

Please write clearly in block capitals.

Centre number

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Candidate number

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Surname StemUp Model Solution

Forename(s) _____

Candidate signature _____

I declare this is my own work.

INTERNATIONAL A-LEVEL CHEMISTRY (9620)

Unit 5 Practical and synoptic

Thursday 23 January 2020 07:00 GMT Time allowed: 1 hour 25 minutes

Materials

For this paper you must have:

- the Periodic Table/Data Sheet, provided as an insert
- a ruler with millimetre measurements
- a scientific calculator, which you are expected to use where appropriate.

Instructions

- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Do not write outside the box around each page or on blank pages.
- If you need extra space for your answer(s), use the lined pages at the end of this book. Write the question number against your answer(s).
- All working must be shown.
- Do all rough work in this book. Cross through any work you do not want to be marked.

Information

- The marks for questions are shown in brackets.
- The maximum mark for this paper is 60.

For Examiner's Use	
Question	Mark
1	
2	
3	
4–33	
TOTAL	



Section A

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

0 1

This question is about experiments to measure the standard electrode potential for the half-reaction

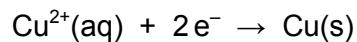
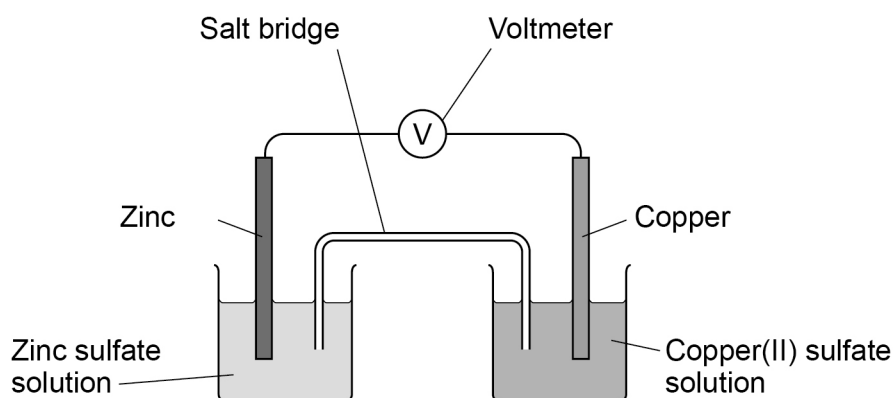


Figure 1 shows a diagram of the apparatus used.

Figure 1



0 1 . 1

Before use the metals are cleaned with sandpaper and washed with propanone.

Suggest what is removed by the sandpaper.

Suggest what is removed by the propanone.

[2 marks]

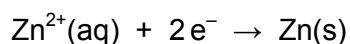
Sandpaper the oxide layer on the metal surface

Propanone grease or oil (dirt) on the metal surface



0 1 . 2 When the apparatus is assembled as in **Figure 1**, the voltmeter reading is 1.05 V

The standard electrode potential is -0.76 V for the half-reaction



Use these data to calculate the electrode potential of this Cu^{2+}/Cu half cell.

[1 mark]

$$EMF = E_{\text{right}} - E_{\text{left}}$$

$$1.05 = E(\text{Cu}^{2+}/\text{Cu}) - (-0.76)$$

$$E(\text{Cu}^{2+}/\text{Cu}) = 1.05 - 0.76 = +0.29\text{ V}$$

+0.29

V

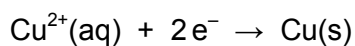
Question 1 continues on the next page

Turn over ►



0 1 . 3

A teacher demonstrates how to measure the standard electrode potential for the half-reaction

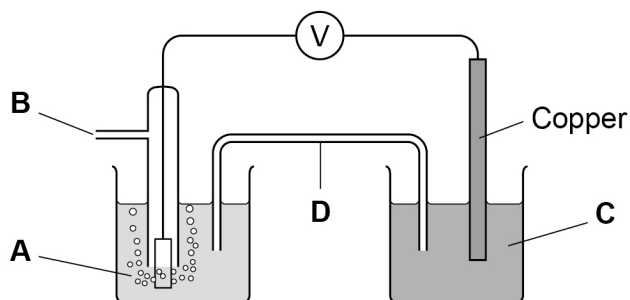


using a standard hydrogen electrode.

Some of the apparatus is shown in **Figure 2**.

[4 marks]

Figure 2



Complete the table to identify the substances **A**, **B**, **C** and **D** in **Figure 2** and their conditions.

	Substance	Condition
A	<i>hydrochloric acid</i>	<i>1.00 mol dm⁻³ H⁺, 298 K</i>
B	<i>hydrogen gas</i>	<i>100 kPa, 298 K</i>
C	<i>copper(II) sulfate solution</i>	<i>1.00 mol dm⁻³ Cu²⁺, 298 K</i>
D	<i>potassium chloride solution</i>	



Table 1 shows some standard electrode potential data.

Table 1

Electrode half-equation	E°/V
$\text{Zn}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Zn}(\text{s})$	-0.76
$\text{Co}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Co}(\text{s})$	-0.28
$\frac{1}{2}\text{O}_2(\text{g}) + 2\text{H}^+(\text{aq}) + 2\text{e}^- \rightarrow \text{H}_2\text{O}(\text{l})$	+1.23
$\text{Au}^+(\text{aq}) + \text{e}^- \rightarrow \text{Au}(\text{s})$	+1.68
$\text{Co}^{3+}(\text{aq}) + \text{e}^- \rightarrow \text{Co}^{2+}(\text{aq})$	+1.82

0 1 . 4 Identify the strongest reducing agent in **Table 1**.

[1 mark]

zinc (Zn)

0 1 . 5 A cell is set up under standard conditions with gold and zinc as the electrodes.

Use the data in **Table 1** to calculate the EMF of the cell.

[1 mark]

$$\begin{aligned} \text{EMF} &= E_{\text{Au}} - E_{\text{Zn}} = +1.68 - (-0.76) \\ &= 2.44 \text{ V} \end{aligned}$$

2.44 V

0 1 . 6 Use the data in **Table 1** to explain why gold does not react with moist air.

[1 mark]

$E^\circ(\text{Au}^+/\text{Au}) = +1.68 \text{ V}$ is more positive than $E^\circ(\text{O}_2/\text{H}_2\text{O}) = +1.23 \text{ V}$, so O_2 cannot oxidise Au: $\text{EMF} = 1.23 - 1.68 = -0.45 \text{ V} < 0$, so the reaction is not feasible.

Question 1 continues on the next page

Turn over ►



0 1 . 7

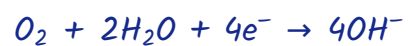
An alkaline hydrogen fuel cell has an EMF of +1.23 V

The cell can be represented by



Write a half-equation for the reaction that occurs at the positive electrode.

[1 mark]



11



0 2

This question is about an experiment to determine a value for the acid dissociation constant (K_a) of a weak acid.

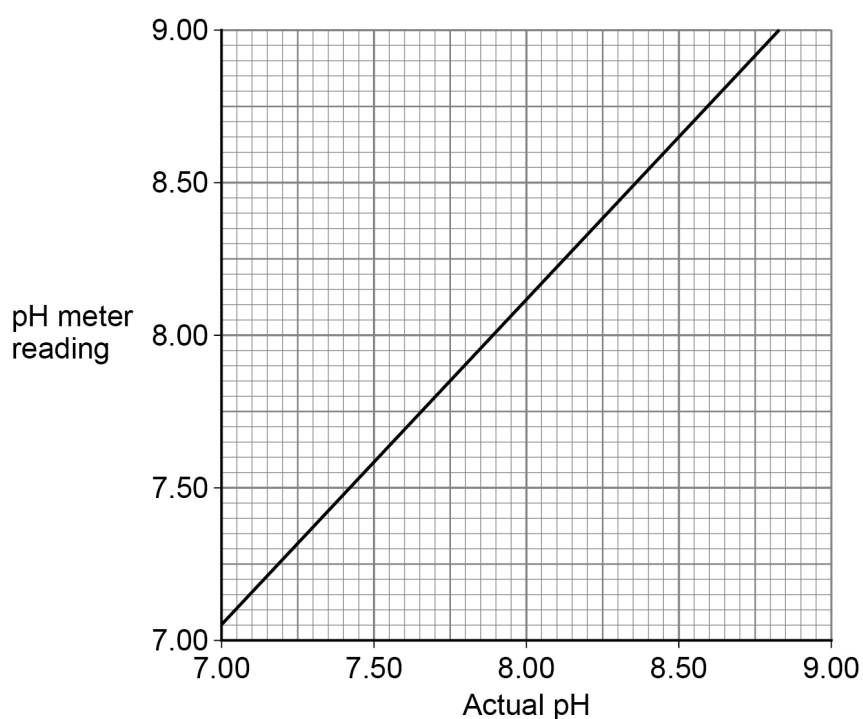
A pH meter is used to measure the pH in a titration between aqueous sodium hydroxide and aqueous chloroethanoic acid, CH_2ClCOOH

The pH meter is calibrated before use.

The probe is placed in three different buffer solutions and the meter readings recorded.

Figure 3 shows part of the calibration graph.

Figure 3



0 2 . 1

Use **Figure 3** to deduce the actual pH of the solution when the meter reading is 8.50
[1 mark]

8.35

Question 2 continues on the next page

Turn over ►



0 2 . 2

During calibration the probe is washed with deionised water between each pH measurement.

During the titration the probe is **not** washed.

Explain why this shows good practical technique.

[2 marks]

Washing during calibration removes the previous buffer solution so it does not contaminate the next buffer and change its pH.

No washing during titration washing would dilute the solution or add water to it, which would affect the pH (and successive values).

In the titration, aqueous sodium hydroxide is added from a burette to 25.00 cm³ of 0.100 mol dm⁻³ aqueous chloroethanoic acid, CH₂ClCOOH

After 20.00 cm³ of 0.0500 mol dm⁻³ sodium hydroxide are added, the actual pH is 2.68

The temperature is kept at 25 °C throughout the titration.

0 2 . 3

Calculate the amount, in mol, of chloroethanoic acid at the start of the titration.

Deduce the amount, in mol, of the unreacted acid and of the chloroethanoate ions in the solution after 20.00 cm³ of sodium hydroxide are added.

[3 marks]

(working out space)

$$n(\text{acid}) \text{ at start} = 25.00 \div 1000 \times 0.100 = 2.50 \times 10^{-3} \text{ mol}$$

$$n(\text{NaOH}) \text{ added} = 20.00 \div 1000 \times 0.0500 = 1.00 \times 10^{-3} \text{ mol}$$



$$\text{unreacted acid} = 2.50 \times 10^{-3} - 1.00 \times 10^{-3} = 1.50 \times 10^{-3} \text{ mol}$$

$$\text{chloroethanoate ions} = n(\text{NaOH}) = 1.00 \times 10^{-3} \text{ mol}$$

Amount of chloroethanoic acid at the start 2.50 × 10⁻³ mol

Amount of unreacted chloroethanoic acid 1.50 × 10⁻³ mol

Amount of chloroethanoate ions 1.00 × 10⁻³ mol



0 2 . 4

Calculate the concentration, in mol dm^{-3} , of hydrogen ions in the solution when the $\text{pH} = 2.68$

[1 mark]

$$[H^+] = 10^{-\text{pH}} = 10^{-2.68}$$

$$= 2.09 \times 10^{-3} \text{ mol dm}^{-3}$$

Concentration 2.09×10^{-3} mol dm^{-3}

0 2 . 5

Give the expression for the acid dissociation constant (K_a) of aqueous chloroethanoic acid, CH_2ClCOOH

Use this expression, and your answers to **Question 02.3** and **Question 02.4**, to calculate a value for K_a

(If you were unable to answer **Questions 02.3** and **Question 02.4**, you should use these values.

Amount of chloroethanoic acid = $1.20 \times 10^{-3} \text{ mol}$

Amount of chloroethanoate ion = $9.00 \times 10^{-4} \text{ mol}$

Concentration of hydrogen ions = $2.36 \times 10^{-3} \text{ mol dm}^{-3}$

These are not the correct values.)

[2 marks]

$$K_a = [H^+][\text{CH}_2\text{ClCOO}^-] \div [\text{CH}_2\text{ClCOOH}]$$

$$K_a = 2.09 \times 10^{-3} \times (1.00 \times 10^{-3} \div 1.50 \times 10^{-3})$$

$$= 1.39 \times 10^{-3} \text{ mol dm}^{-3}$$

(same total volume, so the ratio of moles can be used)

K_a 1.39×10^{-3} mol dm^{-3}

9

Turn over ►



0 3

This question is about test-tube reactions used to distinguish between organic compounds.

0 3 . 1

Give a reagent, or combination of reagents, that could be used to distinguish between compounds **A** and **B** by a simple test-tube reaction.

State what is observed in each case.

A $(\text{CH}_3)_3\text{COH}$

B $\text{CH}_3\text{CH}_2\text{COOH}$

[3 marks]

Reagent(s) sodium carbonate solution (Na_2CO_3)

Observation(s) for **A** no visible change

Observation(s) for **B** effervescence (bubbles of colourless gas, CO_2)

0 3 . 2

Give a reagent, or combination of reagents, that could be used to distinguish between compounds **A** and **C** by a simple test-tube reaction.

State what is observed in each case.

A $(\text{CH}_3)_3\text{COH}$

C $(\text{CH}_3)_2\text{CHCH}_2\text{OH}$

[3 marks]

Reagent(s) acidified potassium dichromate(VI), warm

Observation(s) for **A** no visible change (stays orange)

Observation(s) for **C** orange solution turns green

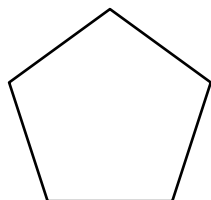


0 3 . 3

Give a reagent or combination of reagents that could be used to distinguish between compounds **D** and **E** by a simple test-tube reaction.

State what is observed in each case.

Explain why it is important to avoid an excess of your chosen reagent.

**D****E****[4 marks]**

Reagent(s) bromine water ($\text{Br}_2(\text{aq})$)

Observation(s) for **D** no visible change (stays orange)

Observation(s) for **E** orange bromine water is decolourised (orange to colourless)

Explanation Only add a few drops: excess bromine could not all react with E, so the orange colour would remain and the decolourisation would not be seen.

10

Turn over for the next question

Turn over ►



There are no questions printed on this page

*Do not write
outside the
box*

**DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED**



Section B

Each question is followed by four responses, **A**, **B**, **C** and **D**.

For each question select the best response.

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.

You may do your working in the blank space around each question but this will not be marked.

0 4

Successive ionisation energies of four elements in Period 3 are shown.

	Ionisation energy / kJ mol ⁻¹				
	1st	2nd	3rd	4th	5th
A	1260	2300	3850	5150	6540
B	736	1450	7740	10 500	13 600
C	494	4560	6940	9540	13 400
D	577	1820	2740	11 600	14 800

Which row of data could represent magnesium?

[1 mark]

A ☐

B ☒

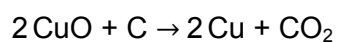
C ☐

D ☐

Turn over ►



0 5 What is the percentage atom economy for the formation of copper in this reaction?



[1 mark]

A 25.7%

☐

B 37.1%

☐

C 69.3%

☐

D 74.3%

☒

0 6 What mass, in g, of iron(II) chloride is needed to make 200 cm³ of a 0.0160 mol dm⁻³ solution?

[1 mark]

A 0.192

☐

B 0.406

☒

C 0.507

☐

D 0.519

☐

0 7

The heat change caused by dissolving compound **Z** in water is determined.

These measurements are made during the experiment.

mass of **Z** = 1.65 g

volume of solution formed = 40.0 cm³

initial temperature of water = 19.3 °C

final temperature of solution = 23.2 °C

The specific heat capacity of the solution = 4.18 J K⁻¹ g⁻¹

You should assume that the density of the solution is 1.00 g cm⁻³

How is the heat change, in joules, calculated for this process?

[1 mark]

A $40.0 \times 4.18 \times (23.2 - 19.3)$

☒

B $\frac{40.0 \times 4.18 \times (23.2 - 19.3)}{1000}$

☐

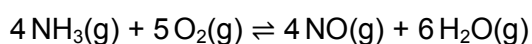
C $1.65 \times 4.18 \times (23.2 - 19.3)$

☐

D $\frac{1.65 \times 4.18 \times (23.2 - 19.3)}{1000}$

☐**0 8**

Which conditions will give the greatest equilibrium yield of nitrogen monoxide gas in this reaction?



$$\Delta H = -905 \text{ kJ mol}^{-1}$$

[1 mark]

A High pressure and high temperature

☐

B High pressure and low temperature

☐

C Low pressure and high temperature

☐

D Low pressure and low temperature

☒

Turn over for the next question

Turn over ►



0 9

The rate of a reaction approximately doubles when it is heated from 293 K to 303 K

Which statement is **incorrect**?

[1 mark]

A The molecules move around more quickly at 303 K than at 293 K

☐

B The molecules collide more frequently at 303 K than at 293 K

☐

C The molecules have more activation energy at 303 K than at 293 K

☒

D The molecules have greater energies at 303 K than at 293 K

☐

1 0

Substance **P** reacts with substance **Q** to form products.

The table shows the initial rate of reaction with different initial concentrations of **P** and **Q**.

Initial [P] / mol dm ⁻³	Initial [Q] / mol dm ⁻³	Initial rate / mol dm ⁻³ s ⁻¹
2.0×10^{-2}	2.0×10^{-3}	1.0×10^{-4}
4.0×10^{-2}	2.0×10^{-3}	2.0×10^{-4}
4.0×10^{-2}	4.0×10^{-3}	8.0×10^{-4}

What is the rate equation for this reaction?

[1 mark]

A $rate = k[P][Q]$

☐

B $rate = k[P]^2[Q]$

☐

C $rate = k[P][Q]^2$

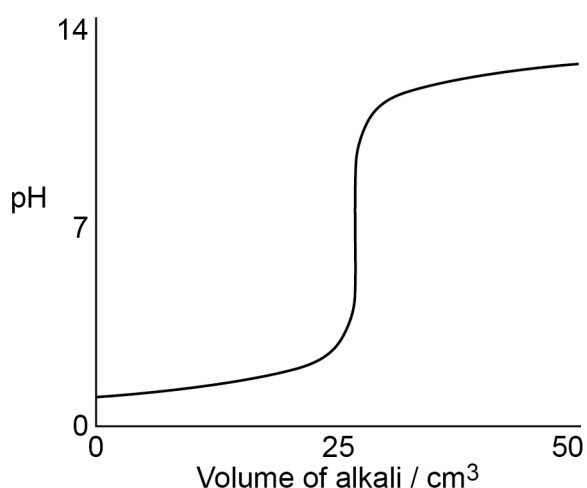
☒

D $rate = k[P]^2[Q]^2$

☐


1 1

Which acid and alkali could have produced this curve in a titration experiment?

**[1 mark]**

	Acid	Alkali	
A	CH ₃ COOH	NH ₄ OH	☐
B	CH ₃ COOH	KOH	☐
C	HNO ₃	NH ₄ OH	☐
D	HNO ₃	KOH	☒

1 2

Which pair of compounds, when mixed together in aqueous solution, would form an alkaline buffer solution?

[1 mark]

- A** NH₃ and NaCl ☐
- B** NH₃ and NH₄Cl ☒
- C** NH₃ and CH₃COONa ☐
- D** NH₃ and NaOH ☐

Turn over ►

1 3

Which of these pairs of substances does **not** give a white precipitate when mixed together?

[1 mark]**A** $\text{MgCl}_2(\text{aq})$ and $\text{Ba}(\text{OH})_2(\text{aq})$ ☐**B** $\text{MgSO}_4(\text{aq})$ and $\text{Ba}(\text{OH})_2(\text{aq})$ ☐**C** $\text{NaOH}(\text{aq})$ and $\text{BaCl}_2(\text{aq})$ ☒**D** $\text{Na}_2\text{SO}_4(\text{aq})$ and $\text{BaCl}_2(\text{aq})$ ☐**1 4**

When dilute sulfuric acid is added to a solution of a sodium compound, effervescence is seen.

Which anion is present?

[1 mark]**A** Cl^- ☐**B** CO_3^{2-} ☒**C** F^- ☐**D** NO_3^- ☐**1 5**

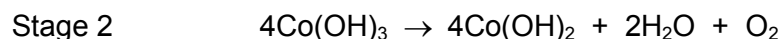
0.1 moles of some Period 3 oxides are added to 1 dm^3 of water.

Which statement is correct?

[1 mark]**A** Sodium oxide dissolves in water to form a solution that has a $\text{pH} < 10$ ☐**B** Aluminium oxide dissolves in water to form a solution that has a $\text{pH} < 4$ ☐**C** Phosphorus(V) oxide dissolves in water to form a solution that has a $\text{pH} < 1$ ☒**D** Sulfur dioxide dissolves in water to form a solution that has a $\text{pH} < 1$ ☐

1 6

The catalytic decomposition of ClO^- ions in aqueous solution occurs in two stages.



Which change in oxidation state occurs in these reactions?

[1 mark]

A Chlorine from 0 to -1 in Stage 1

☐

B Cobalt from $+3$ to $+2$ in Stage 1

☐

C Hydrogen from $+3$ to $+2$ in Stage 2

☐

D Oxygen from -2 to 0 in Stage 2

☒**1 7**

A blue solution contains the complex ion $[\text{Cu}(\text{H}_2\text{O})_6]^{2+}$

Which statement is correct about this solution?

[1 mark]

A When ammonia solution is added, a dark blue precipitate forms.

☐

B When a few drops of sodium hydroxide are added, a blue precipitate forms.

☒

C When sodium carbonate solution is added, bubbles of carbon dioxide gas form.

☐

D When hydrochloric acid is added, the solution changes colour as a new octahedral complex forms.

☐**1 8**

Which of the following will **not** produce a racemic mixture when reacted with KCN followed by dilute acid?

[1 mark]

A CH_3CHO

☐

B $\text{CH}_3\text{CH}_2\text{CHO}$

☐

C $\text{CH}_3\text{COCH}_2\text{CH}_3$

☐

D $\text{CH}_3\text{CH}_2\text{COCH}_2\text{CH}_3$

☒

Turn over ►

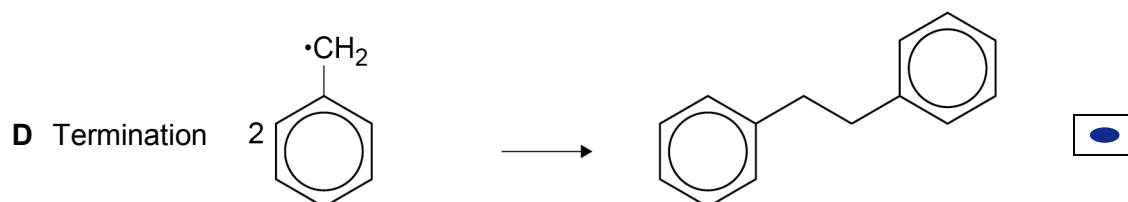
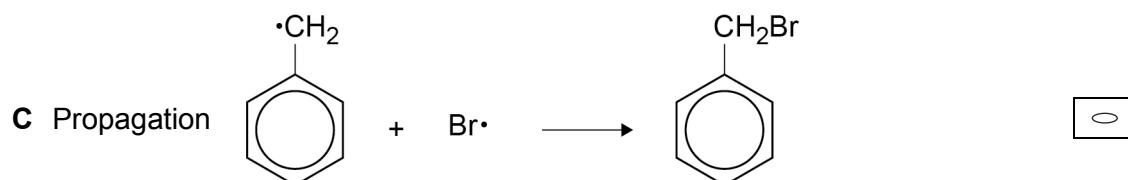
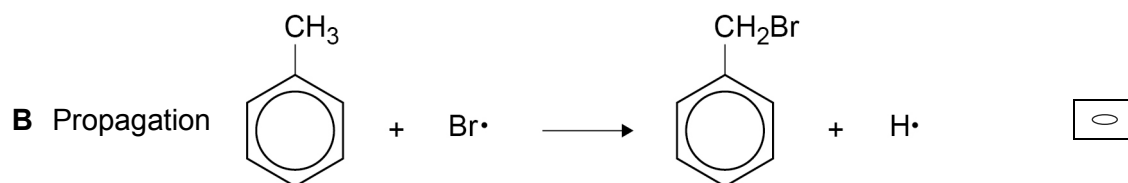
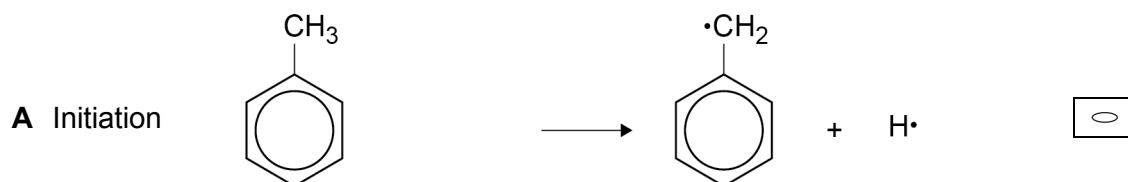


1 9

Methylbenzene reacts with bromine in a free-radical substitution reaction when exposed to UV light.

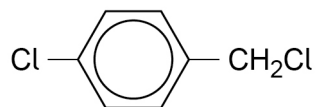
The mechanism of the reaction is similar to the reaction of methane with chlorine.

Which step occurs in the reaction **and** is correctly named?

[1 mark]

2 0

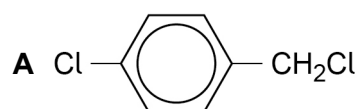
The structure of 1-chloro-4-(chloromethyl)benzene, **N**, is

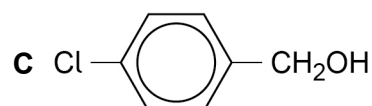


N is warmed with an excess of aqueous sodium hydroxide.

Which organic substance is present in the largest amount once **N** has completely reacted?

[1 mark]


☐

☐

☒

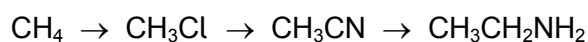
☐

Turn over ►

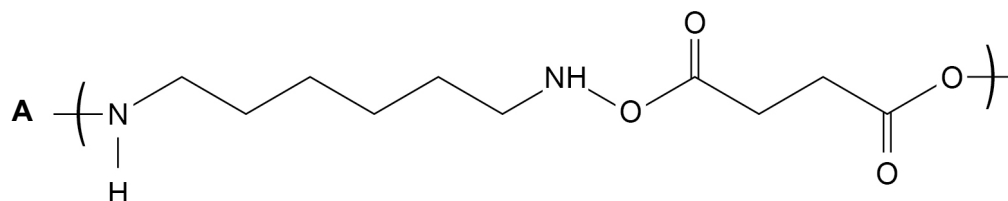
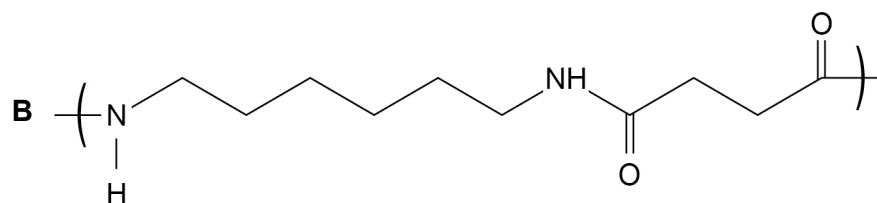
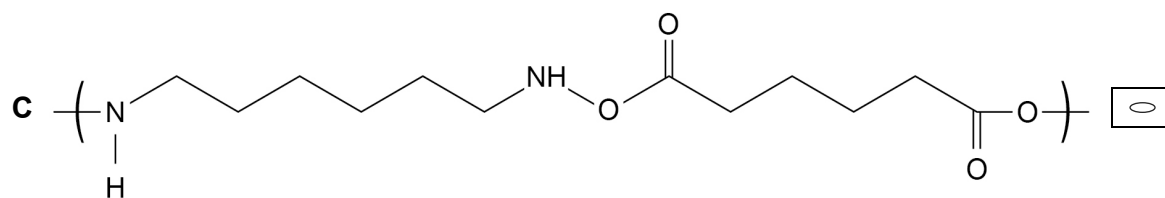
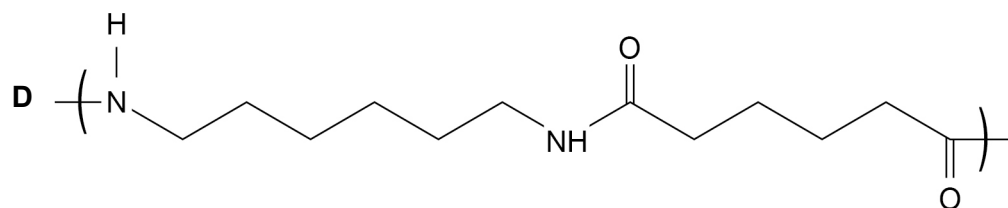


2 1

Methane can be converted into ethylamine in a three-step synthesis.

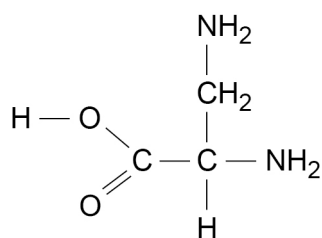
Which reagent and condition are **not** used in this synthesis?**[1 mark]****A** Cl_2 and UV light☐**B** KCN in aqueous alcoholic conditions☐**C** NH_3 in excess☒**D** H_2 with Ni catalyst☐**2 2**

Which shows a correct repeating unit for the polymer formed from 1,6-diaminohexane and butanedioic acid?

[1 mark]☐☒☐☐

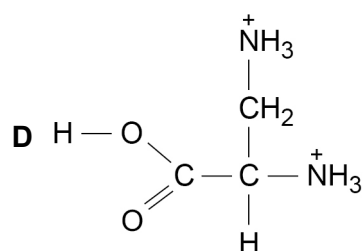
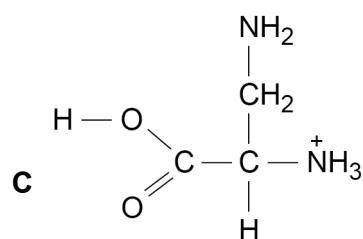
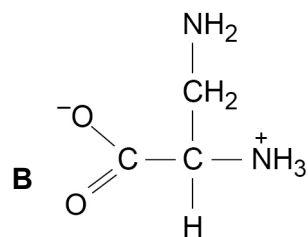
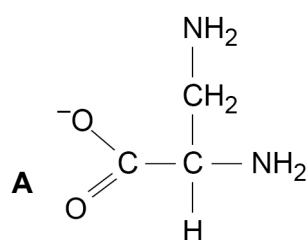
2 3

The structure of an amino acid is shown.



The amino acid is dissolved in a solution with pH = 1

Which species is present at greatest concentration?

[1 mark]**Turn over ►**

2 4

The ^1H NMR spectrum of a compound contains only two peaks. These peaks have an integration trace ratio of 3:2

Which compound would produce this spectrum?

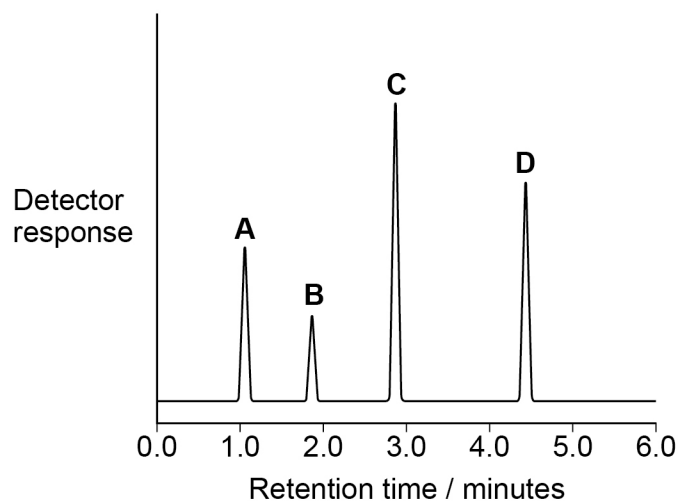
[1 mark]**A** $(\text{CH}_3)_3\text{CCH}_2\text{Cl}$ ☐**B** $\text{CH}_3\text{CH}_2\text{COOCH}_2\text{CH}_3$ ☐**C** $(\text{CH}_3)_2\text{CHCOCH}(\text{CH}_3)_2$ ☐**D** $\text{CH}_3\text{CH}_2\text{COCH}_2\text{CH}_3$ ☒**2 5**

Which compound has a doublet in its ^1H NMR spectrum?

[1 mark]**A** $\text{CH}_3\text{CH}_2\text{COCH}_2\text{CH}_3$ ☐**B** $(\text{CH}_3)_2\text{CHCOCH}(\text{CH}_3)_2$ ☒**C** $(\text{CH}_3)_3\text{CCHO}$ ☐**D** $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH}$ ☐

2 6

A mixture of four compounds **A**, **B**, **C** and **D** was analysed by gas chromatography. The chromatogram is shown.



Which compound has the weakest affinity for the stationary phase?

[1 mark]

- A** ☒
- B** ☐
- C** ☐
- D** ☐

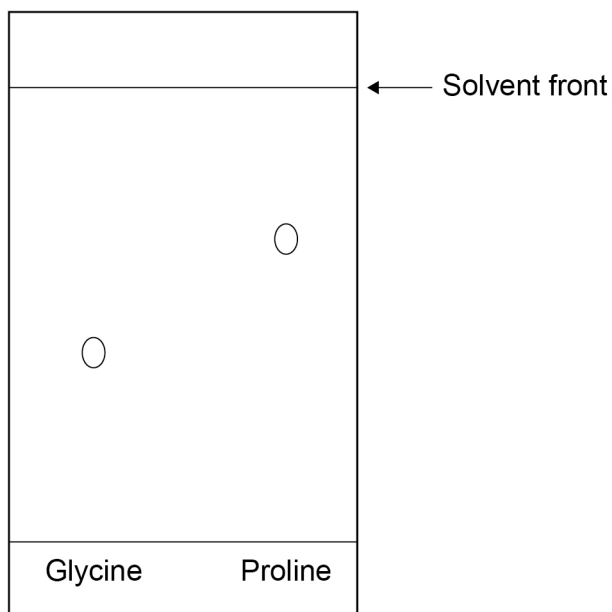
Turn over for the next question

Turn over ►



2 7

Two amino acids were analysed using thin-layer chromatography. The chromatogram obtained is shown.



What is the R_f value for glycine?

[1 mark]

A 0.36
☐
B 0.42
☒
C 0.67
☐
D 2.40
☐
2 8

Which compound does **not** have hydrogen bonding between its molecules?

[1 mark]

A $\text{H}_2\text{O}(\text{l})$
☐
B $\text{CH}_3(\text{CH}_2)_2\text{NH}_2(\text{l})$
☐
C $\text{CH}_3\text{CH}_2\text{CHO}(\text{l})$
☒
D $\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}(\text{l})$
☐


2 9

What are the correct trends in atomic radius and electronegativity down Group 2 from Mg to Ba?

[1 mark]

	Atomic radius	Electronegativity	
A	decrease	decrease	☐
B	decrease	increase	☐
C	increase	decrease	☒
D	increase	increase	☐

3 0

Which alcohol is **not** formed by reducing an aldehyde or a ketone by NaBH_4 in aqueous solution?

[1 mark]

- A** 3-methylbutan-2-ol ☐
- B** 2-methylbutan-1-ol ☐
- C** 2-methylbutan-2-ol ☒
- D** 2,2-dimethylpropan-1-ol ☐

3 1

25.0 cm^3 of a $0.100 \text{ mol dm}^{-3}$ solution of sulfuric acid is titrated with a solution of sodium hydroxide of unknown concentration.

41.65 cm^3 of the sodium hydroxide solution is required to fully neutralise the sulfuric acid.

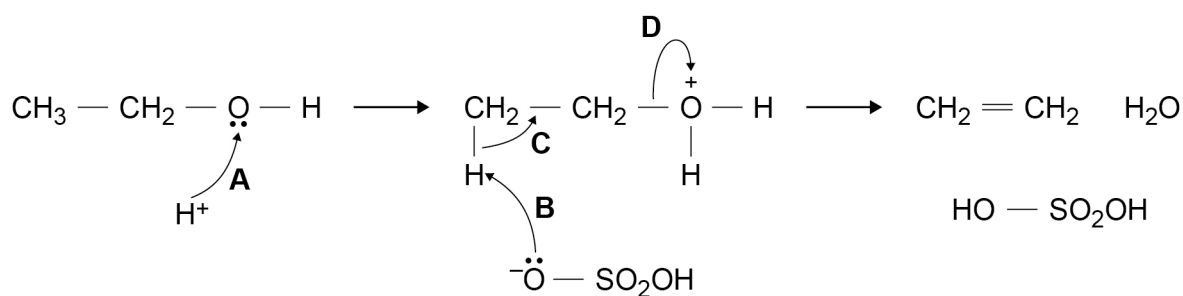
What is the concentration of the sodium hydroxide solution?

[1 mark]

- A** 0.03 mol dm^{-3} ☐
- B** 0.06 mol dm^{-3} ☐
- C** 0.12 mol dm^{-3} ☒
- D** 0.33 mol dm^{-3} ☐

Turn over ►

3 2 Which curly arrow is used **incorrectly** in this mechanism?



[1 mark]

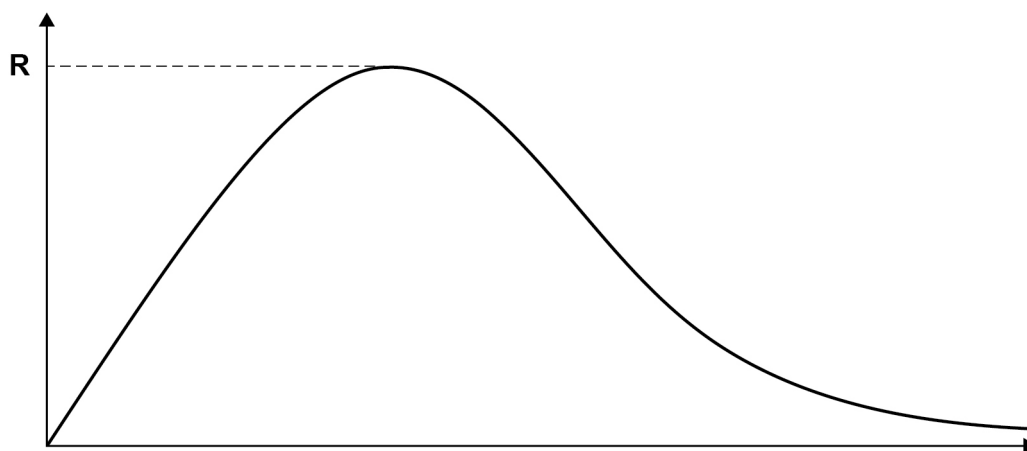
A ☒

B ☐

C ☐

D ☐

3 3 The diagram shows the Maxwell–Boltzmann distribution curve for 1 mol of hydrogen gas at 298 K



Which is the correct statement?

[1 mark]

A The curve for 1 mol of oxygen gas at 298 K is identical. ☒

B The maximum of the curve moves to the left if the pressure is decreased. ☐

C R is the most probable energy of particles. ☐

D Adding a catalyst to the gas moves the maximum of the curve to the right. ☐



END OF QUESTIONS

Turn over ►



There are no questions printed on this page

**DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED**



[illegible]



201XC H05

