Rewarding Learning

71

Candidate Number

ADVANCED
General Certificate of Education
2011

Chemistry

Assessment Unit A2 2

assessing

Analytical, Transition Metals, Electrochemistry and Further Organic Chemistry

[AC222]

AC222

FRIDAY 27 MAY, AFTERNOON

TIME

2 hours.

INSTRUCTIONS TO CANDIDATES

Write your Centre Number and Candidate Number in the spaces provided at the top of this page.
Answer **all fifteen** 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 five** 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 **13(d)(iii)**.
In Section A all questions carry equal marks, i.e. **two** marks for each question.
In Section B the figures printed down the right-hand side of pages indicate the marks awarded to each question or part question.
A Periodic Table of Elements (including some data) is provided.

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

Section A

For each of the 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 Chlorine has two isotopes, chlorine-35 and chlorine-37.
Which one of the following is the number of peaks found in the mass spectrum of chlorine gas?

A 2
B 3
C 4
D 5

2 The mechanism for the nitration of benzene is described as

A electrophilic addition.
B electrophilic substitution.
C nucleophilic addition.
D nucleophilic substitution.

3 Copper(II) ions form a coloured complex with the ligand L. The following absorbances were recorded on mixing different volumes of 0.05 M copper(II) sulfate and 0.1 M ligand L.

volume of 0.05 M $CuSO_4(aq)/cm^3$	volume of 0.1 M $L(aq)/cm^3$	absorbance
3.0	7.0	0.412
4.0	6.0	0.457
5.0	5.0	0.406
6.0	4.0	0.335
7.0	3.0	0.251

Which one of the following is the cation to ligand ratio in this complex?

A 1:2
B 1:3
C 2:3
D 3:2

4 In which one of the following is a metal in the +2 state?

A $[Ag(NH_3)_2]^+$
B $[Co(NH_3)_5Br]^{2+}$
C $K_4Fe(CN)_6$
D $K_2Cr_2O_7$

5 An organic compound X contains carbon, hydrogen and oxygen only. When 1.29 g of X is burnt completely, 3.30 g of carbon dioxide and 1.35 g of water are formed. Which one of the following is the empirical formula of X?

A CH_2O
B C_2H_6O
C C_4H_8O
D $C_5H_{10}O$

6 Which one of the following is the relative molecular mass of 2,4-dichloro-3,5-dimethylphenol?

A 190
B 191
C 192
D 196

7 Given the following standard electrode potentials:

	$E^{\ominus}$/V
$V^{3+}(aq) + e^- \rightarrow V^{2+}(aq)$	−0.26
$SO_4^{2-}(aq) + 2H^+(aq) + 2e^- \rightarrow SO_3^{2-}(aq) + H_2O(l)$	+0.17
$VO^{2+}(aq) + 2H^+(aq) + e^- \rightarrow V^{3+}(aq) + H_2O(l)$	+0.34
$Fe^{3+}(aq) + e^- \rightarrow Fe^{2+}(aq)$	+0.77
$VO_2^+(aq) + 2H^+(aq) + e^- \rightarrow VO^{2+}(aq) + H_2O(l)$	+1.00

Which one of the following reagents will convert $V^{3+}(aq)$ to $VO^{2+}(aq)$?

A Aqueous iron(II) ions
B Aqueous iron(III) ions
C Aqueous sulfate ions in acidic solution
D Aqueous sulfite ions

8 Which one of the following is the volume of water which must be added to $30.0\,cm^3$ of $0.25\,mol\,dm^{-3}$ sulfuric acid to produce $0.05\,mol\,dm^{-3}$ sulfuric acid?

A $30\,cm^3$
B $120\,cm^3$
C $150\,cm^3$
D $270\,cm^3$

9 Which one of the following is the total number of electrons involved in bonding in benzene?

A 12
B 18
C 24
D 30

10 The concentration of aqueous magnesium ions may be determined by titration with standard edta using Eriochrome Black T as indicator. Which one of the following is the colour change at the end point?

A Blue to green
B Blue to red
C Red to blue
D Red to green

Section B

Answer **all five** questions in the spaces provided.

11 Lysine (2,6-diaminohexanoic acid) has the formula

$$H_2N(CH_2)_4CH(NH_2)COOH$$

The molecule is optically active and may undergo polymerisation.

(a) (i) Explain the term **optically active**.

_____ [2]

(ii) Draw the 3D structure of lysine labelling the asymmetric carbon with an asterisk (*).

[2]

(b) Explain why lysine has a relatively high melting point.

_____

_____

_____ [2]

(c) Write the formula of the organic ion present when lysine is dissolved in an alkaline solution.

_____ [1]

(d) Draw the structure of a dimer formed when two molecules of lysine react.

[2]

(e) A mixture of amino acids may be separated using paper chromatography.

(i) Explain the term **R_f value** as applied to paper chromatography.

_____ [1]

(ii) Explain, in terms of partition, what a low R_f value indicates about a particular amino acid.

_____

_____ [2]

(f) An amino acid was found to have the following composition by mass:

element	% composition
N	10.5
C	36.1
H	5.3
O	48.1

Deduce the empirical formula for this amino acid.

_____

_____

_____

_____ [3]

12 Chromium is a transition metal which was discovered by Louis Vauquelin in 1797. He was able to detect traces of chromium in precious gems, such as ruby and emerald.

(a) State the electronic structure of a chromium atom and explain why the arrangement is stable.

_____

_____ [2]

(b) Chromium(III) oxide, Cr_2O_3, can be reduced to the metal by heating with aluminium powder according to the equation:

$$2Al(s) + Cr_2O_3(s) \rightarrow 2Cr(s) + Al_2O_3(s)$$

Calculate the percentage yield when 42.5 g of chromium are obtained from a reaction between 25 g of aluminium and 100 g of chromium(III) oxide.

_____

_____

_____

_____

_____ [3]

(c) Chromium trioxide, CrO_3, is formed by the reaction between excess concentrated sulfuric acid and a concentrated solution of potassium dichromate. Potassium sulfate and water are formed as by-products.

Write the equation for this reaction.

_____ [2]

(d) A data book lists the following standard electrode potentials:

$Cr^{3+}(aq) + e^- \rightarrow Cr^{2+}(aq)$ $-0.41\,V$
$Ag^+(aq) + e^- \rightarrow Ag(s)$ $+0.80\,V$

(i) Cr^{2+} can reduce silver ions to silver atoms. Write the equation for this reduction.

_____ [1]

(ii) Deduce the electrode potential for this change.

_____ [1]

(e) Chrome alum is a double salt prepared by the reduction of potassium dichromate, $K_2Cr_2O_7$, using a suitable reducing agent.

(i) Name a suitable reducing agent.

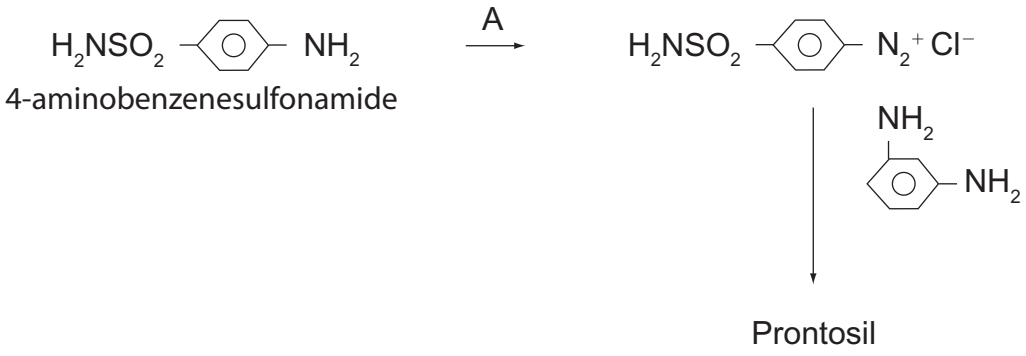
_____ [1]

(ii) State the colour and formula of crystalline chrome alum.

_____

_____ [2]

(f) Chrome alum may be used as a mordant in dyeing, binding the dye molecules to the fibre. The dye Prontosil is prepared by the following sequence:



4-aminobenzenesulfonamide

Prontosil

(i) Deduce the empirical formula for 4-aminobenzenesulfonamide.

_____ [1]

(ii) Name the reagents required for step A.

_____ [1]

(iii) State and explain the condition necessary for the first step.

_____

_____ [2]

(iv) Suggest a structure of the dye Prontosil which is formed by a coupling reaction.

[2]

(v) Explain why Prontosil is coloured.

_____

_____

_____

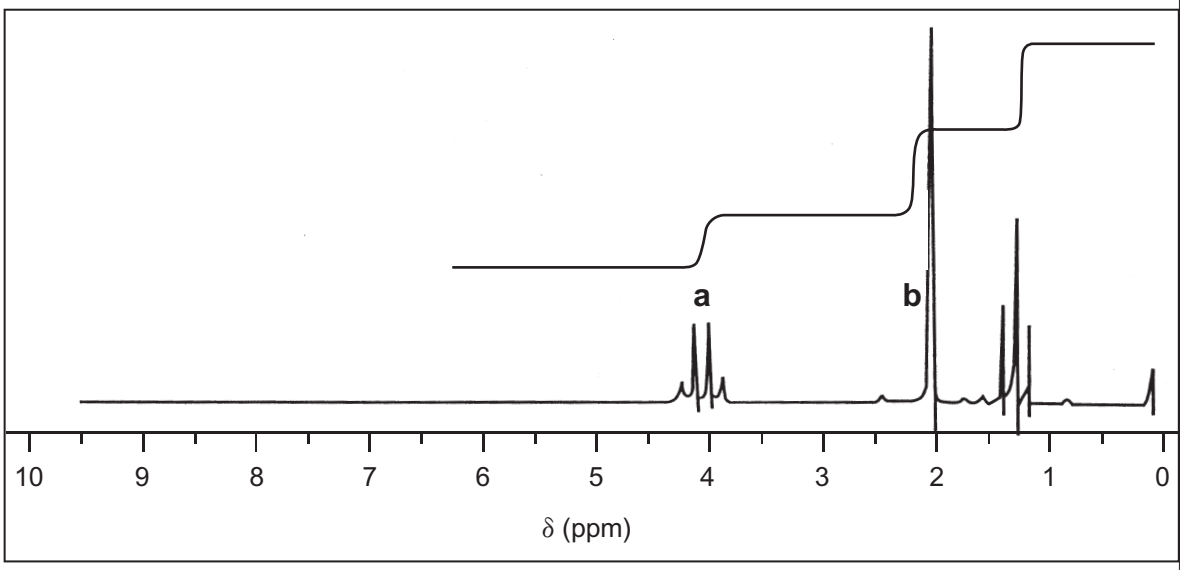
_____ [3]

13 The first person to extract ethanoic acid from vinegar was the alchemist Jabir ibn Hayyan Geber (c. 721–815 AD). However the pure compound was not produced for another ten centuries.

(a) The mass spectrum of ethanoic acid shows a distinct peak at m/e = 59. State the formula of the species giving rise to this peak.

_____ [1]

(b) Ethanoic acid reacts with ethanol to form the ester ethyl ethanoate, $CH_3COOC_2H_5$. The n.m.r. spectrum of ethyl ethanoate consists of three sets of peaks as shown below.



(i) Explain the peak integrations.

_____

_____

_____ [2]

(ii) Explain the chemical shifts.

_____

_____

_____ [2]

(iii) Explain the splitting pattern **a**.

_____

_____ [1]

(iv) Explain why **b** is a singlet.

_____

_____ [1]

(c) Ethanoic acid can be converted to ethanamide via the thermal decomposition of the ammonium salt.

(i) Write the equation for the reaction of ethanoic acid with ammonia.

_____ [1]

(ii) Write the equation for the thermal decomposition.

_____ [1]

(iii) Ethanamide is hydrolysed by either hydrochloric acid or sodium hydroxide to form different organic products. State the formula of the organic product in each case.

hydrochloric acid _____

sodium hydroxide _____ [2]

(d) Ethanamide can be converted to an amine in the following sequence.

$$CH_3CONH_2 \xrightarrow{A} CH_3CN \xrightarrow{B} CH_3CH_2NH_2$$

(i) Give the formula of reagents A and B.

A _____

B _____ [2]

(ii) Write the equation for the reaction of an unknown amine, RNH_2, with ethanoyl chloride.

_____ [1]

(iii) Describe how you would identify the unknown amine using the pure N-substituted amide. Include relevant practical steps.

_____

_____

_____

_____

_____

_____

_____ [4]

Quality of written communication. [2]

(e) 1,2-diaminoethane (en) is a bidentate ligand forming stable complex ions with transition metal ions.

(i) Explain the term **bidentate**.

_____

_____ [2]

(ii) Hexaaquanickel(II) ions react with en in solution. Write the equation for this reaction in which all the water ligands are replaced.

_____ [2]

(iii) Explain why this ligand replacement takes place.

_____

_____ [2]

14 Iron is a transition metal which fulfils vital biological, industrial and chemical roles.

(a) The most common oxidation states of iron in its compounds are +2 and +3. State the electronic structures of the Fe^{2+} and Fe^{3+} ions.

Fe^{2+} _____

Fe^{3+} _____ [2]

(b) Metallic iron is used as a heterogeneous catalyst in the Haber Process to make ammonia.

$$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$$

Explain in terms of chemisorption how the reaction takes place.

_____

_____

_____ [3]

(c) Iron filings are used to catalyse the monohalogenation of aromatic compounds such as methylbenzene, $C_6H_5CH_3$.

(i) Draw a flow scheme for the mechanism of the monobromination of methylbenzene to form 4-bromomethylbenzene.

[3]

(ii) Suggest the name of the product formed in the monobromination of 1,4-dimethylbenzene.

_____ [2]

(d) (i) Explain the role of iron(II) in haemoglobin.

_____

_____ [2]

(ii) Explain the effect of the inhalation of carbon monoxide on haemoglobin.

_____ [1]

(e) Aqueous iron(III) ions form a stable complex with the bidentate ligand ethanedioate, $C_2O_4^{2-}$.
The iron(III) ions combine with three ethanedioate ions. Deduce the formula of the complex formed.

_____ [1]

(f) Potassium manganate(VII) oxidises iron(II) ions and ethanedioate ions according to the equations:

$$MnO_4^-(aq) + 5Fe^{2+}(aq) + 8H^+(aq) \rightarrow 5Fe^{3+}(aq) + Mn^{2+}(aq) + 4H_2O(l)$$

$$2MnO_4^-(aq) + 5C_2O_4^{2-}(aq) + 16H^+(aq) \rightarrow 2Mn^{2+}(aq) + 10CO_2(g) + 8H_2O(l)$$

(i) Describe, with observations, how you could confirm the presence of aqueous iron(III) ions, following the oxidation of iron(II) ions, without interference from manganese(II) ions.

_____

_____

_____ [3]

(ii) 25.0 cm^3 of an acidified iron(II) ethanedioate solution required 32.2 cm^3 of 0.025 mol dm^{-3} of potassium manganate(VII) solution for complete reaction. Calculate the concentration, in mol dm^{-3}, of the iron(II) ethanedioate solution.

_____

_____

_____

_____

_____ [4]

15 Polymers have become invaluable materials with many familiar names e.g. polythene, Perspex, and nylon.

(a) The manufacture of High Density (HD) polythene was first developed by Ziegler in the 1950s.

(i) State the conditions used to manufacture HD polythene.

_____

_____

_____ [3]

(ii) State and explain the flexibility and softening temperature of HD polythene.

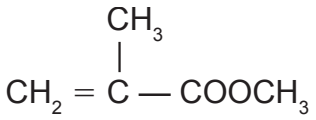
_____

_____

_____

_____ [3]

(b) Perspex is an addition polymer made by polymerisation of methyl 2-methylpropenoate monomer shown below.



Draw a section of the Perspex polymer showing at least two repeating units.

[2]

(c) Nylon is a condensation polymer made from the two monomers 1,6-diaminohexane and hexanedioic acid.

$H_2N(CH_2)_6NH_2$ $HOOC(CH_2)_4COOH$

1,6-diaminohexane hexanedioic acid

(i) Explain the term **condensation** polymer.

_____

_____ [1]

(ii) Draw the repeat unit in nylon circling the peptide link in the structure.

[3]

(d) Explain why the disposal of polyesters in landfill sites is more environmentally acceptable than the similar disposal of polythene.

_____

_____ [2]

(e) Proteins are natural polymers which act as structural materials.

(i) State what is meant by the primary structure of a protein.

_____ [1]

(ii) Proteins hydrolyse slowly in acid conditions. Suggest how enzymes work to allow the process to occur more quickly.

_____

_____

_____ [2]

THIS IS THE END OF THE QUESTION PAPER

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