

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

A-level CHEMISTRY

Paper 3

Tuesday 27 June 2017

Morning

Time allowed: 2 hours

Materials

For this paper you must have:

- the Periodic Table/Data Booklet, provided as an insert (enclosed)
- a ruler with millimetre measurements
- a 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 the 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.
- 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 90.

Advice

- You are advised to spend about 70 minutes on **Section A** and 50 minutes on **Section B**.

For Examiner's Use	
Question	Mark
1	
2	
3	
4	
Section B	
TOTAL	



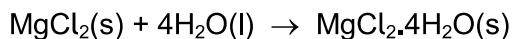
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Section A

Answer **all** questions in the spaces provided

0 1

Anhydrous magnesium chloride, MgCl_2 , can absorb water to form the hydrated salt $\text{MgCl}_2 \cdot 4\text{H}_2\text{O}$



0 1 . 1

Suggest **one** reason why the enthalpy change for this reaction cannot be determined directly by calorimetry.

[1 mark]

It is not possible to stop some of the anhydrous MgCl_2 dissolving in the water instead of just forming the hydrate.

0 1 . 2

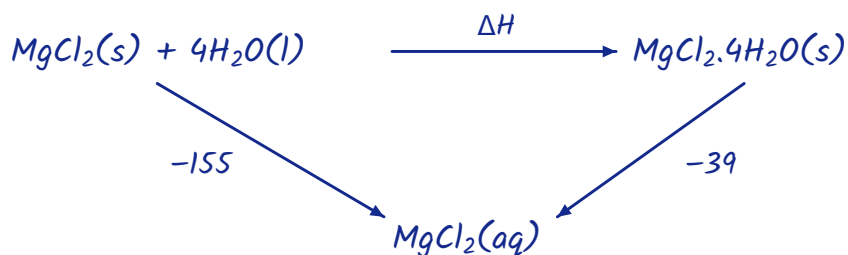
Some enthalpies of solution are shown in **Table 1**.

Table 1

Salt	Enthalpy of solution / kJ mol^{-1}
$\text{MgCl}_2(\text{s})$	-155
$\text{MgCl}_2 \cdot 4\text{H}_2\text{O}(\text{s})$	-39

Calculate the enthalpy change for the absorption of water by $\text{MgCl}_2(\text{s})$ to form $\text{MgCl}_2 \cdot 4\text{H}_2\text{O}(\text{s})$.

[2 marks]



$$\Delta H = -155 - (-39) = -116 \text{ kJ mol}^{-1}$$

Enthalpy change -116 kJ mol^{-1}



0	1	3
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Describe how you would carry out an experiment to determine the enthalpy of solution of anhydrous magnesium chloride.

You should use about 0.8 g of anhydrous magnesium chloride.

Explain how your results could be used to calculate the enthalpy of solution.

[6 marks]

Use a measuring cylinder to put 50 cm³ of water into a polystyrene cup

(insulated container) with a lid, standing in a beaker.

Weigh about 0.8 g of anhydrous MgCl₂ in a weighing bottle and record

the mass.

Record the temperature of the water every minute for 3 minutes (at

least 2 readings).

At 4 minutes add the MgCl₂ and stir. Reweigh the empty weighing

bottle so the mass added is found by difference.

Keep stirring and record the temperature every minute for a further 6

minutes, until a clear cooling trend is seen.

Plot a graph of temperature against time. Extrapolate both lines to the

time of addition (4 minutes) and read off $\Delta T = T_{\text{final}} - T_{\text{initial}}$ at that

time.

Heat released $q = mc\Delta T$, with $m = 50$ g of water and $c = 4.18$ J g⁻¹

K⁻¹.

Amount of MgCl₂ = mass / M_r = 0.80 / 95.3 = 8.39×10^{-3} mol.

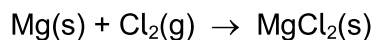
$\Delta H_{\text{soln}} = -q / 8.39 \times 10^{-3}$, divided by 1000 to give kJ mol⁻¹ (negative,

as the temperature rises).



0 1 . 4

Anhydrous magnesium chloride can be formed by direct reaction between its elements.



The free-energy change, ΔG , for this reaction varies with temperature as shown in Table 2.

Table 2

T / K	$\Delta G / \text{kJ mol}^{-1}$
298	-592.5
288	-594.2
273	-596.7
260	-598.8
240	-602.2

Use these data to plot a graph of free-energy change against temperature on the grid opposite.

Calculate the gradient of the line on your graph and hence calculate the entropy change, ΔS , in $\text{J K}^{-1} \text{mol}^{-1}$, for the formation of anhydrous magnesium chloride from its elements.

Show your working.

[5 marks]

From the line: at 250 K, $\Delta G = -600.5$; at 280 K, $\Delta G = -595.5$

Gradient = $\Delta(\Delta G) / \Delta T = (-595.5 - (-600.5)) / (280 - 250)$

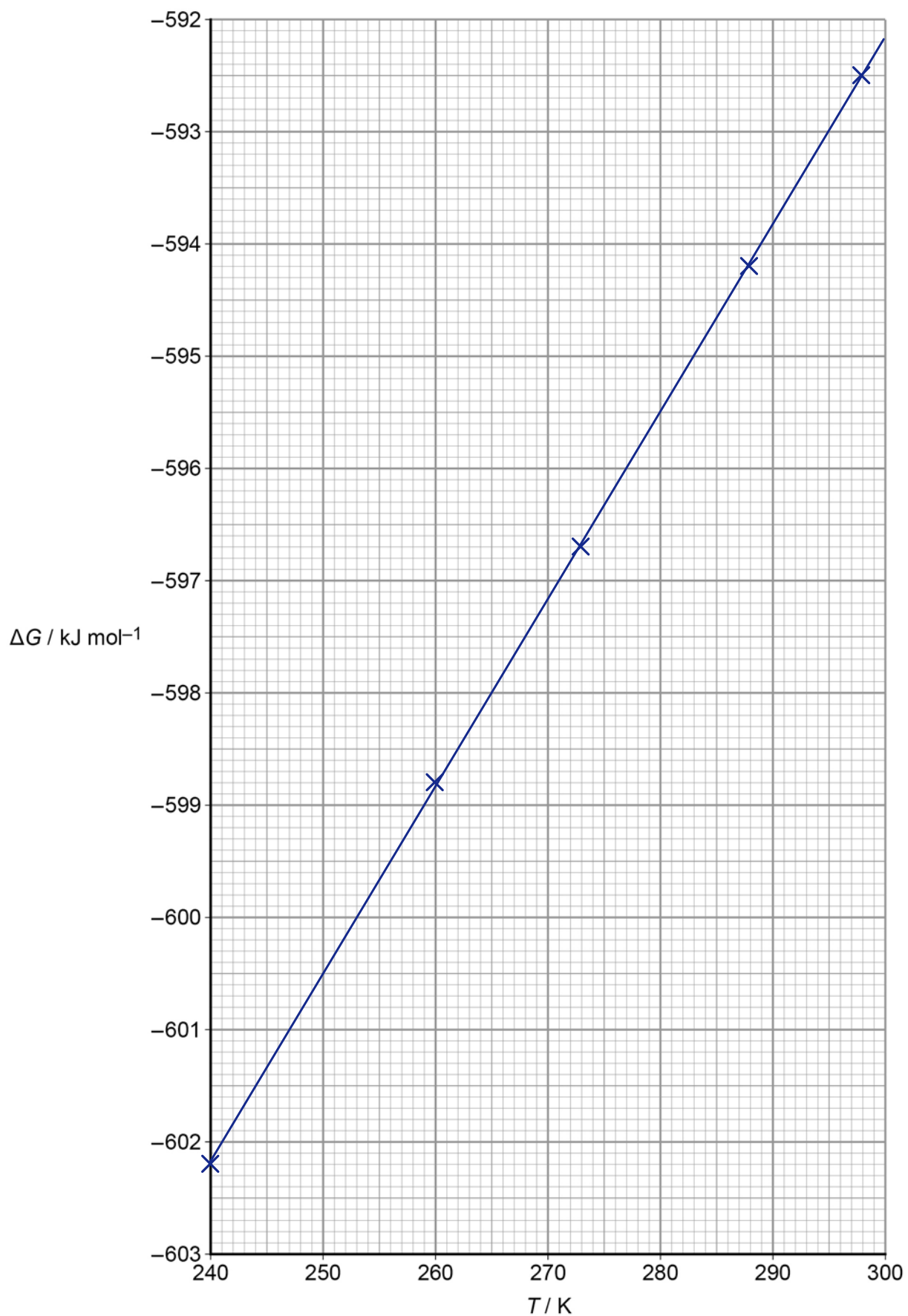
= $5.0 / 30 = 0.167 \text{ kJ K}^{-1} \text{mol}^{-1}$

$\Delta G = \Delta H - T\Delta S$, so gradient = $-\Delta S$

$\Delta S = -0.167 \text{ kJ K}^{-1} \text{mol}^{-1}$

$\Delta S = -0.167 \times 1000 = -167 \text{ J K}^{-1} \text{mol}^{-1}$



 ΔS -167 $\text{J K}^{-1} \text{mol}^{-1}$

14



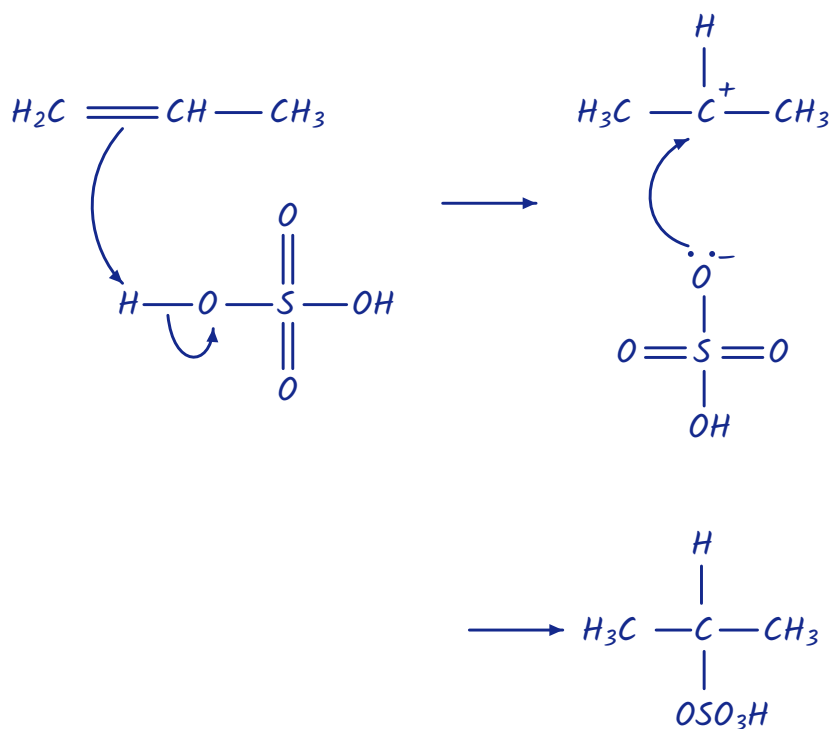
0 5

0 2 Concentrated sulfuric acid reacts with alkenes, alcohols and sodium halides.

0 2 . 1 Name the mechanism for the reaction of concentrated sulfuric acid with an alkene.
[1 mark]

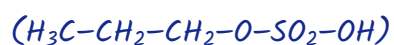
Electrophilic addition

0 2 . 2 Outline the mechanism for the reaction of concentrated sulfuric acid with propene to show the formation of the major product.
[4 marks]



0 2 . 3 Draw the structure of the minor product of the reaction between concentrated sulfuric acid and propene.

[1 mark]



0 2 . 4 Explain why the product shown in your answer to Question 2.2 is the major product. **[2 marks]**

The major product is formed via the more stable carbocation: the secondary carbocation is more stable than the primary carbocation.

This is because of the electron-releasing (positive inductive) effect of the two alkyl (methyl) groups on the positive carbon, compared with only one in the primary carbocation.

0 2 . 5 Butan-2-ol reacts with concentrated sulfuric acid to form a mixture of three isomeric alkenes. Two of the alkenes are stereoisomers.

Draw the skeletal formula of each of the three isomeric alkenes formed by the reaction of butan-2-ol with concentrated sulfuric acid.

Give the full IUPAC name of each isomer.

[3 marks]

Skeletal formula	Name
	<i>but-1-ene</i>
	<i>E-but-2-ene</i>
	<i>Z-but-2-ene</i>



0 2 . 6

A by-product of the reaction of butan-2-ol with concentrated sulfuric acid has the molecular formula C_4H_8O

Name this by-product, identify the role of the sulfuric acid in its formation and suggest the name of a method that could be used to separate the products of this reaction.

[3 marks]

By-product Butanone

Role of sulfuric acid Oxidising agent

Name of separation method

Fractional distillation

0 2 . 7

Concentrated sulfuric acid reacts with solid sodium chloride.

Give the observation you would make in this reaction.
State the role of the sulfuric acid.

[2 marks]

Observation with sodium chloride White misty (steamy) fumes

Role of sulfuric acid Acid (proton donor)

0 2 . 8

Concentrated sulfuric acid reacts with solid sodium iodide, to produce several products.

Observations made during this reaction include the formation of a black solid, a yellow solid and a gas with the smell of bad eggs.

Identify the product responsible for each observation.

[3 marks]

Black solid Iodine, I_2

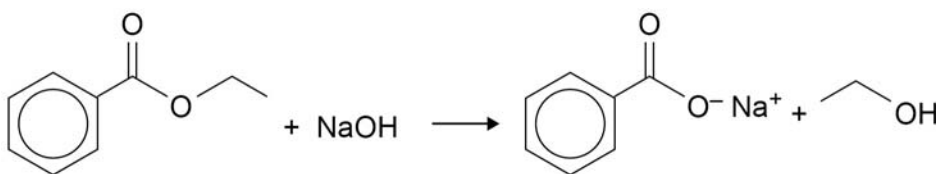
Yellow solid Sulfur, S

Gas Hydrogen sulfide, H_2S



0 3

Benzoic acid can be prepared from ethyl benzoate.
Ethyl benzoate is first hydrolysed in alkaline conditions as shown:



A student used the following method.

Add 5.0 cm³ of ethyl benzoate (density = 1.05 g cm⁻³, M_r = 150) to 30.0 cm³ of aqueous 2 mol dm⁻³ sodium hydroxide in a round-bottomed flask.

Add a few anti-bumping granules and attach a condenser to the flask. Heat the mixture under reflux for half an hour. Allow the mixture to cool to room temperature.

Pour 50.0 cm³ of 2 mol dm⁻³ hydrochloric acid into the cooled mixture.

Filter off the precipitate of benzoic acid under reduced pressure.

0 3 . 1

Suggest how the anti-bumping granules prevent bumping during reflux.

[1 mark]

They provide a large (rough) surface area on which lots of small bubbles form, which prevents very large bubbles forming suddenly.

0 3 . 2

Show, by calculation, that an excess of sodium hydroxide is used in this reaction.

[2 marks]

$$\text{Mass of ester} = 1.05 \times 5.0 = 5.25 \text{ g}$$

$$\text{Amount of ester} = 5.25 / 150 = 0.0350 \text{ mol}$$

$$\text{Amount of NaOH} = 30.0 \times 2 / 1000 = 0.0600 \text{ mol}$$

Ester and NaOH react 1 : 1, so only 0.0350 mol of NaOH is needed.

0.0600 mol > 0.0350 mol, so the NaOH is in excess.

Question 3 continues on the next page



0 3 . 3 Suggest why an excess of sodium hydroxide is used.

[1 mark]

To make sure that all of the ester reacts (is completely hydrolysed).

0 3 . 4 Suggest why an electric heater is used rather than a Bunsen burner in this hydrolysis.

[1 mark]

The ester and ethanol are flammable, so a naked flame could ignite their vapours.

0 3 . 5 State why reflux is used in this hydrolysis.

[1 mark]

Reflux returns the vapours of the volatile reactants to the reaction mixture, so no reactant vapour escapes.

0 3 . 6 Write an equation for the reaction between sodium benzoate and hydrochloric acid.

[1 mark]



0 3 . 7 Suggest why sodium benzoate is soluble in cold water but benzoic acid is insoluble in cold water.

[2 marks]

Sodium benzoate is ionic, so its ions are attracted to (hydrated by) the polar water molecules.

Benzoic acid is insoluble because, despite the polar COOH group (which can hydrogen bond to water), the large benzene ring is non-polar.



0	3	.	8
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After the solid benzoic acid has been filtered off, it can be purified.

Describe the method that the student should use to purify the benzoic acid.

[6 marks]

Dissolve the crude benzoic acid in the minimum volume of hot water

(solvent), to form a saturated solution.

Filter the hot solution to remove insoluble impurities.

*Leave the filtrate to cool (then in ice) so that the benzoic acid
recrystallises; soluble impurities stay in solution.*

*Filter off the crystals under reduced pressure using a Buchner funnel and
flask.*

*Wash the crystals with a little cold water (solvent) and then dry them,
e.g. between filter papers or in a desiccator.*

Question 3 continues on the next page



0 3 . 9

In a similar experiment, another student used 0.040 mol of ethyl benzoate and obtained 5.12 g of benzoic acid.

Calculate the percentage yield of benzoic acid.

Suggest why the yield is not 100%.

[3 marks]

$$M_r \text{ of benzoic acid, } C_6H_5COOH = 122$$

$$\text{Amount} = 5.12 / 122 = 0.0420 \text{ mol}$$

$$\% \text{ yield} = (0.0420 / 0.040) \times 100 = 105\%$$

Percentage yield 105 %

Suggestion The product was not dried (still contains water) or impurities are present, so the mass is too high.

18



0 4

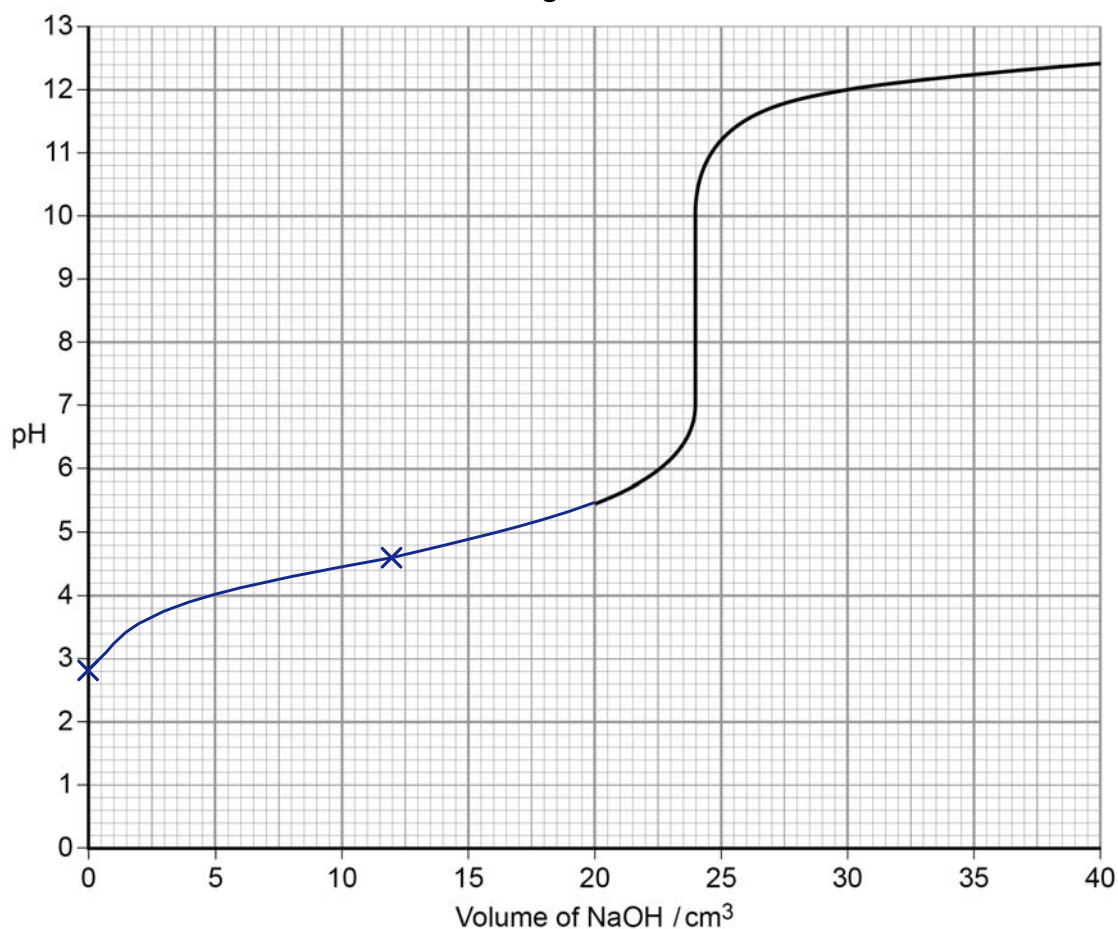
A $0.100 \text{ mol dm}^{-3}$ solution of sodium hydroxide was gradually added to 25.0 cm^3 of a solution of a weak acid, HX, in the presence of a suitable indicator.

A graph was plotted of pH against the volume of sodium hydroxide solution, as shown in **Figure 1**.

The first pH reading was taken after 20.0 cm^3 of sodium hydroxide solution had been added.

The acid dissociation constant of HX, $K_a = 2.62 \times 10^{-5} \text{ mol dm}^{-3}$

Figure 1



0 4 . 1

The pH range of an indicator is the range over which it changes colour.

Suggest the pH range of a suitable indicator for this titration.

[1 mark]

pH 8.2 to 10.0 (e.g. phenolphthalein)

0 4 . 2

Give the expression for the acid dissociation constant of HX.

[1 mark]

$$K_a = \frac{[H^+][X^-]}{[HX]}$$



0 4 . 3 Calculate the concentration of HX in the original solution.

[2 marks]

End point at 24.0 cm³ of NaOH

Amount NaOH = 24.0 × 0.100 / 1000 = 2.40 × 10⁻³ mol = amount of HX

[HX] = 2.40 × 10⁻³ / 0.0250 = 0.0960 mol dm⁻³

Concentration 0.0960 mol dm⁻³

0 4 . 4 Calculate the pH of the solution of HX before the addition of any sodium hydroxide.

(If you were unable to calculate a value for the concentration of HX in Question 4.3 you should use a value of 0.600 mol dm⁻³ in this calculation. This is **not** the correct value.)

[2 marks]

K_a = [H⁺]² / [HX], so [H⁺] = √(K_a × [HX])

[H⁺] = √(2.62 × 10⁻⁵ × 0.0960) = 1.59 × 10⁻³ mol dm⁻³

pH = -log(1.59 × 10⁻³) = 2.80

pH of HX 2.80

0 4 . 5 Calculate the pH of the solution when half of the acid has reacted.

[1 mark]

At half-neutralisation [HX] = [X⁻], so pH = pK_a

pH = -log(2.62 × 10⁻⁵) = 4.58

pH of solution 4.58

0 4 . 6 Plot your answers to Questions 4.4 and 4.5 on the grid in **Figure 1**. Use these points to sketch the missing part of the curve between 0 and 20 cm³ of NaOH solution added.

[2 marks]



Section B

Answer **all** questions in the spaces providedOnly **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.
Do **not** use additional sheets for this working.

0 5

Which compound has the highest boiling point?

[1 mark]

A $\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$ B $\text{CH}_3\text{CH}_2\text{CHO}$ C CH_3COCH_3 D $\text{CH}_3\text{COOCH}_3$ 

0 6

Which is the correct order of melting points of these Period 3 elements?

[1 mark]

A phosphorus > sulfur > chlorine > argon



B argon > chlorine > phosphorus > sulfur



C sulfur > phosphorus > chlorine > argon



D chlorine > phosphorus > sulfur > argon



Turn over for the next question

Turn over ►



0 7

Which is **not** a correct statement?

[1 mark]

- A Transition metals form coloured ions and complexes ☐
- B Transition metals display variable oxidation states ☐
- C A ligand accepts a pair of electrons from a transition metal ☒
- D A complex is a central metal atom or ion surrounded by ligands ☐

0 8

The table shows possible conditions and products for the cracking of alkanes.

Which row is correct?

[1 mark]

	Type of cracking	Conditions	Products	
A	Thermal	High pressure High temperature	Mainly alkanes	☐
B	Thermal	Slight pressure High temperature	Mainly alkenes	☐
C	Catalytic	Slight pressure High temperature	Mainly branched alkanes and aromatics	☒
D	Catalytic	High pressure High temperature	Mainly branched alkanes and aromatics	☐

0 9

2,4,6-Trichlorophenol is a weak monoprotic acid, with $K_a = 2.51 \times 10^{-8} \text{ mol dm}^{-3}$ at 298 K.

What is the concentration, in mol dm^{-3} , of hydrogen ions in a $2.00 \times 10^{-3} \text{ mol dm}^{-3}$ solution of 2,4,6-trichlorophenol at 298 K?

[1 mark]

- A 5.02×10^{-11} ☐
- B 7.09×10^{-6} ☒
- C 1.26×10^{-5} ☐
- D 3.54×10^{-3} ☐



1 0

What is the pH of a 0.46 mol dm^{-3} solution of potassium hydroxide at 298 K?

($K_w = 1.0 \times 10^{-14} \text{ mol}^2 \text{ dm}^{-6}$ at 298 K)

[1 mark]

A 0.34

☐

B 13.66

☒

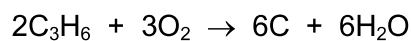
C 13.96

☐

D 14.34

☐**1 1**

What is the mass, in mg, of carbon formed when 3.0×10^{-3} mol of propene undergoes incomplete combustion?

**[1 mark]**

A 9.0×10^{-3}

☐

B 3.6×10^{-2}

☐

C 1.08×10^2

☒

D 2.16×10^2

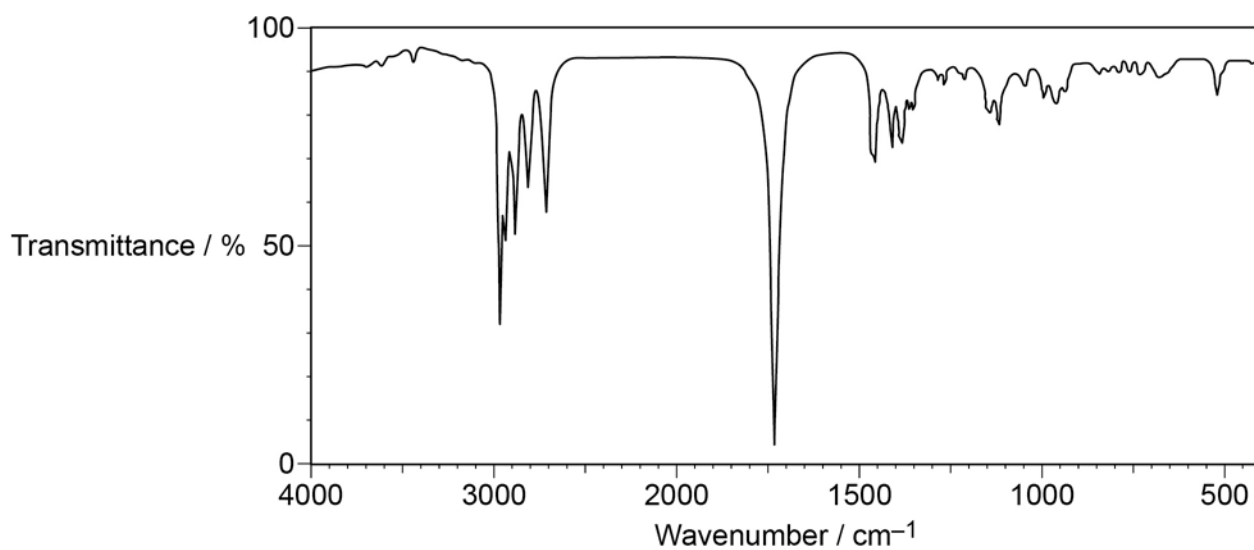
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Turn over for the next question



1 2

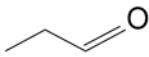
Which compound gives this infrared spectrum?

[1 mark]**A** 1-bromobutane☐**B** butan-1-ol☐**C** butanal☒**D** butanoic acid☐

1 3

Which pair of compounds does **not** form a racemic mixture when the compounds react?

[1 mark]

A	 + HCl
B	 + HCN
C	 + HCl
D	 + HCN

A

☐

B

☐

C

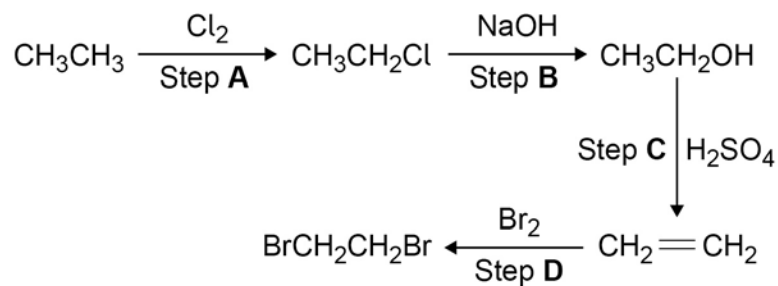
☐

D

☒

1 4

The reaction sequence shows how CH_3CH_3 can be converted into $\text{BrCH}_2\text{CH}_2\text{Br}$



Which step occurs by nucleophilic substitution?

[1 mark]

A Step A

☐

B Step B

☒

C Step C

☐

D Step D

☐

Turn over for the next question

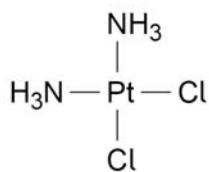
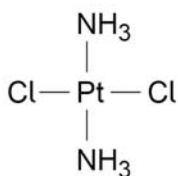
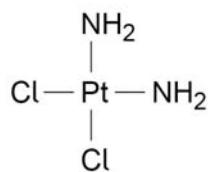
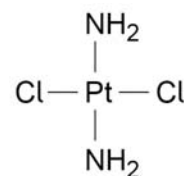
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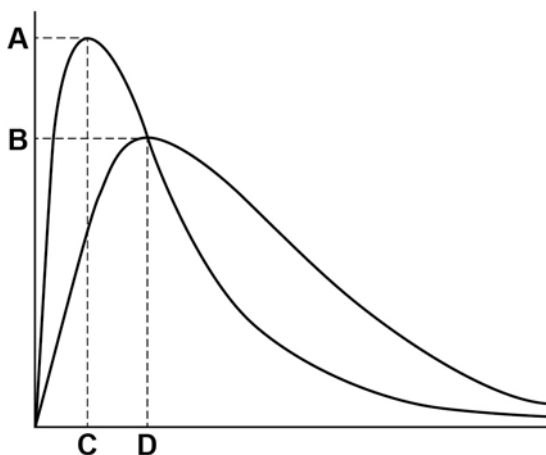
1 5

Cisplatin is an anti-cancer drug.

Which structure represents a stereoisomer of cisplatin?

[1 mark]**A****B****C****D****A**☐**B**☒**C**☐**D**☐**1 6**

The diagram shows the Maxwell-Boltzmann distribution of molecular energies in a gas at two different temperatures.



Which letter represents the most probable energy of the molecules at the higher temperature?

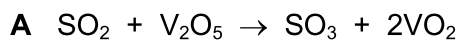
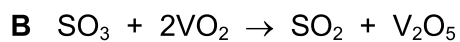
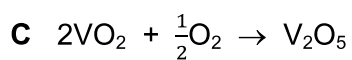
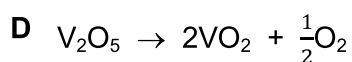
[1 mark]**A**☐**B**☐**C**☐**D**☒

1 7

V_2O_5 can be used as a catalyst in the Contact Process.

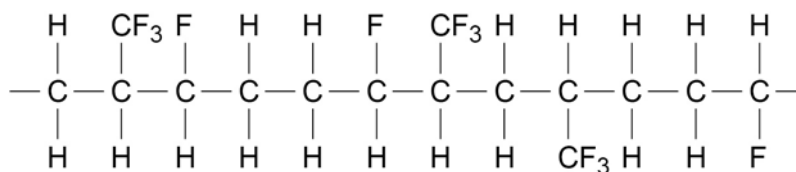
Which is a step in the Contact Process in which the vanadium is oxidised?

[1 mark]


☐

☐

☒

☐

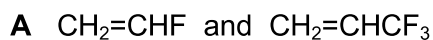
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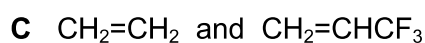
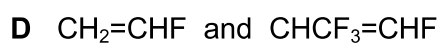
This structure shows a section of a polymer chain formed from the random polymerisation of two different monomers.



Which pair of monomers could produce this polymer?

[1 mark]


☒

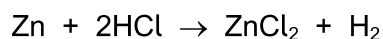
☐

☐

☐

Turn over for the next question



1 9

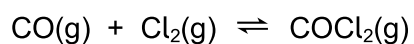
The equation for the reaction between zinc and hydrochloric acid is



What is the minimum mass, in mg, of zinc ($A_r = 65.4$) needed to react with 50.0 cm^3 of 1.68 mol dm^{-3} hydrochloric acid?

[1 mark]**A** 2.75☐**B** 5.49☐**C** 2.75×10^3 ☒**D** 5.49×10^3 ☐**2 0**

An equilibrium mixture is prepared in a container of fixed volume.



$$\Delta H = -108 \text{ kJ mol}^{-1}$$

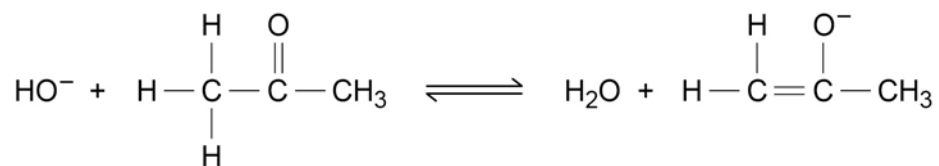
The temperature of this mixture is decreased and the mixture is allowed to reach a new equilibrium.

Which is greater for the new equilibrium than for the original equilibrium?

[1 mark]**A** The mole fraction of carbon monoxide☐**B** The partial pressure of chlorine☐**C** The total pressure of the mixture☐**D** The value of the equilibrium constant, K_p ☒

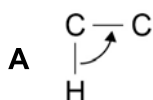
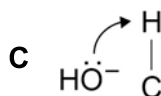
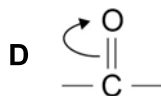
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In concentrated alkali, propanone reacts with hydroxide ions to form an equilibrium mixture as shown.



Which curly arrow does **not** appear in the mechanism of this reaction?

[1 mark]

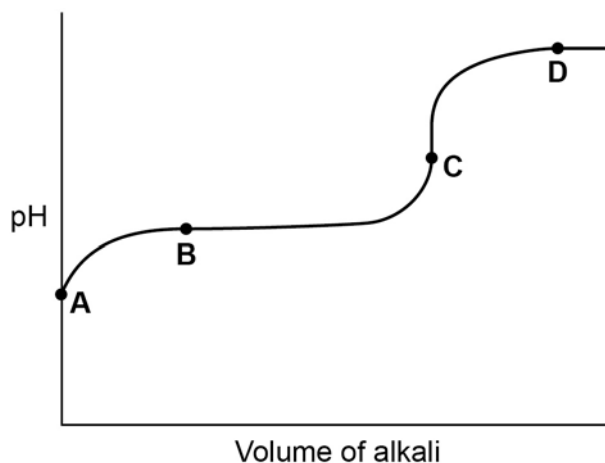
☐☒☐☐

Turn over for the next question



2 2

The diagram shows a pH curve produced by adding a strong alkali to a weak acid.



Which point on the curve represents a solution that can act as a buffer?

[1 mark]**A**☐**B**☒**C**☐**D**☐**2 3**

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

[1 mark]**A** 2,2-dimethylpropan-1-ol☐**B** 2-methylbutan-2-ol☒**C** 3-methylbutan-2-ol☐**D** pentan-3-ol☐

2 4Which compound does **not** show stereoisomerism?**[1 mark]****A** 1,2-dichloropropene☐**B** 1,2-dichloropropane☐**C** 1,3-dichloropropene☐**D** 1,3-dichloropropane☒**2 5**

Which compound can form a polymer without needing another reagent?

[1 mark]**A** HOCH₂CH₂OH☐**B** HOOCCH₂CH₂COOH☐**C** HOCH₂CH₂COCl☒**D** ClCH₂CH₂COOH☐**2 6**

A solution of lead(II) chloride ($M_r = 278.2$) contains 1.08 g of PbCl₂ in 100 cm³ of solution. In this solution, the lead(II) chloride is fully dissociated into ions.

What is the concentration of chloride ions in this solution?

[1 mark]**A** $3.88 \times 10^{-3} \text{ mol dm}^{-3}$ ☐**B** $7.76 \times 10^{-3} \text{ mol dm}^{-3}$ ☐**C** $3.88 \times 10^{-2} \text{ mol dm}^{-3}$ ☐**D** $7.76 \times 10^{-2} \text{ mol dm}^{-3}$ ☒**Turn over for the next question**

2 7

The rate equation for the acid-catalysed reaction between iodine and propanone is:

$$\text{rate} = k [\text{H}^+] [\text{C}_3\text{H}_6\text{O}]$$

The rate of reaction was measured for a mixture of iodine, propanone and sulfuric acid at pH = 0.70

In a second mixture the concentration of the sulfuric acid was different but the concentrations of iodine and propanone were unchanged. The new rate of reaction was a quarter of the original rate.

What was the pH of the second mixture?

[1 mark]

A 1.00

☐

B 1.30

☒

C 1.40

☐

D 2.80

☐**2 8**

A 385 cm^3 sample of carbon dioxide at 100 kPa and 25°C was mixed with $2.89 \times 10^{-2} \text{ mol}$ of argon. The gas constant, $R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$

What is the mole fraction of carbon dioxide in the mixture?

[1 mark]

A 0.35

☒

B 0.46

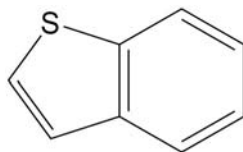
☐

C 0.54

☐

D 0.65

☐

2 9How many peaks does this compound have in its ^{13}C spectrum?**[1 mark]****A** 5☐**B** 6☐**C** 7☐**D** 8☒**3 0**

A student is provided with 5.00 cm^3 of 1.00 mol dm^{-3} ammonia solution. The student was asked to prepare an ammonia solution with a concentration of 0.050 mol dm^{-3}

What volume of water should the student add?

[1 mark]**A** 45.0 cm^3 ☐**B** 95.0 cm^3 ☒**C** 100 cm^3 ☐**D** 995 cm^3 ☐**3 1**

A solution absorbs light with wavelengths corresponding to red, yellow and green light.

Which ion is most likely to be in the solution?

[1 mark]**A** $\text{Cr}_2\text{O}_7^{2-}(\text{aq})$ ☐**B** $\text{Fe}^{2+}(\text{aq})$ ☐**C** $\text{Fe}^{3+}(\text{aq})$ ☐**D** $\text{Cu}^{2+}(\text{aq})$ ☒

Turn over for the next question

Turn over ►



3 2

A reaction is exothermic and has a negative entropy change.

Which statement is correct?

[1 mark]

A The reaction is always feasible

☐

B The reaction is feasible above a certain temperature

☐

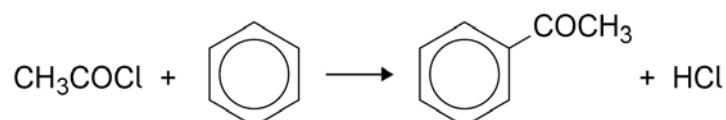
C The reaction is feasible below a certain temperature

☒

D The reaction is never feasible

☐**3 3**

Phenylethanone can be prepared by the reaction between ethanoyl chloride and benzene.



In a preparation, with an excess of benzene, the mass of ethanoyl chloride ($M_r = 78.5$) used was 5.7×10^{-2} kg.

The percentage yield of phenylethanone was 62%.

What mass, in grams, of phenylethanone was produced?

[1 mark]

A 35 g

☐

B 54 g

☒

C 87 g

☐

D 102 g

☐

3	4
---	---

130 cm³ of oxygen and 40 cm³ of nitrogen, each at 298 K and 100 kPa, were placed into an evacuated flask of volume 0.50 dm³.

What is the pressure of the gas mixture in the flask at 298 K?

[1 mark]

A 294 kPa

☐

B 68.0 kPa

☐

C 34.0 kPa

☒

D 13.7 kPa

☐

30

END OF QUESTIONS



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