AQA

A-level
Chemistry (7405/3)
Paper 3

Specimen 2015 v0.5   Session   2 hours

Materials

For this paper you must have:

- the Data Booklet, provided as an insert
- a ruler
- a calculator.

Instructions

- Answer **all** questions.
- Show **all** your working.

Information

- The maximum mark for this paper is 90.

Section A

Answer **all** questions in this section.

1 Ethanol can be oxidised by acidified potassium dichromate(VI) to ethanoic acid in a two-step process.

$$\text{ethanol} \longrightarrow \text{ethanal} \longrightarrow \text{ethanoic acid}$$

0 1 . 1 In order to ensure that the oxidation to ethanoic acid is complete, the reaction is carried out under reflux.

Describe what happens when a reaction mixture is refluxed and why it is necessary, in this case, for complete oxidation to ethanoic acid.

[3 marks]

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0 1 . 2 Write a half-equation for the overall oxidation of ethanol into ethanoic acid.

[1 mark]

_____

| 0 | 1 | . | 3 | The boiling points of the organic compounds in a reaction mixture are shown in **Table 1**.

Table 1

Compound	ethanol	ethanal	ethanoic acid
Boiling point / °C	78	21	118

Use these data to describe how you would obtain a sample of ethanal from a mixture of these three compounds. Include in your answer a description of the apparatus you would use and how you would minimise the loss of ethanal. Your description of the apparatus can be either a description in words or a labelled sketch.

[5 marks]

Question 1 continues on the next page

0 1 . 4 Use your knowledge of structure and bonding to explain why it is possible to separate ethanal in this way.

[2 marks]

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0 1 . 5 A student obtained a sample of a liquid using the apparatus in Question **1.3**.

Describe how the student could use chemical tests to confirm that the liquid contained ethanal and did **not** contain ethanoic acid.

[5 marks]

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2 Ethanol and ethanoic acid react reversibly to form ethyl ethanoate and water according to the equation:

$$CH_3COOH + CH_3CH_2OH \rightleftharpoons CH_3COOCH_2CH_3 + H_2O$$
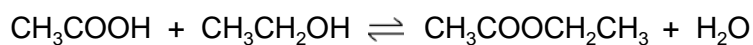
A mixture of 8.00×10^{-2} mol of ethanoic acid and 1.20×10^{-1} mol of ethanol is allowed to reach equilibrium at 20 °C.

- The equilibrium mixture is placed in a graduated flask and the volume made up to 250 cm^3 with distilled water.
- A 10.0 cm^3 sample of this equilibrium mixture is titrated with sodium hydroxide added from a burette.
- The ethanoic acid in this sample reacts with 3.20 cm^3 of 2.00×10^{-1} mol dm^{-3} sodium hydroxide solution.

| 0 | 2 | . | 1 | Calculate the value for K_c for the reaction of ethanoic acid and ethanol at 20 °C.
Give your answer to the appropriate number of significant figures.

[6 marks]

$K_c =$ _____

Question 2 continues on the next page

A student obtained the titration results given in **Table 2**.

Table 2

	Rough	**1**	**2**	**3**
Final burette reading / cm^3	4.60	8.65	12.85	16.80
Initial burette reading / cm^3	0.10	4.65	8.65	12.85
Titre / cm^3				

0 2 . **2** Complete **Table 2**.

[1 mark]

0 2 . **3** Calculate the mean titre and justify your choice of titres.

[2 marks]

Calculation

Mean titre = _____cm^3

Justification _____

_____

0 2 . **4** The pH ranges of three indicators are shown in **Table 3**.

Table 3

Indicator	pH range
Bromocresol green	3.8–5.4
Bromothymol blue	6.0–7.6
Thymol blue	8.0–9.6

Select from **Table 3** a suitable indicator for the titration of ethanoic acid with sodium hydroxide.

[1 mark]

_____

0 2 . 5 The uncertainty in the mean titre for this experiment is ±0.15 cm^3.

Calculate the percentage uncertainty in this mean titre.

[1 mark]

Percentage uncertainty = _____ %

0 2 . 6 Suggest how, using the same mass of ethanoic acid, the experiment could be improved to reduce the percentage uncertainty.

[2 marks]

_____

_____

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Turn over for the next question

3   A peptide is hydrolysed to form a solution containing a mixture of amino acids. This mixture is then analysed by silica gel thin-layer chromatography (TLC) using a toxic solvent. The individual amino acids are identified from their R_f values.

Part of the practical procedure is given below.

1. **Wearing plastic gloves to hold a TLC plate**, draw a pencil line 1.5 cm from the bottom of the plate.
2. Use a capillary tube to apply a very small drop of the solution of amino acids to the mid-point of the pencil line.
3. Allow the spot to dry completely.
4. In the developing tank, add the developing solvent to **a depth of not more than 1 cm**.
5. Place your TLC plate in the developing tank.
6. Allow the developing solvent to rise up the plate **to the top**.
7. Remove the plate and quickly mark the position of the solvent front with a pencil.
8. Allow the plate to dry **in a fume cupboard**.

0 3 . 1 Parts of the procedure are in bold text.

For each of these parts, consider whether it is essential and justify your answer.

[4 marks]

0 3 . 2 Outline the steps needed to locate the positions of the amino acids on the TLC plate and to determine their R_f values.

[4 marks]

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0 3 . 3 Explain why different amino acids have different R_f values.

[2 marks]

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_____

4 Ethanedioic acid is a weak acid.
Ethanedioic acid acts, initially, as a monoprotic acid.

$\boxed{0}\ \boxed{4}$. $\boxed{1}$ Use the concept of electronegativity to justify why the acid strengths of ethanedioic acid and ethanoic acid are different.

[6 marks]

| 0 | 4 | . | 2 | A buffer solution is made by adding 6.00×10^{-2} mol of sodium hydroxide to a solution containing 1.00×10^{-1} mol of ethanedioic acid ($H_2C_2O_4$).

Assume that the sodium hydroxide reacts as shown in the following equation and that in this buffer solution, the ethanedioic acid behaves as a monoprotic acid.

$$H_2C_2O_4(aq) \ + \ OH^-(aq) \ \longrightarrow \ HC_2O_4^-(aq) + H_2O(l)$$
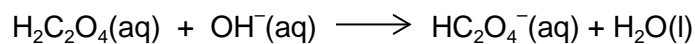
The dissociation constant K_a for ethanedioic acid is 5.89×10^{-2} mol dm^{-3}.

Calculate a value for the pH of the buffer solution.
Give your answer to the appropriate number of significant figures.

[5 marks]

pH = _____

Question 4 continues on the next page

0	4	.	3

In a titration, the end point was reached when 25.0 cm^3 of an acidified solution containing ethanedioic acid reacted with 20.20 cm^3 of 2.00×10^{-2} mol dm^{-3} potassium manganate(VII) solution.

Deduce an equation for the reaction that occurs and use it to calculate the original concentration of the ethanedioic acid solution.

[4 marks]

Equation _____

Calculation

Original concentration = _____ mol dm^{-3}

5 A sample of ethanedioic acid was treated with an excess of an unknown alcohol in the presence of a strong acid catalyst. The products of the reaction were separated and analysed in a time of flight (TOF) mass spectrometer. Two peaks were observed at m/z = 104 and 118.

0 5 . 1 Identify the species responsible for the two peaks.

[2 marks]

0 5 . 2 Outline how the TOF mass spectrometer is able to separate these two species to give two peaks.

[4 marks]

Section B

Answer **all** questions in this section.

Only **one** answer per question is allowed.

For each answer completely fill in the circle alongside the appropriate answer.

CORRECT METHOD ● WRONG METHODS ⊗ ⊙ ⊜ ⌀

If you want to change your answer you must cross out your original answer as shown. ⊠

If you wish to return to an answer previously crossed out, ring the answer you now wish to select as shown. ⊗

| 0 6 | Which change requires the largest amount of energy? |
| | **[1 mark]** |

A $He^+(g) \longrightarrow He^{2+}(g) + e^-$ ⬭

B $Li(g) \longrightarrow Li^+(g) + e^-$ ⬭

C $Mg^+(g) \longrightarrow Mg^{2+}(g) + e^-$ ⬭

D $N(g) \longrightarrow N^+(g) + e^-$ ⬭

| 0 7 | A sample of 2.18 g of oxygen gas has a volume of 1870 cm^3 at a pressure of 101 kPa. |

What is the temperature of the gas?
The gas constant is $R = 8.31$ J K^{-1} mol^{-1}.

[1 mark]

A   167 K   ⬭

B   334 K   ⬭

C   668 K   ⬭

D   334 000 K   ⬭
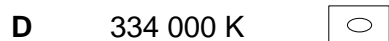
0 8 An ester is hydrolysed as shown by the following equation.

$$RCOOR' + H_2O \longrightarrow RCOOH + R'OH$$
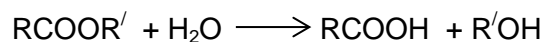
What is the percentage yield of RCOOH when 0.50 g of RCOOH ($M_r = 100$) is obtained from 1.0 g of RCOOR' ($M_r = 150$)?

[1 mark]

A	33%	◯
B	50%	◯
C	67%	◯
D	75%	◯

0 9 A saturated aqueous solution of magnesium hydroxide contains 1.17×10^{-3} g of $Mg(OH)_2$ in 100 cm^3 of solution. In this solution, the magnesium hydroxide is fully dissociated into ions.

What is the concentration of Mg^{2+}(aq) ions in this solution?

[1 mark]

A	2.82×10^{-2} mol dm^{-3}	◯
B	2.01×10^{-3} mol dm^{-3}	◯
C	2.82×10^{-3} mol dm^{-3}	◯
D	2.01×10^{-4} mol dm^{-3}	◯

Turn over for the next question

1 0 The rate equation for the hydrogenation of ethene

$$C_2H_4(g) + H_2(g) \longrightarrow C_2H_6(g)$$
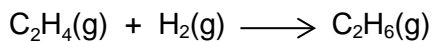
is $Rate = k[C_2H_4][H_2]$

At a fixed temperature, the reaction mixture is compressed to triple the original pressure.

What is the factor by which the rate of reaction changes?

[1 mark]

A   6   ☐

B   9   ☐

C   12   ☐

D   27   ☐

1 1 When one mole of ammonia is heated to a given temperature, 50% of the compound dissociates and the following equilibrium is established.

$$NH_3(g) \rightleftharpoons \tfrac{1}{2}N_2(g) + \tfrac{3}{2}H_2(g)$$
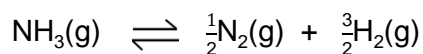
What is the total number of moles of gas present in this equilibrium mixture?

[1 mark]

A   1.5   ☐

B   2.0   ☐

C   2.5   ☐

D   3.0   ☐

1 2 Which change would alter the value of the equilibrium constant (K_p) for this reaction?

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$
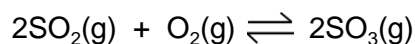
[1 mark]

A   Increasing the total pressure of the system.   ☐

B   Increasing the concentration of sulfur trioxide.   ☐

C   Increasing the concentration of sulfur dioxide.   ☐

D   Increasing the temperature.   ☐

1	3

What is the pH of a 0.020 mol dm^{-3} solution of a diprotic acid which is completely dissociated?

[1 mark]

A   1.00   ⬭

B   1.40   ⬭

C   1.70   ⬭

D   4.00   ⬭

1	4

The acid dissociation constant, K_a, of a weak acid HA has the value
2.56×10^{-4} mol dm^{-3}

What is the pH of a 4.25×10^{-3} mol dm^{-3} solution of HA?

[1 mark]

A   5.96   ⬭

B   3.59   ⬭

C   2.98   ⬭

D   2.37   ⬭

1	5

Magnesium reacts with hydrochloric acid according to the following equation.

$$Mg + 2HCl \longrightarrow MgCl_2 + H_2$$
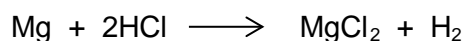
A student calculated the minimum volume of 2.56 mol dm^{-3} hydrochloric acid required to react with an excess of magnesium to form 5.46 g of magnesium chloride ($M_r = 95.3$).

Which of the following uses the correct standard form and the appropriate number of significant figures to give the correct result of the calculation?

[1 mark]

A 4.476×10^{-2} dm^3 ⬭

B 4.48×10^{-2} dm^3 ⬭

C 4.50×10^{-2} dm^3 ⬭

D 44.8×10^{-3} dm^3 ⬭

1	6

In which reaction is hydrogen acting as an oxidising agent?

[1 mark]

A $Cl_2 + H_2 \longrightarrow 2HCl$ ⬭

B $(CH_3)_2CO + H_2 \longrightarrow (CH_3)_2CHOH$ ⬭

C $N_2 + 3H_2 \longrightarrow 2NH_3$ ⬭
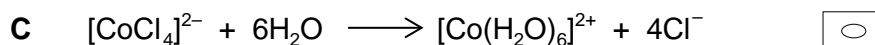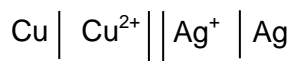
D $2Na + H_2 \longrightarrow 2NaH$ ⬭
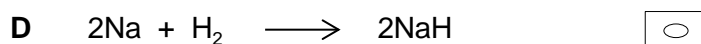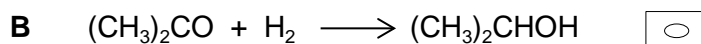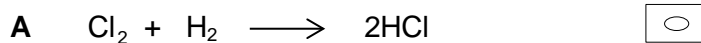
1	7

In which reaction is the metal oxidised?

[1 mark]

A $2Cu^{2+} + 4I^- \longrightarrow 2CuI + I_2$ ⬭

B $[Fe(H_2O)_6]^{3+} + Cl^- \longrightarrow [Fe(H_2O)_5(Cl)]^{2+} + H_2O$ ⬭

C $[CoCl_4]^{2-} + 6H_2O \longrightarrow [Co(H_2O)_6]^{2+} + 4Cl^-$ ⬭

D $Mg + S \longrightarrow MgS$ ⬭
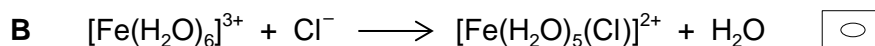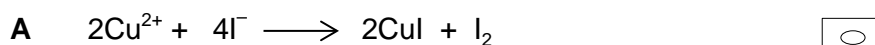
1	8

The following cell has an EMF of +0.46 V.

$$Cu \mid Cu^{2+} \mid\mid Ag^+ \mid Ag$$

Which statement is correct about the operation of the cell?

[1 mark]

**A**   Metallic copper is oxidised by Ag^+ ions.   ⬭

B   The silver electrode has a negative polarity.   ⬭

C   The silver electrode gradually dissolves to form Ag^+ ions.   ⬭

D   Electrons flow from the silver electrode to the copper electrode   ⬭
via an external circuit.

1 9 In an experiment to identify a Group 2 metal (X), 0.102 g of X reacts with an excess of aqueous hydrochloric acid according to the following equation.

$$X + 2HCl \longrightarrow XCl_2 + H_2$$
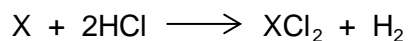
The volume of hydrogen gas given off is 65 cm³ at 99 kPa pressure and 303 K. The gas constant is $R = 8.31$ J K^{-1} mol^{-1}.

Which is X?

[1 mark]

A   Barium   ⬯

B   Calcium   ⬯

C   Magnesium   ⬯

D   Strontium   ⬯

2 0 What forms when a solution of sodium carbonate is added to a solution of gallium(III) nitrate?

[1 mark]

A   A white precipitate of gallium(III) carbonate.   ⬯

B   A white precipitate of gallium(III) hydroxide.   ⬯

C   A white precipitate of gallium(III) carbonate and bubbles of carbon dioxide.   ⬯

D   A white precipitate of gallium(III) hydroxide and bubbles of carbon dioxide.   ⬯

2 1 Which compound gives a colourless solution when an excess of dilute aqueous ammonia is added?

[1 mark]

A $MgCl_2$ ⬯

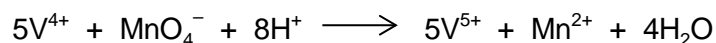**B**   AgCl   ⬯

C $CuCl_2$ ⬯

D $AlCl_3$ ⬯

2 2 What is the final species produced when an excess of aqueous ammonia is added to aqueous aluminium chloride?

[1 mark]

A $[Al(NH_3)_6]^{3+}$ ▢

B $[Al(OH)_3(H_2O)_3]$ ▢

C $[Al(OH)_4(H_2O)_2]^-$ ▢

D $[Al(OH)(H_2O)_5]^{2+}$ ▢

2 3 The following equation represents the oxidation of vanadium(IV) ions by manganate(VII) ions in acid solution.

$$5V^{4+} + MnO_4^- + 8H^+ \longrightarrow 5V^{5+} + Mn^{2+} + 4H_2O$$

What volume of 0.020 mol dm^{-3} KMnO$_4$ solution is required to oxidise completely a solution containing 0.010 mol of vanadium(IV) ions?

[1 mark]

A 10 cm^3 ▢

B 25 cm^3 ▢

C 50 cm^3 ▢

D 100 cm^3 ▢

2 4 How many isomers have the molecular formula C_5H_{12}?

[1 mark]

A 2 ▢

B 3 ▢

C 4 ▢

D 5 ▢

2 5 Which molecule is **not** produced when ethane reacts with bromine in the presence of ultraviolet light?

[1 mark]

A $C_2H_4Br_2$ ⬭

B HBr ⬭

C H_2 ⬭

D C_4H_{10} ⬭

2 6 How many structural isomers have the molecular formula C_4H_9Br?

[1 mark]

A 2 ⬭

B 3 ⬭

C 4 ⬭

D 5 ⬭

2 7 What is the major product of the reaction between but-1-ene and DBr?
(D is deuterium and represents ^2H)

[1 mark]

A $CH_2DCH_2CH_2CH_2Br$ ⬭

B $CH_2DCH_2CHBrCH_3$ ⬭

C $CH_3CH_2CHBrCH_2D$ ⬭

D $CH_3CH_2CHDCH_2Br$ ⬭

2 8 Why are fluoroalkanes unreactive?

[1 mark]

A Fluorine is highly electronegative. ⬭

B The F^- ion is very stable. ⬭

C They are polar molecules. ⬭

D The C–F bond is very strong. ⬭

2 9   Which alcohol could **not** be produced by the reduction of an aldehyde or a ketone?

[1 mark]

    A   2-methylbutan-1-ol   ⬭

    B   2-methylbutan-2-ol   ⬭

    C   3-methylbutan-1-ol   ⬭

    D   3-methylbutan-2-ol   ⬭

3 0   Which compound forms optically active compounds on reduction?

[1 mark]

    A $CH_3CH_2C(CH_3)=CHCH_3$ ⬭

    B $CH_3CH_2C(CH_3)=CH_2$ ⬭

    C CH_3COCH_3 ⬭

    D $CH_3CH_2COCH_3$ ⬭

3 1   How many secondary amines have the molecular formula $C_4H_{11}N$?

[1 mark]

    A   2   ⬭

    B   3   ⬭

    C   4   ⬭

    D   5   ⬭

3 2   Which compound has the highest boiling point?

[1 mark]

    A C_2H_4 ⬭

    B C_2H_6 ⬭

    C CH_3NH_2 ⬭

    D CH_3F ⬭

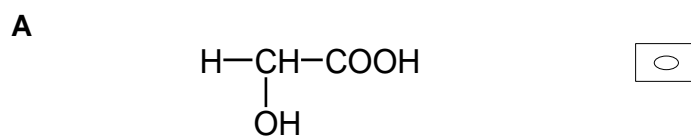**3 3**   Which compound can polymerise by reaction with itself?

[1 mark]

A $NH_2CH_2CH_2NH_2$ ⬭

B $CH_3CH_2CONH_2$ ⬭

C $HOOCCH_2COOH$ ⬭

D NH_2CH_2COCl ⬭

3 4   A drug is designed to simulate one of the following molecules that adsorbs onto the active site of an enzyme.

Which molecule requires the design of an optically active drug?

[1 mark]

A

$$H-\underset{\underset{OH}{|}}{CH}-COOH$$ ⬭

B

$$CH_3-\underset{\underset{O}{\|}}{C}-COOH$$ ⬭

C

$$CH_3-\underset{\underset{OH}{|}}{CH}-COOH$$ ⬭

D

$$\underset{\underset{OH}{|}}{CH_2}-CH_2-COOH$$ ⬭

Turn over for the next question

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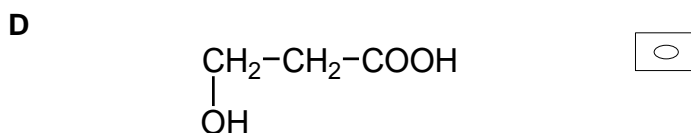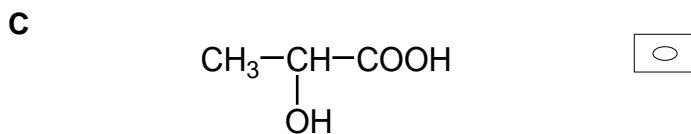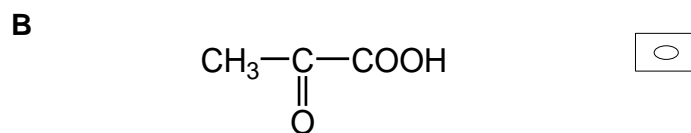
3 5   Which amine has only **three** peaks in its proton NMR spectrum?

[1 mark]

    A   Methylamine   ⬭

    B   Trimethylamine   ⬭

    C   Diethylamine   ⬭

    D   Propylamine   ⬭

END OF QUESTIONS