



Rewarding Learning

**ADVANCED**  
General Certificate of Education  
2022

Centre Number

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# Chemistry

Assessment Unit A2 2

*assessing*

Analytical, Transition Metals,  
Electrochemistry and Further  
Organic Chemistry

**[ACH24]**

\*ACH24\*

**TUESDAY 14 JUNE, MORNING**

## 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 in **Sections A and B**.

**You must answer the questions in the spaces provided.**

**Do not write outside the boxed area on each page or on blank pages.**

Complete in black ink only. **Do not write with a gel pen or a pencil.**

## INFORMATION FOR CANDIDATES

The total mark for this paper is 110.

Quality of written communication will be assessed in Questions **14(d)** and **15(b)(iii)**.

The figures in brackets printed down the right-hand side of pages indicate the marks awarded to each question or part question.

A Periodic Table of Elements, containing some data, is included with this question paper.

13012



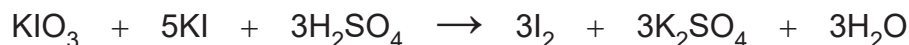
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## Section A

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

**Select the correct response for each question and write the appropriate letter in the space provided.**

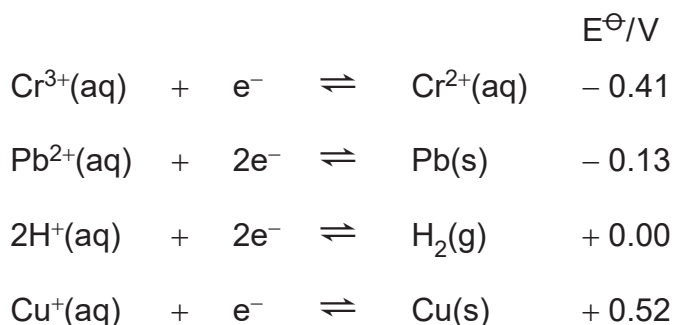
1 Which one of the following is the reducing agent in the reaction below?



- A iodate(V) ions
- B iodide ions
- C potassium ions
- D sulfate(VI) ions

Answer \_\_\_\_\_ [1]

2 Using the standard electrode potentials given below:



Identify the reaction which would be expected to occur.

- A  $2\text{Cr}^{2+}(\text{aq}) + \text{Pb}^{2+}(\text{aq}) \rightarrow 2\text{Cr}^{3+}(\text{aq}) + \text{Pb}(\text{s})$
- B  $2\text{Cu}(\text{s}) + \text{Pb}^{2+}(\text{aq}) \rightarrow 2\text{Cu}^+(\text{aq}) + \text{Pb}(\text{s})$
- C  $\text{Pb}(\text{s}) + 2\text{Cr}^{3+}(\text{aq}) \rightarrow 2\text{Cr}^{2+}(\text{aq}) + \text{Pb}^{2+}(\text{aq})$
- D  $\text{Pb}^{2+}(\text{aq}) + \text{H}_2(\text{g}) \rightarrow 2\text{H}^+(\text{aq}) + \text{Pb}(\text{s})$

Answer \_\_\_\_\_ [1]



- 3 A gaseous compound of nitrogen and oxygen was completely decomposed into its elements.



60 cm<sup>3</sup> of the compound (N<sub>x</sub>O<sub>y</sub>) were decomposed and the total volume of gas produced was 90 cm<sup>3</sup> which was reduced to 60 cm<sup>3</sup> after passage over heated copper to remove oxygen. All volumes were measured at room temperature and pressure.

What is the formula of N<sub>x</sub>O<sub>y</sub>?

- A NO
- B NO<sub>2</sub>
- C N<sub>2</sub>O
- D N<sub>2</sub>O<sub>2</sub>

Answer \_\_\_\_\_ [1]

- 4 Which one of the following is produced when a solid mixture of ethanamide and P<sub>4</sub>O<sub>10</sub> is heated?

- A aminoethanoic acid
- B ethanenitrile
- C ethanoic acid
- D ethylamine

Answer \_\_\_\_\_ [1]

[Turn over

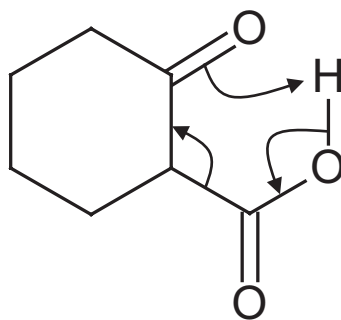


5 Which one of the following peaks is present in the mass spectrum of propan-1-ol but **not** present in the mass spectrum of propan-2-ol?

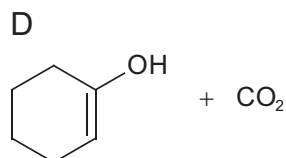
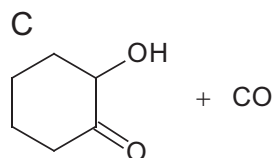
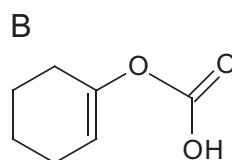
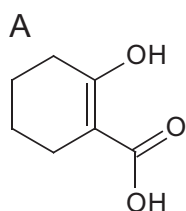
- A  $m/z = 15$
- B  $m/z = 31$
- C  $m/z = 45$
- D  $m/z = 60$

Answer \_\_\_\_\_ [1]

6 The curly arrows below represent the movement of electrons in a mechanism for a chemical reaction.



Which one of the following would be the product(s) from this reaction?



Answer \_\_\_\_\_ [1]



- 7 The  $^1\text{H}$  nmr spectrum of 1,1-dibromoethane consists of two well-separated signals, one with an integration of 1 and the other with an integration of 3. Which one of the following is correct?

	Signal with integration of 1	Signal with integration of 3
A	doublet	quartet
B	singlet	triplet
C	triplet	singlet
D	quartet	doublet

Answer \_\_\_\_\_ [1]

- 8 How many aromatic compounds with the molecular formula  $\text{C}_6\text{H}_4\text{Br}_2$  exist?

- A 1  
B 2  
C 3  
D 4

Answer \_\_\_\_\_ [1]

- 9 An unknown compound has a molecular ion at  $m/z = 79$ . Analysis shows its composition to be 17.7% nitrogen by mass. What is its molecular formula?

- A  $\text{C}_3\text{HN}_3$   
B  $\text{C}_4\text{H}_3\text{N}_2$   
C  $\text{C}_4\text{H}_{15}\text{N}$   
D  $\text{C}_5\text{H}_5\text{N}$

Answer \_\_\_\_\_ [1]

[Turn over



10 Which one of the following statements is the definition of the base peak in a mass spectrum?

- A The highest mass ion
- B The peak of greatest abundance
- C The lowest  $m/z$  peak
- D The molecular ion peak

Answer \_\_\_\_\_ [1]





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## Section B

Answer **all five** questions in this section

- 11 The ethanedioate ion,  $\text{C}_2\text{O}_4^{2-}$ , may act as a bidentate ligand. Ethanedioate ions,  $\text{C}_2\text{O}_4^{2-}$ , can be titrated using manganate(VII) ions in solution.

(a) Explain the term **bidentate ligand**.

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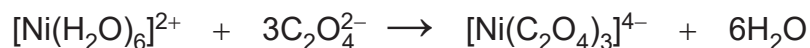
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[2]

- (b) The reaction below occurs when a solution containing ethanedioate ions is added to a solution containing hexaaquanickel(II) ions.



(i) Suggest why the enthalpy change for this reaction is approximately zero.

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[2]

(ii) Explain, with reference to the equation, why this reaction occurs despite the enthalpy change being approximately zero.

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[2]





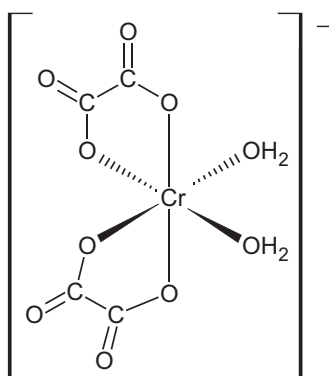
(iii) State the co-ordination number and oxidation state of nickel and the shape of the  $[\text{Ni}(\text{C}_2\text{O}_4)_3]^{4-}$  complex.

co-ordination number: \_\_\_\_\_

oxidation state of nickel: \_\_\_\_\_

shape of complex: \_\_\_\_\_ [3]

(c) Hexaaquachromium(III) ions react with ethanedioate ions in solution. The complex formed is shown below. This complex exhibits isomerism. The cis (Z) isomer is shown below and is blue-grey in solution. The trans (E) isomer is purple in solution.



(i) Write an equation for the formation of this complex from hexaaquachromium(III) ions.

\_\_\_\_\_ [2]

(ii) Suggest the structure of the trans (E) isomer.

[1]

[Turn over



(d) A 25.0 cm<sup>3</sup> portion of a solution of iron(II) ethanedioate was acidified using an excess of sulfuric acid and titrated with 0.0150 mol dm<sup>-3</sup> potassium manganate(VII) solution.

The overall equation for the reaction is:



(i) Explain in terms of oxidation states why this is a redox reaction.

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[4]

(ii) Write three half-equations to show the oxidation and reduction reactions occurring in this overall reaction.

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[3]



(iii) State the colour change which would be observed at the end point during this titration.

\_\_\_\_\_ [1]

(iv) The mean titre was found to be  $12.45 \text{ cm}^3$ . Calculate the concentration of the iron(II) ethanedioate solution in  $\text{mol dm}^{-3}$ . Give your answer to an appropriate number of significant figures.

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\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_ [4]

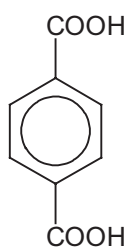
(v) The iron(II) ethanedioate solution was originally made by dissolving  $0.561 \text{ g}$  of hydrated iron(II) ethanedioate ( $\text{FeC}_2\text{O}_4 \cdot x\text{H}_2\text{O}$ ) in  $250 \text{ cm}^3$  of deionised water. Calculate the value of  $x$  in  $\text{FeC}_2\text{O}_4 \cdot x\text{H}_2\text{O}$ .

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_ [3]

[Turn over



12 Benzene-1,4-dicarboxylic acid may be used to synthesise polyamide and polyester polymers.



benzene-1,4-dicarboxylic acid

(a) (i) Name the polyester formed from benzene-1,4-dicarboxylic acid and ethane-1,2-diol.

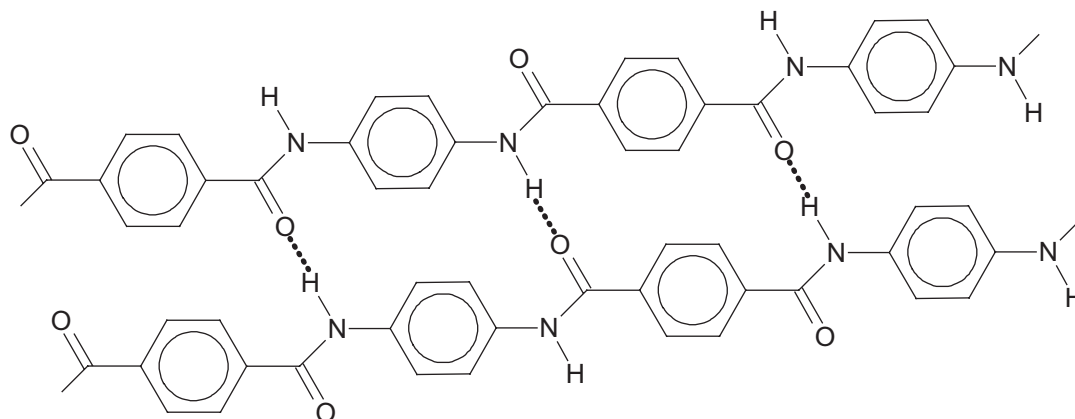
[1]

(ii) Draw one repeating unit of the polyester named in (a)(i).

[1]



- (b) The polyamide Kevlar is made from the reaction of 1,4-diaminobenzene with benzene-1,4-dicarboxylic acid. The melting point of Kevlar is over 500 °C. The diagram below shows two Kevlar polymer chains.



- (i) Suggest the type of bond represented by the dotted lines in the diagram above.

\_\_\_\_\_ [1]

- (ii) Explain, using the diagram above, why Kevlar has such a high melting point.

\_\_\_\_\_  
\_\_\_\_\_ [1]

- (c) Explain why polyamides and polyesters are biodegradable.

\_\_\_\_\_  
\_\_\_\_\_ [2]

[Turn over





- (ii) Draw the structure and state the IUPAC name of the aldehyde or ketone needed to form the amino acid valine,  $(\text{CH}_3)_2\text{CHCH}(\text{NH}_2)\text{COOH}$ , via the Strecker synthesis.

\_\_\_\_\_ [2]

- (iii) Write an equation for the reaction of ethanal with ammonia and hydrogen cyanide to form the  $\alpha$ -aminonitrile.

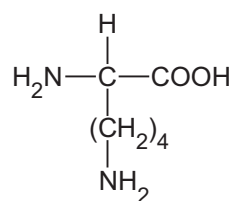
\_\_\_\_\_ [1]

- (iv) Write an equation for the hydrolysis of the  $\alpha$ -aminonitrile formed in (b)(iii) above using hydrochloric acid.

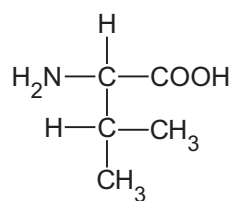
\_\_\_\_\_ [2]



(c) The structures of the amino acids lysine and valine are shown below.



lysine



valine

(i) Draw the structure of lysine in solution at pH 1.

[1]

(ii) Draw the structures of two possible dipeptides formed between one molecule of lysine and one molecule of valine. Circle the peptide link in one of the structures you have drawn.

[3]







(ii) Describe how lysine and valine may be located and identified from the chromatogram.

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[4]

(iii) Explain why two-way paper chromatography is a more effective method of separating amino acids than one-way paper chromatography.

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[1]





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14 Vanadium is a transition metal.

- (a) State what is meant by the term **transition metal** and explain using electronic configuration why vanadium is a transition metal.

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[2]

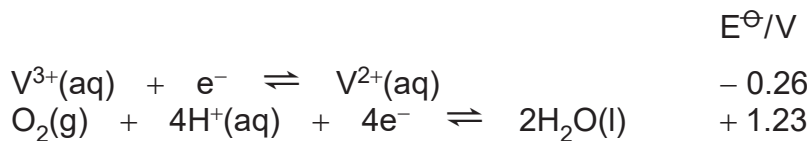
- (b) Complete the table below by giving the half-equations and the colour changes for the reduction reactions given.

Reduction reaction	Half-equation	Colour change
$\text{VO}_2^+$ to $\text{VO}^{2+}$		
$\text{VO}^{2+}$ to $\text{V}^{3+}$		
$\text{V}^{3+}$ to $\text{V}^{2+}$	$\text{V}^{3+} + \text{e}^- \rightarrow \text{V}^{2+}$	

[5]



(c)  $V^{2+}$  is a powerful reducing agent and is oxidised by oxygen in the presence of acid to  $V^{3+}$ . The half-equations with their standard electrode potentials are shown below.



(i) Write the ionic equation for the oxidation of  $V^{2+}$  using oxygen in the presence of acid.

\_\_\_\_\_ [2]

(ii) Write the conventional cell representation for the cell which would be set up using the half cells associated with these two half-equations.

\_\_\_\_\_ [2]

(iii) State and explain, in terms of electrons, which half cell is the negative electrode in the cell.

\_\_\_\_\_  
\_\_\_\_\_ [2]

(iv) Calculate the emf of the cell.

\_\_\_\_\_  
\_\_\_\_\_ [1]

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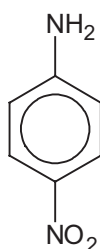
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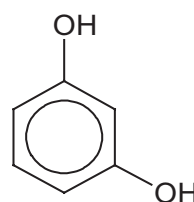


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- 15 The azo dye magneson I is also called azo violet as it is violet in colour. It is prepared from 4-nitrophenylamine and resorcinol.



4-nitrophenylamine



resorcinol

- (a) In this preparation, 4-nitrophenylamine is converted into its diazonium ion and reacted with resorcinol.
- (i) State the reagents and conditions required for the formation of the diazonium ion from 4-nitrophenylamine.

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[3]

- (ii) Suggest the IUPAC name for resorcinol.

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[2]





(iii) Suggest the structure of the azo dye magneson I formed when the diazonium ion of 4-nitrophenylamine reacts with resorcinol.

[2]

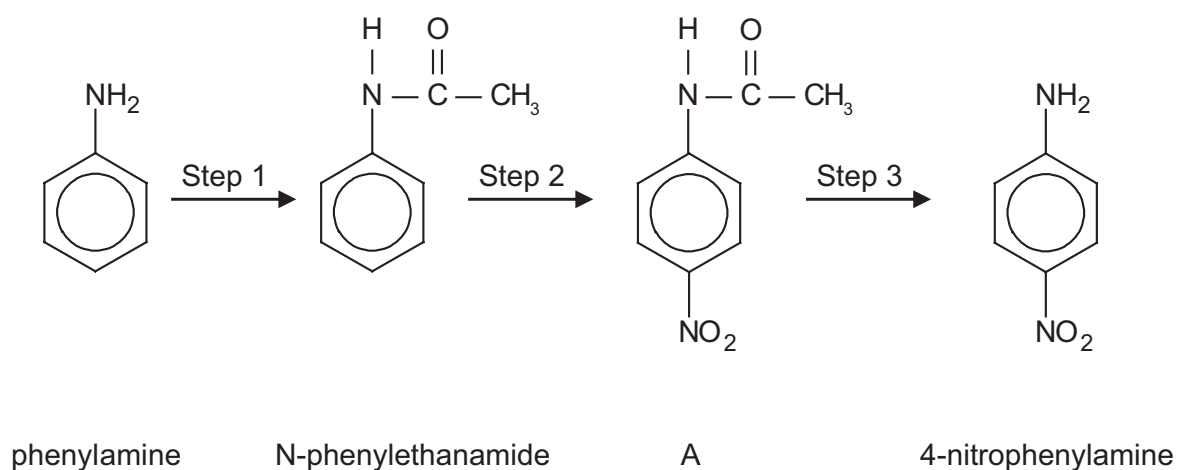
(iv) Explain why magneson I is coloured.

[3]



- (b) 4-nitrophenylamine cannot be prepared by nitration of phenylamine because the amino group is oxidised by nitric acid. The amino group is therefore protected by converting it to an amide group before the nitration is carried out. The amide group is then hydrolysed.

The following diagram shows the steps in the synthesis



- (i) Name a reagent which could be used to carry out Step 1.

\_\_\_\_\_ [1]

- (ii) Write the molecular formula for A.

\_\_\_\_\_ [1]





(c) 4-nitrophenylamine may be reduced to 1,4-diaminobenzene using tin in concentrated hydrochloric acid. The mixture is heated under reflux for 30 minutes. Sodium hydroxide solution is then added.

(i) Write an equation, using [H] to represent the reducing agent, for the reduction of 4-nitrophenylamine to 1,4-diaminobenzene.

\_\_\_\_\_ [2]

(ii) Explain why sodium hydroxide is added.

\_\_\_\_\_  
\_\_\_\_\_ [1]

\_\_\_\_\_  
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## General Information

1 tonne =  $10^6$  g

1 metre =  $10^9$  nm

One mole of any gas at 293 K and a pressure of 1 atmosphere ( $10^5$  Pa) occupies a volume of 24 dm<sup>3</sup>

Avogadro Constant =  $6.02 \times 10^{23}$  mol<sup>-1</sup>

Planck Constant =  $6.63 \times 10^{-34}$  Js

Specific Heat Capacity of water =  $4.2$  J g<sup>-1</sup> K<sup>-1</sup>

Speed of Light =  $3 \times 10^8$  ms<sup>-1</sup>



## Characteristic absorptions in IR spectroscopy

Wavenumber/cm <sup>-1</sup>	Bond	Compound
550–850	C–X (X = Cl, Br, I)	Haloalkanes
750–1100	C–C	Alkanes, alkyl groups
1000–1300	C–O	Alcohols, esters, carboxylic acids
1450–1650	C=C	Arenes
1600–1700	C=C	Alkenes
1650–1800	C=O	Carboxylic acids, esters, aldehydes, ketones, amides, acyl chlorides
2200–2300	C≡N	Nitriles
2500–3200	O–H	Carboxylic acids
2750–2850	C–H	Aldehydes
2850–3000	C–H	Alkanes, alkyl groups, alkenes, arenes
3200–3600	O–H	Alcohols
3300–3500	N–H	Amines, amides

## Proton Chemical Shifts in Nuclear Magnetic Resonance Spectroscopy (relative to TMS)

Chemical Shift	Structure	
0.5–2.0	–CH	Saturated alkanes
0.5–5.5	–OH	Alcohols
1.0–3.0	–NH	Amines
2.0–3.0	–CO–CH	Ketones
	–N–CH	Amines
	C <sub>6</sub> H <sub>5</sub> –CH	Arene (aliphatic on ring)
2.0–4.0	X–CH	X = Cl or Br (3.0–4.0) X = I (2.0–3.0)
4.5–6.0	–C=CH	Alkenes
5.5–8.5	RCONH	Amides
6.0–8.0	–C <sub>6</sub> H <sub>5</sub>	Arenes (on ring)
9.0–10.0	–CHO	Aldehydes
10.0–12.0	–COOH	Carboxylic acids

These chemical shifts are concentration and temperature dependent and may be outside the ranges indicated above.

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# Data Leaflet

## Including the Periodic Table of the Elements

For the use of candidates taking  
Advanced Subsidiary and  
Advanced Level Examinations

**Copies must be free from notes or additions of any kind. No other type of data booklet or information sheet is authorised for use in the examinations**

# gce a/as examinations

# chemistry

