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

AC222

## [AC222]
## TUESDAY 2 JUNE, 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 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 down the right-hand side of pages 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.

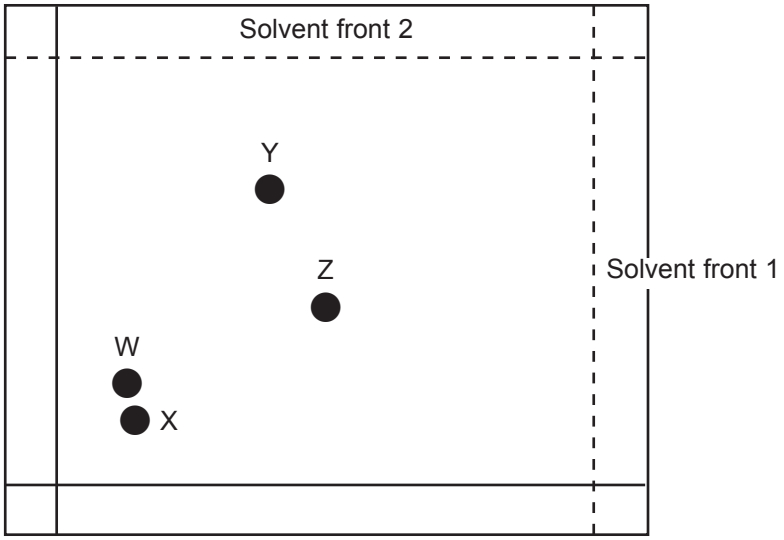
| For Examiner's use only | |
|---|---|
| Question Number | Marks |
| Section A | |
| 1–10 | |
| Section B | |
| 11 | |
| 12 | |
| 13 | |
| 14 | |
| 15 | |
| 16 | |
| 17 | |
| Total Marks | |

## 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?

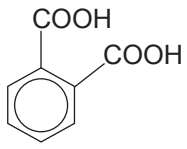
A The liquid phase is mobile and the gas phase is stationary

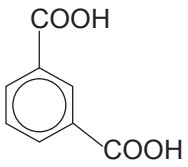
B The molecules in the mixture have characteristic retention times

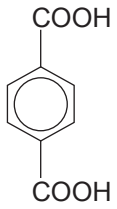
C The mixture is separated by partition between the liquid and the gas phase

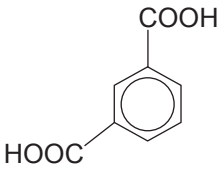
D The percentage composition of the mixture can be determined

**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 $\pi$ 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

| Examiner Only | |
|---|---|
| Marks | Remark |
| | |

**11** Vanadium is a typical transition metal.

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

_____

_____ [1]

**(b)** Vanadium has a variety of oxidation states.

**(i)** What is the electronic configuration of the $V^{2+}$ ion?

_____ [1]

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

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

[4]

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

| Examiner Only | |
|---|---|
| Marks | Remark |

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

_____

_____ [1]

**(ii)** Explain, in terms of chemisorption, how vanadium(V) oxide acts as a catalyst.

_____

_____

_____

_____ [3]

**(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]

**(iv)** Complete the table below by naming the catalyst used for each industrial process.

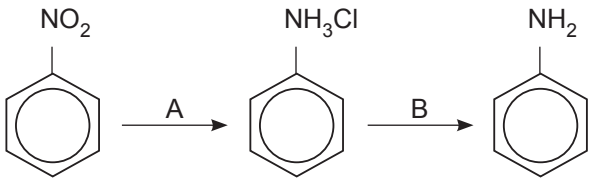
| industrial process | catalyst |
|---|---|
| formation of ammonia | |
| oxidation of ammonia | |

[2]

| Examiner Only | |
|---|---|
| Marks | Remark |

**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.

Step A _____ [1]

Step B _____ [1]

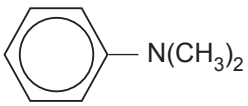
**(b)** Phenylamine is then converted to benzenediazonium chloride. Name the reagents and state the condition required to convert phenylamine to benzenediazonium chloride.

_____

_____

_____ [2]

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

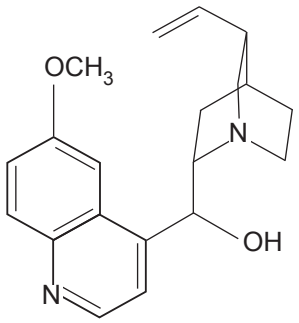



dimethylaminobenzene

Write the equation for the reaction and circle the azo group.

_____ [3]

**(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]

**(ii)** Quinine is optically active. Circle the carbon asymmetric centres on the above diagram.

[2]

| Examiner Only | |
|---|---|
| Marks | Remark |
| | |

| Examiner Only | |
|---|---|
| Marks | Remark |

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

**(i)** What type of reaction do alkenes undergo with bromine?

_____ [1]

**(ii)** Name a catalyst required for the reaction of benzene with bromine.

_____ [1]

**(iii)** Draw a flow scheme to show the mechanism for the catalysed reaction of benzene with bromine.

[3]

**(iv)** Name the mechanism for the reaction of benzene with bromine.

_____ [1]

**(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]

**(ii)** Name the reagents used and write the equation for the formation of the nitronium ion.

Reagents: _____

Equation: _____ [2]

| Examiner Only | |
|---|---|
| Marks | Remark |

**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.

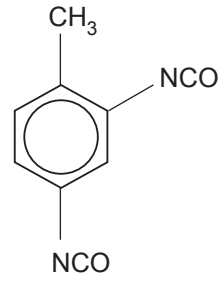
**(i)** What type of polymers are polyesters?

_____ [1]

**(ii)** Draw a diagram of **one** repeating unit of the polyester.

[2]

**(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]

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

_____

_____ [2]

**(d)** Explain why polyurethanes are biodegradable.

_____

_____ [1]

**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]

**(ii)** State why putrescine is soluble in water.

_____

_____ [1]

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

**(i)** Write an equation for the reaction of putrescine with excess nitrous acid.

_____ [2]

**(ii)** Write an equation for the reaction of putrescine with excess ethanoyl chloride

_____ [2]

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

_____

_____ [2]

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

**(i)** Amino acids form zwitterions. What is a **zwitterion**?

_____ [2]

**(ii)** Draw the zwitterion formed by valine.

[1]

Examiner Only

| Marks | Remark |
|---|---|
| | |

**(iii)** Valine is optically active. Draw the 3D representations of the optical isomers.

[2]

**(d)** Amino acids combine to form proteins. Describe the structure of proteins under the following headings.

Primary: _____

_____

Secondary: _____

_____

Tertiary: _____

_____ [3]

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

**(i)** Describe how enzymes act as catalysts.

_____

_____ [2]

**(ii)** Explain why biological washing powders do not work at high temperatures.

_____

_____ [2]

Examiner Only

| Marks | Remark |
|---|---|
| | |

| Examiner Only | |
|---|---|
| Marks | Remark |

**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]

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

_____

_____

_____ [2]

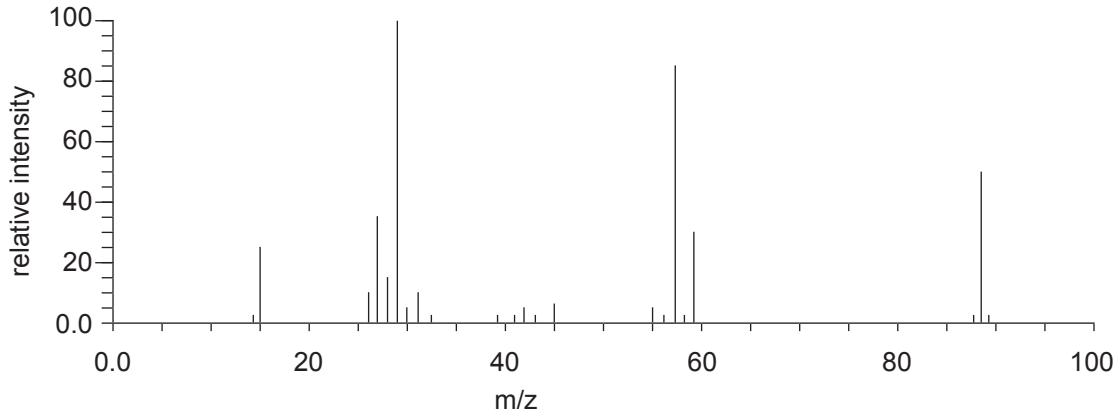
**(b)** Sketch the nmr spectrum for methyl propanoate, $CH_3CH_2COOCH_3$ showing the integration curve together with the splitting patterns. Indicate which hydrogen atoms are responsible for each peak.

TMS

[5]

| Examiner Only | |
|---|---|
| Marks | Remark |

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




**(i)** What is the m/z value of the base peak?

_____ [1]

**(ii)** Suggest the formulae of the species responsible for the peaks at 31 and 57.

31: _____

57: _____ [2]

**(iii)** Explain why there is a peak at 89.

_____ [1]

**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]

**(ii)** The formation of $Na_2Cr_2O_4$ from sodium dichromate in Step 2.

_____ [1]

**(iii)** The reduction of the chromium(III) oxide in Step 3.

_____ [1]

**(b)** What is the colour change when sodium chromate(VI) is converted to sodium dichromate?

From: _____ to _____ [2]

**(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]

Examiner Only

| Marks | Remark |
|---|---|
| | |

**(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]

**(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]

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

**(i)** Explain what is meant by the term **ligand**.

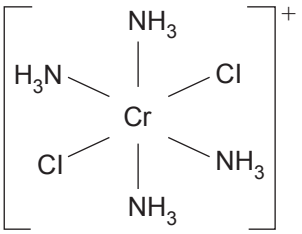
_____

_____ [2]

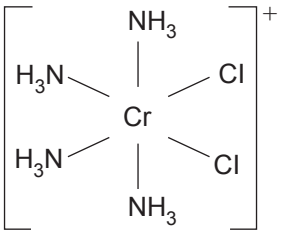
Examiner Only

| Marks | Remark |
|---|---|
| | |

**(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]

**(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]

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

_____ [1]

**(iii)** Explain, in terms of entropy, why the reaction takes place.

_____

_____

_____ [2]

Examiner Only

| Marks | Remark |
|---|---|
| | |

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

| Examiner Only | |
|---|---|
| Marks | Remark |
| | |

_____

_____

_____

_____

_____

_____

_____

_____ [4]

Quality of written communication [2]

**THIS IS THE END OF THE QUESTION PAPER**

180451