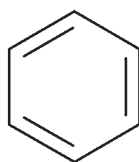
20 This question is about benzene and some related compounds.

(a) Some standard enthalpies of combustion are shown.

Compound	Structure	Standard enthalpy of combustion, $\Delta_c H^\ominus / \text{kJ mol}^{-1}$
cyclohexene		-3752
cyclohexa-1,4-diene		-3584
benzene		-3267

(i) Using the standard enthalpies of combustion of cyclohexene and cyclohexa-1,4-diene, calculate a value for the enthalpy of combustion of the theoretical compound 'cyclohexa-1,3,5-triene'.

(2)



cyclohexa-1,3,5-triene

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(ii) Explain the difference between the enthalpy of combustion of 'cyclohexa-1,3,5-triene' calculated in (a)(i) and the enthalpy of combustion of benzene given in the table.

(3)

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(b) Bromine reacts with cyclohexene to form 1,2-dibromocyclohexane, and with benzene to form bromobenzene.

Compare and contrast these reactions, considering the type and mechanism of each reaction and the conditions required.

You are **not** required to draw the mechanisms of the reactions.

(4)

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(c) Bromine also reacts with phenol.

- (i) Identify, by name or formula, the organic product when phenol reacts with **excess** bromine.

(1)

- (ii) Explain why bromine reacts much faster with phenol than with benzene.

(2)

(Total for Question 20 = 12 marks)

**TOTAL FOR SECTION B = 50 MARKS**



## SECTION C

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

21

### Iron Chemistry

Iron is a typical transition metal. Due to the similar energies of the 3d and 4s electrons, iron forms compounds in a number of oxidation states. Iron(II) and iron(III) are the most common oxidation states, and iron(III) is the most stable.

Iron ions form many complexes, including that in haemoglobin which is responsible for oxygen transport in the blood of most vertebrates. The haemoglobin-iron complex with oxygen is responsible for the red colour of blood.

Iron(III) ions may be detected in solution by the addition of thioglycolic acid ( $\text{HSCH}_2\text{COOH}$ ). All the water ligands of the iron(III) ion are replaced giving a complex with an intense red colour which can be detected in very low concentrations.

The complexes of iron(II) and iron(III) usually have a coordination number of six and are octahedral but the chloro complexes have a coordination number of four and are tetrahedral.

Iron and its compounds can act as catalysts. The element catalyses the Haber process, acting as a typical heterogeneous catalyst. However, the compounds and complexes of iron are usually homogeneous catalysts.

- (a) Explain, in terms of electronic structure, why iron(III) compounds are more stable than iron(II) compounds.

(2)

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(b) The third ionisation energy of iron is  $2958 \text{ kJ mol}^{-1}$ .

- (i) Write the equation for the third ionisation energy of iron.  
Include state symbols.

(1)

- (ii) Explain how **stable** iron(III) ions can be formed from iron(II) ions in aqueous solution. Refer to the relevant energy changes of these ions only.

(3)

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(c) Invertebrates use a copper complex, haemocyanin, to transport oxygen.  
Blue oxyhaemocyanin gives invertebrate blood its characteristic colour.

Explain why oxyhaemocyanin and oxyhaemoglobin have different colours.

(3)

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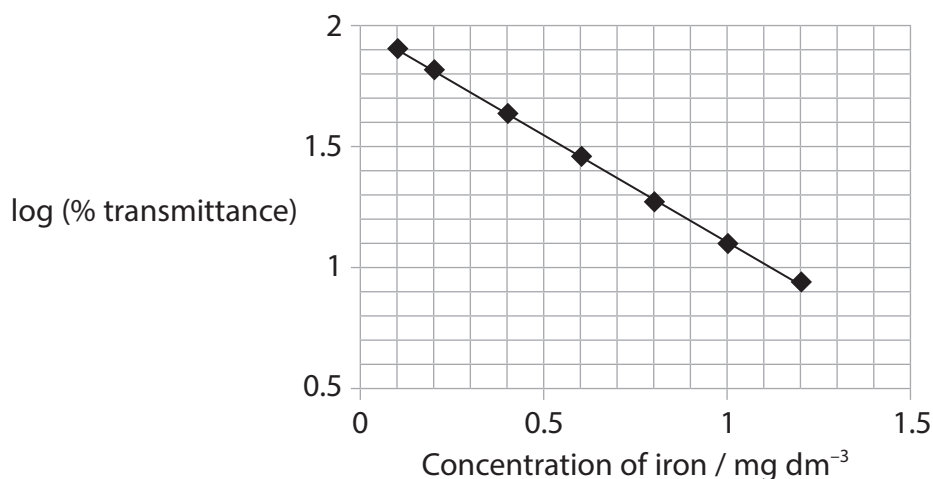
29  
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- (d) The presence of iron in sodium carbonate can affect its properties; the higher the quality of the sodium carbonate, the lower the proportion of iron.

The proportion of iron in a laboratory grade anhydrous sodium carbonate was listed as less than 20 ppm by mass.

In an experiment to check this specification, 20 g of the sodium carbonate was dissolved in sulfuric acid, and thioglycolic acid added in excess to form the iron(III) thioglycolic acid complex,  $\text{Fe}(\text{HSCH}_2\text{COOH})_3^{3+}$ . The solution was made up to  $500 \text{ cm}^3$  in a volumetric flask and thoroughly mixed.

**Colorimeter calibration graph**



The transmittance of the resulting solution was determined using a colorimeter and found to be 39.8%.

- (i) Using the calibration graph, determine whether or not the iron concentration in this sample of sodium carbonate meets the stated specification.

(4)



(ii) Suggest what type of ligand thioglycolic acid is in the iron(III) thioglycolic acid complex. Justify your answer.

(2)

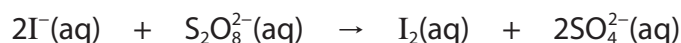
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(e) Iodide ions are oxidised to iodine by peroxodisulfate ions.



Iron(II) ions act as a homogeneous catalyst for this reaction.

(i) State why the catalyst is described as 'homogeneous'.

(1)

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(ii) Write two equations to show how iron(II) ions catalyse this oxidation. State symbols are not required.

(2)

(iii) Suggest how iron(II) ions lower the activation energy of this reaction.

(1)

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(f) Give a possible reason why the chloro complexes of iron ions have a coordination number of four rather than six.

(1)

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**(Total for Question 21 = 20 marks)**

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**TOTAL FOR SECTION C = 20 MARKS**  
**TOTAL FOR PAPER = 90 MARKS**

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P 6 4 6 2 7 A 0 3 5 3 6

# The Periodic Table of Elements

1	2	3	4	5	6	7	0 (8)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
6.9 <b>Li</b> lithium 3	9.0 <b>Be</b> beryllium 4	23.0 <b>Na</b> sodium 11	24.3 <b>Mg</b> magnesium 12	39.1 <b>K</b> potassium 19	85.5 <b>Rb</b> rubidium 37	132.9 <b>Cs</b> caesium 55	226 <b>Ra</b> radium 88
45.0 <b>Sc</b> scandium 21	88.9 <b>Y</b> yttrium 39	87.6 <b>Sr</b> strontium 38	137.3 <b>Ba</b> barium 56	47.9 <b>Ti</b> titanium 22	91.2 <b>Zr</b> zirconium 40	178.5 <b>Hf</b> hafnium 72	261 <b>Rf</b> rutherfordium 104
49.0 <b>V</b> vanadium 23	50.9 <b>Nb</b> niobium 41	92.9 <b>Ta</b> tantalum 73	180.9 <b>La*</b> lanthanum 57	54.9 <b>Mn</b> manganese 25	95.9 <b>Mo</b> molybdenum 42	186.2 <b>Re</b> rhenium 75	266 <b>Sg</b> seaborgium 106
55.8 <b>Fe</b> iron 26	58.9 <b>Co</b> cobalt 27	58.7 <b>Ni</b> nickel 28	59.0 <b>Cu</b> copper 29	54.9 <b>Zn</b> zinc 30	63.5 <b>Ga</b> gallium 31	69.0 <b>Ge</b> germanium 32	65.4 <b>In</b> indium 49
55.8 <b>Fe</b> iron 26	58.9 <b>Co</b> cobalt 27	58.7 <b>Ni</b> nickel 28	59.0 <b>Cu</b> copper 29	63.5 <b>Zn</b> zinc 30	65.4 <b>Ga</b> gallium 31	69.0 <b>Ge</b> germanium 32	72.6 <b>As</b> arsenic 33
101.1 <b>Ru</b> ruthenium 44	102.9 <b>Rh</b> rhodium 45	106.4 <b>Pd</b> palladium 46	107.9 <b>Ag</b> silver 47	112.4 <b>Cd</b> cadmium 48	114.8 <b>In</b> indium 49	118.7 <b>Sn</b> tin 50	121.8 <b>Sb</b> antimony 51
190.2 <b>Os</b> osmium 76	192.2 <b>Ir</b> iridium 77	195.1 <b>Pt</b> platinum 78	197.0 <b>Au</b> gold 79	200.6 <b>Hg</b> mercury 80	204.4 <b>Tl</b> thallium 81	207.2 <b>Pb</b> lead 82	209.0 <b>Bi</b> bismuth 83
264 <b>Bh</b> bohrium 107	266 <b>Sg</b> seaborgium 106	268 <b>Mt</b> meitnerium 109	271 <b>Ds</b> darmstadtium 110	272 <b>Rg</b> roentgenium 111	277 <b>Hs</b> hassium 108	281 <b>Ts</b> tennessine 115	285 <b>Lv</b> livermorium 116
140 <b>Ce</b> cerium 58	141 <b>Pr</b> praseodymium 59	144 <b>Nd</b> neodymium 60	150 <b>Sm</b> samarium 62	152 <b>Eu</b> europium 63	157 <b>Gd</b> gadolinium 64	163 <b>Dy</b> dysprosium 66	169 <b>Tm</b> thulium 69
232 <b>Th</b> thorium 90	231 <b>Pa</b> protactinium 91	238 <b>U</b> uranium 92	242 <b>Pu</b> plutonium 94	243 <b>Am</b> americium 95	247 <b>Cm</b> curium 96	251 <b>Cf</b> californium 98	256 <b>Md</b> mendelevium 101
175 <b>Lu</b> lutetium 71	173 <b>Yb</b> ytterbium 70	167 <b>Er</b> erbium 68	165 <b>Ho</b> holmium 67	163 <b>Dy</b> dysprosium 66	162 <b>Tb</b> terbium 65	159 <b>Tm</b> thulium 69	175 <b>Lu</b> lutetium 71
103 <b>Lr</b> lawrencium	102 <b>No</b> nobelium	100 <b>Fm</b> fermium	99 <b>Es</b> einsteinium	98 <b>Cf</b> californium	97 <b>Bk</b> berkelium	96 <b>Cm</b> curium	103 <b>Lr</b> lawrencium

1.0  
**H**  
hydrogen  
1

**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  
\* Actinide series



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