Rewarding Learning

ADVANCED
General Certificate of Education
2015

Centre Number

Candidate Number

Chemistry

Assessment Unit A2 2
assessing
Analytical, Transition Metals, Electrochemistry and Further Organic Chemistry

MV18

[AC222]

TUESDAY 2 JUNE, AFTERNOON

TIME

2 hours, plus your additional time allowance.

INSTRUCTIONS TO CANDIDATES

Write your Centre Number and Candidate Number in the spaces provided at the top of this page.
Answer **all seventeen** questions.
Answer **all ten** questions in **Section A**. Record your answers by marking the appropriate letter on the answer sheet provided. Use only the spaces numbered 1 to 10. Keep in sequence when answering.
Answer **all seven** questions in **Section B**. Write your answers in the spaces provided in this question paper.

INFORMATION FOR CANDIDATES

The total mark for this paper is 120.
Quality of written communication will be assessed in Question **17(g)**.
In Section A all questions carry equal marks, i.e. **two** marks for each question.
In Section B the figures printed at the end of each question indicate the marks awarded to each question or part question.
A Periodic Table of the Elements, containing some data, is included in this question paper.

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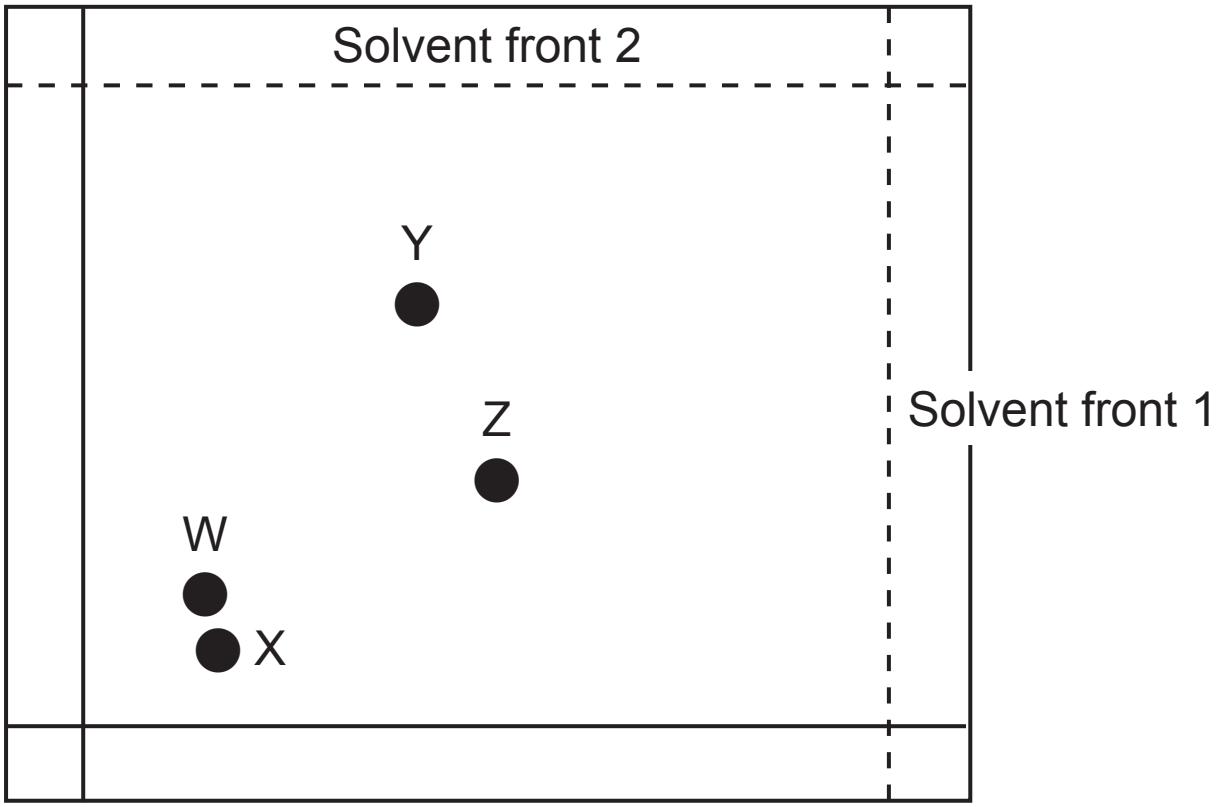
(Questions start overleaf)

Section A

For each of the following questions only **one** of the lettered responses (A–D) is correct.

Select the correct response in each case and mark its code letter by connecting the dots as illustrated on the answer sheet.

1 The chromatogram below was produced by two-way paper chromatography of a mixture of amino acids.



The table below gives the R_f values of some amino acids.

Amino acid	**R_f values**	
	Solvent 1	**Solvent 2**
Alanine	0.51	0.38
Asparagine	0.63	0.21
Isoleucine	0.44	0.72
Glycine	0.12	0.26
Lysine	0.18	0.14

Which one of the spots, W, X, Y or Z is glycine?

A W

B X

C Y

D Z

2 Standard electrode potentials for two half-cells are shown below:

half-cell	**standard electrode potential/V**
$Ce^{3+}(aq) + 3e^- \rightleftharpoons Ce(s)$	–2.3
$Th^{4+}(aq) + 4e^- \rightleftharpoons Th(s)$	–1.9

Which one of the following species is the most powerful reducing agent?

A $Ce^{3+}(aq)$

B Ce(s)

C $Th^{4+}(aq)$

D Th(s)

3 Which one of the following is **not** true for gas-liquid chromatography of a mixture?

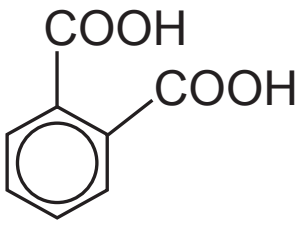
A The liquid phase is mobile and the gas phase is stationary

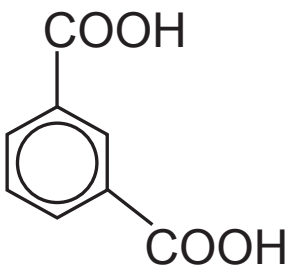
B The molecules in the mixture have characteristic retention times

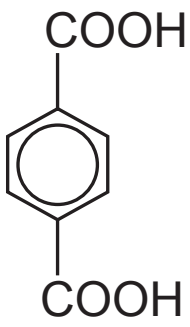
C The mixture is separated by partition between the liquid and the gas phase

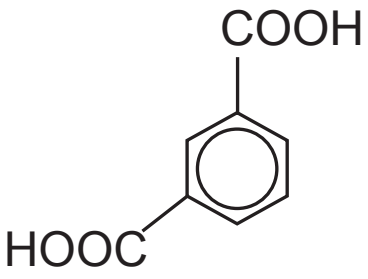
D The percentage composition of the mixture can be determined

4 Which one of the following is the structure of terephthalic acid?

A 

B 

C 

D 

5 When carrying out an edta titration to find the concentration of calcium ions in a solution the solution is buffered to

A pH 4 and the colour change at the end point is blue to red.

B pH 4 and the colour change at the end point is red to blue.

C pH 10 and the colour change at the end point is blue to red.

D pH 10 and the colour change at the end point is red to blue.

6 Which one of the following is the weakest base?

A CH_3CONH_2

B $C_2H_5NH_2$

C $C_6H_5NH_2$

D NH_3

7 The concentration of which one of the following solutions could be determined using colorimetry?

A $Al^{3+}(aq)$

B $Ca^{2+}(aq)$

C $Fe^{3+}(aq)$

D $Zn^{2+}(aq)$

8 Which one of the following is **not** true for glycine?

A It forms a blue solution with $Cu^{2+}(aq)$ ions

B It is optically active

C It reacts with sodium carbonate forming carbon dioxide

D It reacts with nitrous acid forming nitrogen

9 How many p orbitals are involved in the delocalised π electrons of a benzene molecule?

A 2

B 3

C 6

D 12

10 Which one of the following is produced when $CH_3CONHCH_3$ is refluxed with excess dilute hydrochloric acid?

A CH_3COOH and CH_3NH_2

B CH_3COO^- and $CH_3NH_3^+$

C CH_3COOH and $CH_3NH_3^+$

D CH_3COO^- and CH_3NH_2

Section B

Answer **all seven** questions in this section

11 Vanadium is a typical transition metal.

(a) Explain, in terms of electronic configuration, what is meant by a **transition metal**. [1 mark]

_____

_____

(b) Vanadium has a variety of oxidation states.

(i) What is the electronic configuration of the V^{2+} ion? [1 mark]

_____

(ii) Complete the table below giving the formula, oxidation number and colour in solution of some vanadium ions. [4 marks]

ion	**oxidation number**	**colour**
$V^{2+}(aq)$		
		yellow
$VO^{2+}(aq)$		
$V^{3+}(aq)$		

(c) Vanadium(V) oxide is used as a catalyst in the manufacture of sulfuric acid.

(i) Vanadium(V) oxide is a heterogeneous catalyst. Explain why it is described as **heterogeneous**. [1 mark]

(ii) Explain, in terms of chemisorption, how vanadium(V) oxide acts as a catalyst. [3 marks]

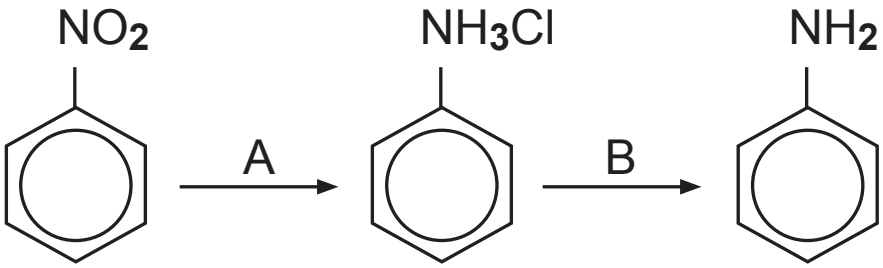
(iii) The vanadium(V) oxide converts sulfur dioxide to sulfur trioxide forming vanadium(IV) oxide, which then reacts with oxygen to re-form the vanadium(V) oxide. Write equations for these two reactions. [2 marks]

(iv) Complete the table below by naming the catalyst used for each industrial process. [2 marks]

industrial process	**catalyst**
formation of ammonia	
oxidation of ammonia	

12 Phenylamine is involved in the manufacture of azo-compounds which can be used as dyestuffs.

(a) Phenylamine can be prepared from nitrobenzene according to the following flow scheme:



Name the reagents for steps A and B. [1 mark for each]

Step A _____

Step B _____

(b) Phenylamine is then converted to benzenediazonium chloride. Name the reagents and state the condition required to convert phenylamine to benzenediazonium chloride. [2 marks]

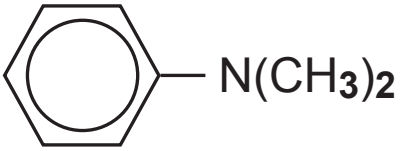
_____

_____

_____

_____

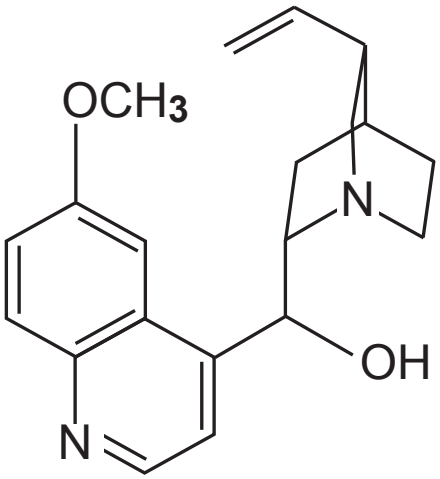
(c) Benzenediazonium chloride forms a yellow dye when coupled with dimethylaminobenzene.



dimethylaminobenzene

Write the equation for the reaction and circle the azo group. [3 marks]

(d) Quinine is fluorescent, it absorbs ultraviolet light and then emits it as visible light.



quinine

(i) How does the frequency of visible light differ from the frequency of ultraviolet light? [1 mark]

_____

(ii) Quinine is optically active. Circle the carbon asymmetric centres on the above diagram. [2 marks]

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(Questions continue overleaf)

13 (a) Benzene is more resistant than alkenes to reaction with bromine.

(i) What type of reaction do alkenes undergo with bromine? [1 mark]

_____

(ii) Name a catalyst required for the reaction of benzene with bromine. [1 mark]

_____

(iii) Draw a flow scheme to show the mechanism for the catalysed reaction of benzene with bromine.
[3 marks]

(iv) Name the mechanism for the reaction of benzene with bromine. [1 mark]

_____

(b) Toluene, $C_6H_5CH_3$, can be nitrated in a similar way to benzene to form 2,4,6-trinitrotoluene.

(i) Suggest the structure of 2,4,6-trinitrotoluene. [1 mark]

(ii) Name the reagents used and write the equation for the formation of the nitronium ion. [2 marks]

Reagents: _____

Equation: _____

14 Polyurethane products have a wide variety of uses including insoles in shoes and structural foams. Polyurethane is made in a two-step process.

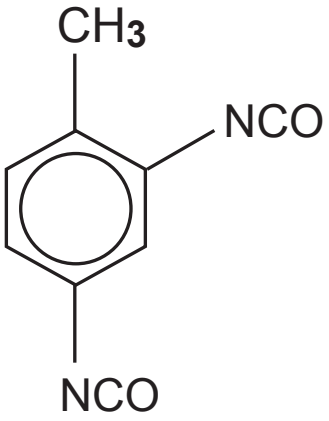
(a) Step 1: Ethane-1,2-diol and hexanedioic acid are polymerised to form a polyester.

(i) What type of polymers are polyesters? [1 mark]

_____

(ii) Draw a diagram of **one** repeating unit of the polyester. [2 marks]

(b) Step 2: The polyester is then reacted with a di-isocyanate forming an amide linkage.



di-isocyanate

Draw a diagram for the isocyanate group, **–**NCO, showing all the bonds present. [1 mark]

(c) Polyurethane foams are readily combustible and are a fire hazard producing carbon monoxide when burnt. Explain why carbon monoxide is poisonous. [2 marks]

_____

_____

(d) Explain why polyurethanes are biodegradable. [1 mark]

_____

_____

15 Putrescine is a foul smelling liquid produced by the breakdown of amino acids in dead organisms.

$H_2N(CH_2)_4NH_2$

putrescine

(a) (i) Suggest the systematic name for putrescine. [1 mark]

_____

(ii) State why putrescine is soluble in water. [1 mark]

_____

_____

(b) Putrescine reacts in a similar way to ethylamine.

(i) Write an equation for the reaction of putrescine with excess nitrous acid. [2 marks]

_____

(ii) Write an equation for the reaction of putrescine with excess ethanoyl chloride. [2 marks]

_____

(iii) Explain how the purified product formed between putrescine and excess ethanoyl chloride could be used to identify putrescine. [2 marks]

_____

_____

_____

(c) Valine, $CH_3CH(CH_3)CH(NH_2)COOH$, is an amino acid.

(i) Amino acids form zwitterions. What is a **zwitterion**? [2 marks]

_____

(ii) Draw the zwitterion formed by valine. [1 mark]

(iii) Valine is optically active. Draw the 3D representations of the optical isomers. [2 marks]

(d) Amino acids combine to form proteins. Describe the structure of proteins under the following headings. [3 marks]

Primary: _____

_____

Secondary: _____

_____

Tertiary: _____

_____

(e) Some enzymes formed by proteins are used in biological washing powders.

(i) Describe how enzymes act as catalysts. [2 marks]

_____

_____

_____

(ii) Explain why biological washing powders do not work at high temperatures. [2 marks]

_____

_____

_____

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(Questions continue overleaf)

16 Nuclear magnetic resonance spectroscopy (nmr) is used to help understand the structure of molecules.

(a) TMS is the standard used in nmr.

(i) What is the chemical name for TMS? [1 mark]

_____

(ii) Give **two** reasons why TMS is suitable for use as a standard in nmr. [2 marks]

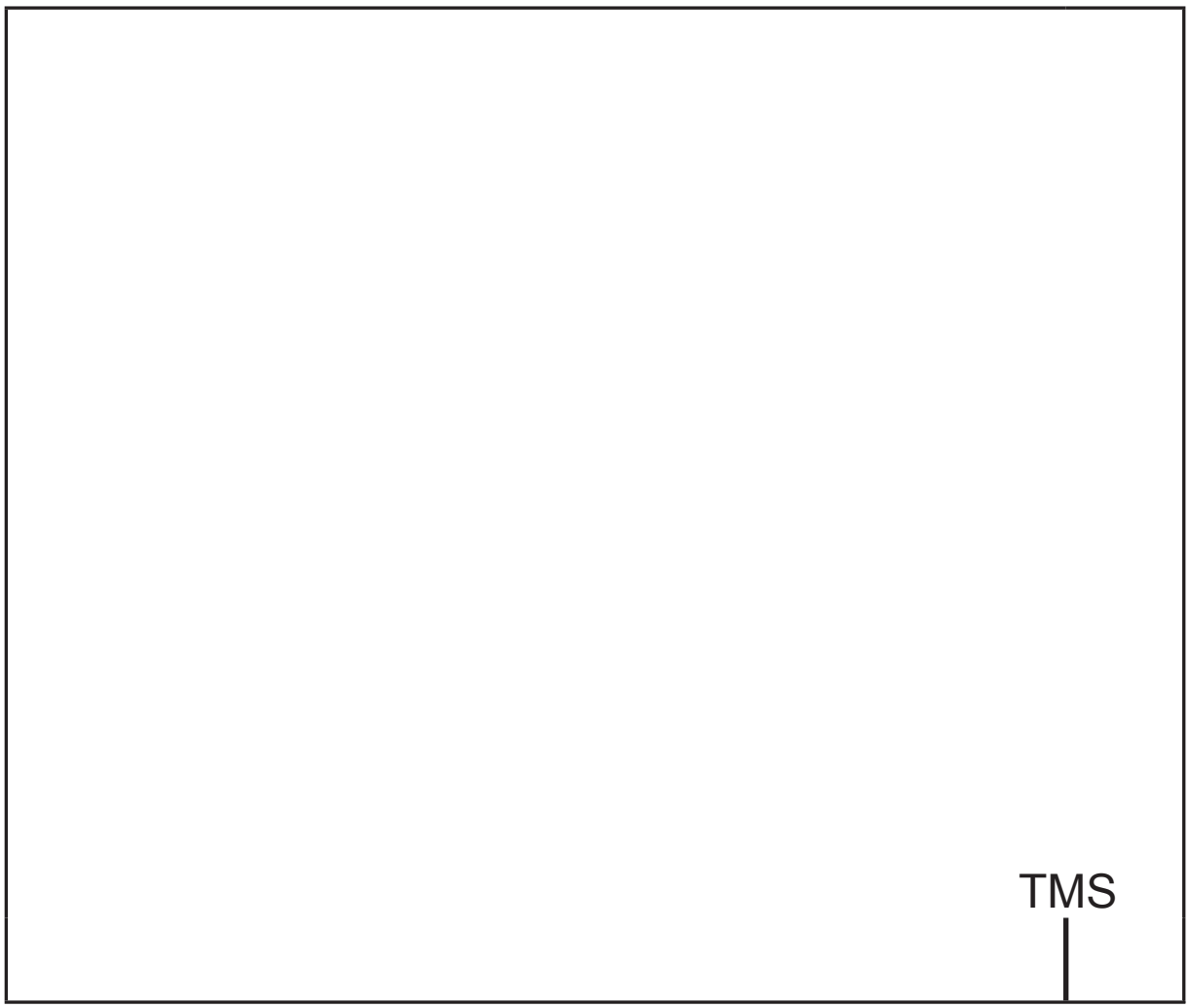
_____

_____

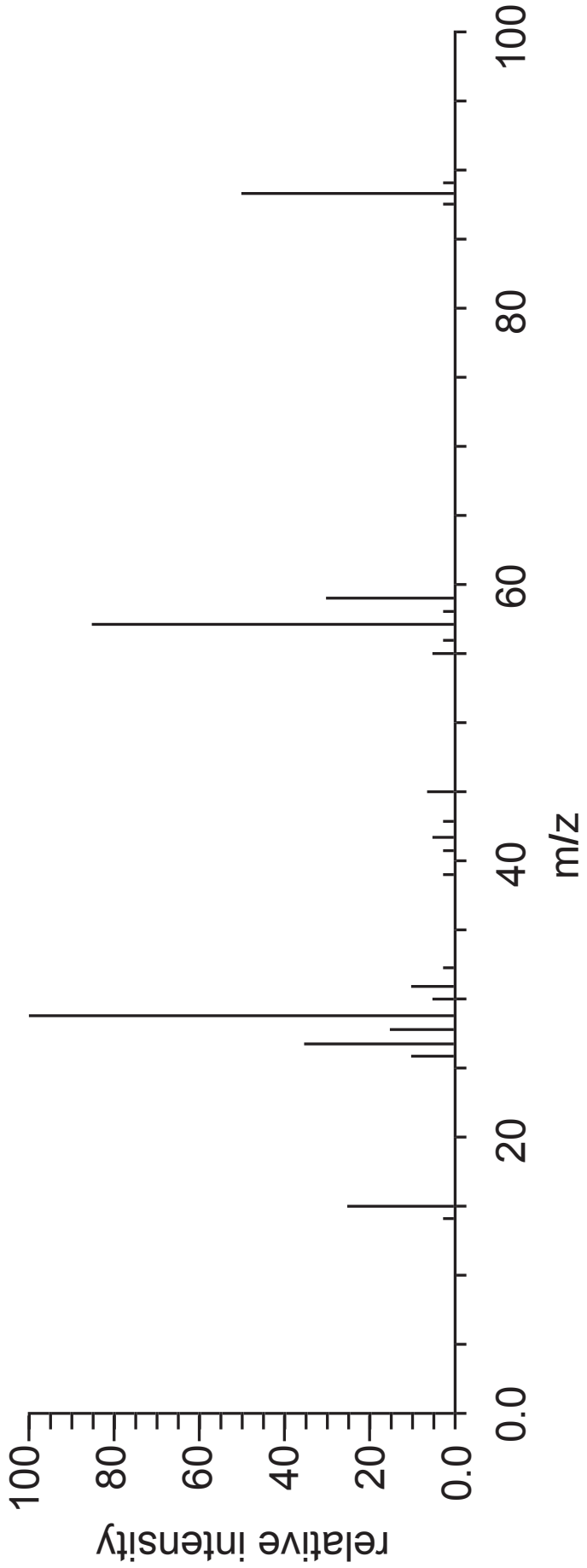
_____

_____

(b) Sketch the nmr spectrum for methyl propanoate, $CH_3CH_2COOCH_3$ showing the integration curve together with the splitting patterns. Indicate which hydrogen atoms are responsible for each peak. [5 marks]



(c) The mass spectrum for methyl propanoate is shown below.



(i) What is the m/z value of the base peak? [1 mark]

_____

(ii) Suggest the formulae of the species responsible for the peaks at 31 and 57. [2 marks]

31: _____

57: _____

(iii) Explain why there is a peak at 89. [1 mark]

_____

17 Chromium is purified in a number of steps after it is extracted from its ore.

Step 1: The impure chromium is heated with sodium carbonate in the presence of air to form sodium chromate(VI), Na_2CrO_4.

Step 2: The sodium chromate(VI) is converted to sodium dichromate which is then heated with carbon to form sodium chromate(III), $Na_2Cr_2O_4$, and carbon monoxide.

Step 3: The $Na_2Cr_2O_4$ is hydrolysed to form chromium(III) oxide. This is then reduced to chromium by aluminium.

(a) Write equations for the following reactions.

(i) The formation of sodium chromate(VI) in Step 1. [2 marks]

(ii) The formation of $Na_2Cr_2O_4$ from sodium dichromate in Step 2. [1 mark]

(iii) The reduction of the chromium(III) oxide in Step 3. [1 mark]

(b) What is the colour change when sodium chromate(VI) is converted to sodium dichromate? [2 marks]

From _____ to _____

(c) The oxygen atoms in the dichromate ion are arranged tetrahedrally around both chromium atoms. Draw a diagram below to suggest the 3D arrangement of the atoms in the dichromate ion. [2 marks]

(d) Acidified dichromate ions can be used to determine the concentration of iron(II) ions. The half-equations for the reaction are:

$$Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O$$

$$Fe^{2+} \rightarrow Fe^{3+} + e^-$$

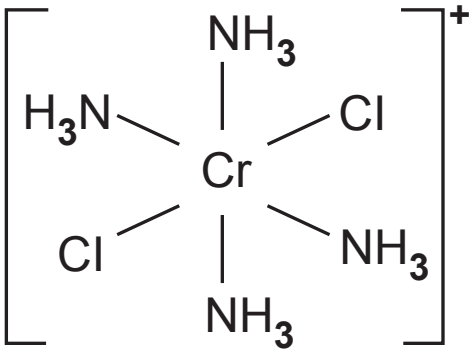
(i) Write a balanced ionic equation for the reaction between acidified dichromate and iron(II) ions. [1 mark]

(ii) Five iron tablets containing iron(II) sulfate, $FeSO_4$, were dissolved in acid and the solution made up to 250 cm^3 in a volumetric flask. 25.0 cm^3 of this solution required 23.5 cm^3 of 0.01 mol dm^{-3} sodium dichromate solution for complete oxidation. Calculate the mass of iron(II) sulfate in an iron tablet. [4 marks]

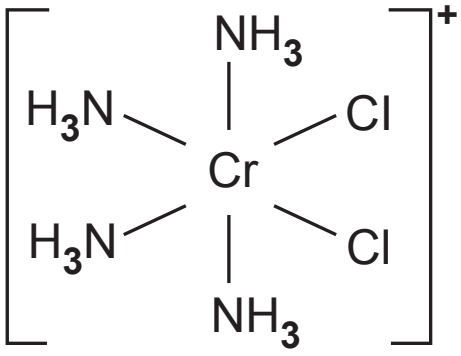
(e) Chromium(III) ions form a range of complex ions with a variety of ligands.

(i) Explain what is meant by the term **ligand**. [2 marks]

(ii) The E–Z isomers of the complex ion $[Cr(NH_3)_4Cl_2]^+$ are shown below.



Isomer 1



Isomer 2

Suggest and explain which structure is that of the E isomer and which is that of the Z isomer. [3 marks]

(f) The hydrated chromium(III) ions, $[Cr(H_2O)_6]^{3+}$, readily react with edta^{4-} ions in a ligand replacement reaction.

(i) What term is given to ligands such as edta? [1 mark]

_____

(ii) Write an equation for the reaction taking place between hydrated chromium(III) ions and edta^{4-} ions. [1 mark]

_____

(iii) Explain, in terms of entropy, why the reaction takes place. [2 marks]

_____

_____

_____

_____

(g) Chromium forms the double salt chrome alum. Describe, giving experimental details, how you would prepare crystals of chrome alum from potassium dichromate. [4 marks]

Quality of written communication [2 marks]

THIS IS THE END OF THE QUESTION PAPER

For Examiner's use only	
Question Number	**Marks**
Section A	
1–10	
Section B	
11	
12	
13	
14	
15	
16	
17	
Total Marks	

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