Please write clearly, in block capitals.

Centre number | | | | | | Candidate number | | | | |

Surname _____

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	

Section A

Answer **all** questions in the spaces provided

0 1 Anhydrous magnesium chloride, $MgCl_2$, can absorb water to form the hydrated salt $MgCl_2.4H_2O$

$$MgCl_2(s) + 4H_2O(l) \rightarrow MgCl_2.4H_2O(s)$$

0 1 . 1 Suggest **one** reason why the enthalpy change for this reaction cannot be determined directly by calorimetry.

[1 mark]

0 1 . 2 Some enthalpies of solution are shown in **Table 1**.

Table 1

Salt	Enthalpy of solution / kJ mol^{-1}
$MgCl_2(s)$	−155
$MgCl_2.4H_2O(s)$	−39

Calculate the enthalpy change for the absorption of water by $MgCl_2(s)$ to form $MgCl_2.4H_2O(s)$.

[2 marks]

Enthalpy change _____ kJ mol^{-1}

0 1 . 3 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]

0 1 . 4 Anhydrous magnesium chloride can be formed by direct reaction between its elements.

$$Mg(s) + Cl_2(g) \rightarrow MgCl_2(s)$$

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

Table 2

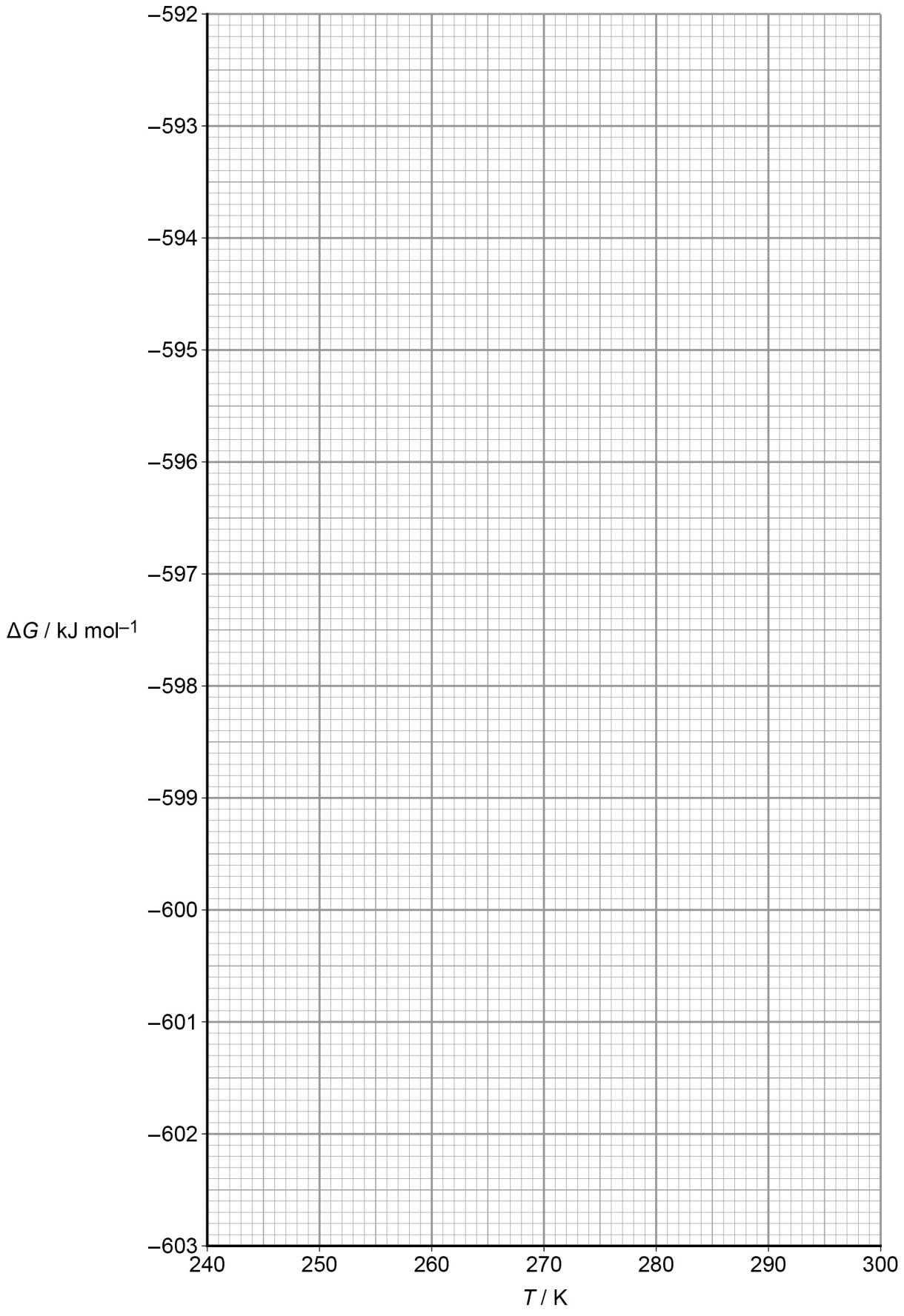
T / K	ΔG / kJ mol^{-1}
298	−592.5
288	−594.2
273	−596.7
260	−598.8
240	−602.2

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 J K^{-1} mol^{-1}, for the formation of anhydrous magnesium chloride from its elements.

Show your working.

[5 marks]



ΔS _____ $J\,K^{-1}\,mol^{-1}$

14

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]

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]

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

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 _____

_____

Role of sulfuric acid _____

_____

Name of separation method

_____

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 _____

_____

Role of sulfuric acid _____

_____

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]

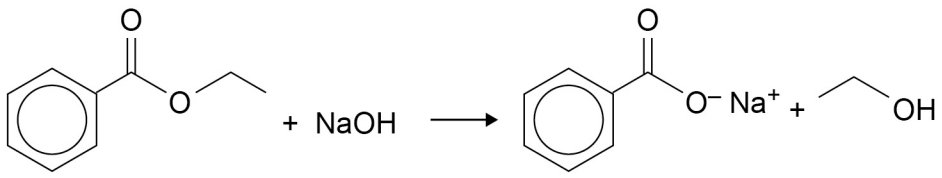
Black solid _____

Yellow solid _____

Gas _____

19

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 cm^3 of ethyl benzoate (density = 1.05 g cm^{-3}, M_r = 150) to 30.0 cm^3 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 cm^3 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]

0 3 . 2 Show, by calculation, that an excess of sodium hydroxide is used in this reaction.

[2 marks]

Question 3 continues on the next page

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

[1 mark]

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

[1 mark]

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

[1 mark]

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]

0 3 . 8 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]

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]

Percentage yield _____ %

Suggestion _____

_____

_____

18

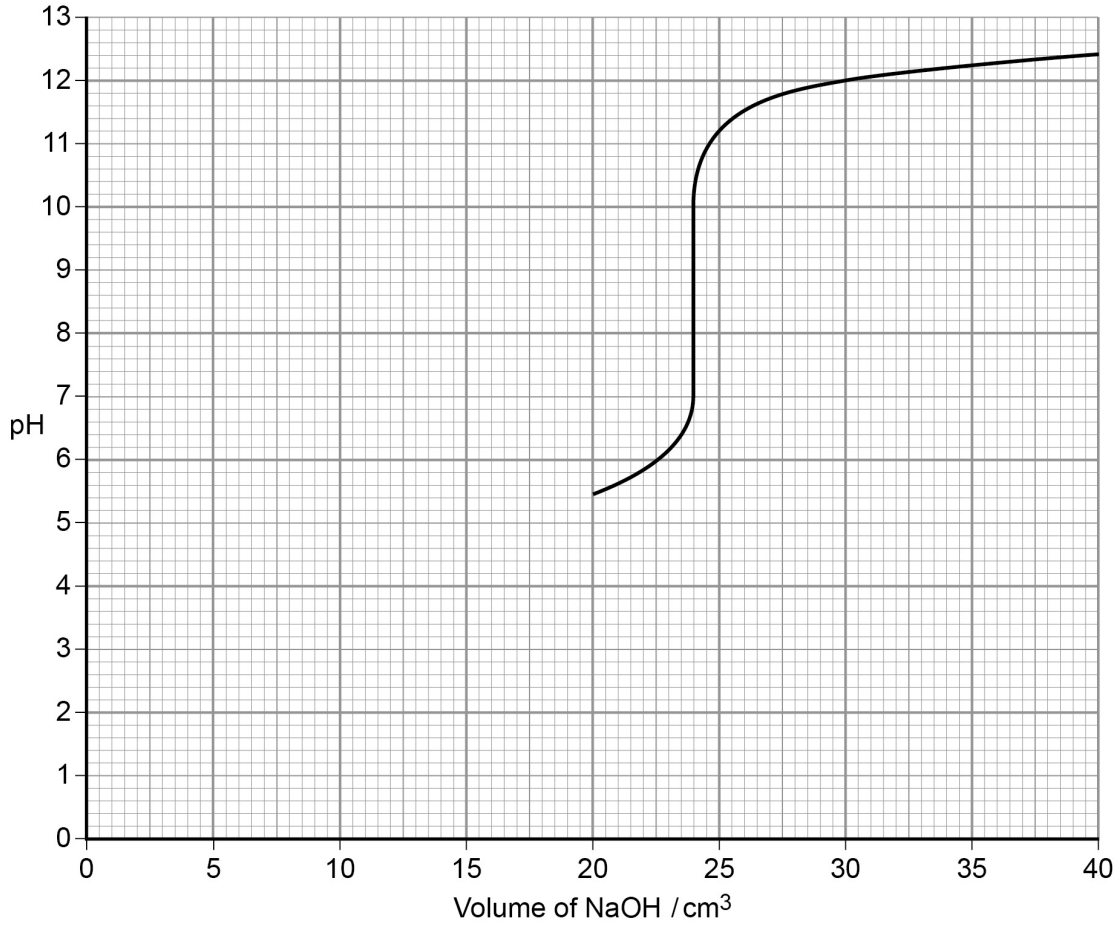
0 4 A 0.100 mol dm^{-3} solution of sodium hydroxide was gradually added to 25.0 cm^3 of a solution of a weak acid, HX, in the presence of a suitable indicator.

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, = 2.62×10^{-5} 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]

0 4 . 2 Give the expression for the acid dissociation constant of HX.

[1 mark]

K_a =

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

[2 marks]

Concentration _____ 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]

pH of HX _____

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

[1 mark]

pH of solution _____

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 cm^3 of NaOH solution added.

[2 marks]

9

Section B

Answer **all** questions in the spaces provided

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.
Do **not** use additional sheets for this working.

0 5 Which compound has the highest boiling point?

[1 mark]

A $CH_3CH_2CH_2OH$ ⬭

B CH_3CH_2CHO ⬭

C CH_3COCH_3 ⬭

D CH_3COOCH_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

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 $K_a = 2.51 \times 10^{-8}$ mol dm^{-3} at 298 K.

What is the concentration, in mol dm^{-3}, of hydrogen ions in a 2.00×10^{-3} 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?

($K_w = 1.0 \times 10^{-14}$ mol^2 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?

$$2C_3H_6 + 3O_2 \rightarrow 6C + 6H_2O$$

[1 mark]

A 9.0×10^{-3} ⬭

B 3.6×10^{-2} ⬭

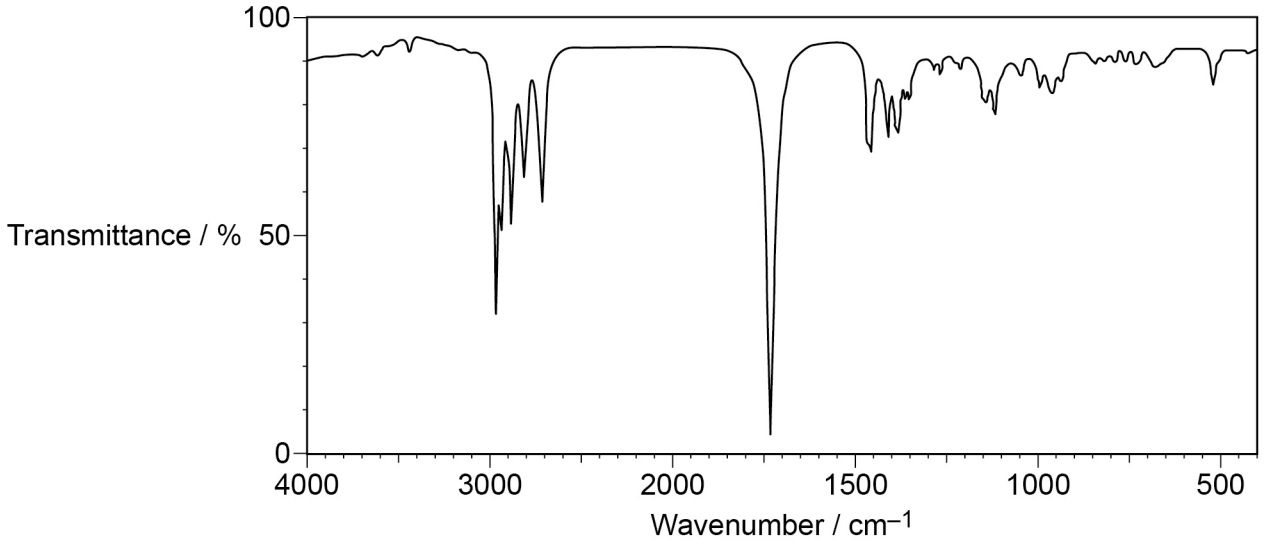
C 1.08×10^{2} ⬭

D 2.16×10^{2} ⬭

Turn over for the next question

1 2 Which compound gives this infrared spectrum?

[1 mark]



A 1-bromobutane ⬭

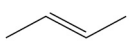
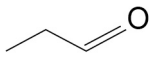
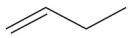
B butan-1-ol ⬭

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

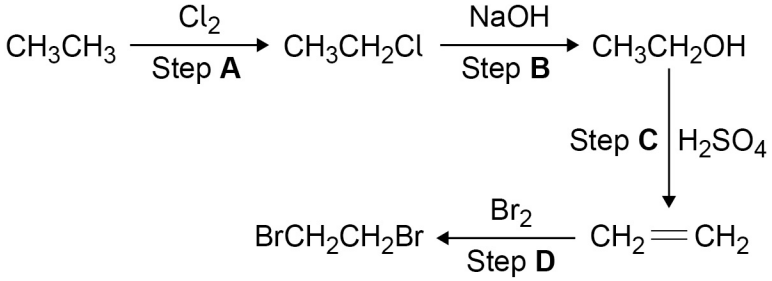
A ⬭

B ⬭

C ⬭

D ⬭

1 4 The reaction sequence shows how CH_3CH_3 can be converted into $BrCH_2CH_2Br$



Which step occurs by nucleophilic substitution?

[1 mark]

A Step **A** ⬭

B Step **B** ⬭

C Step **C** ⬭

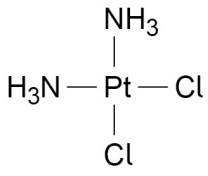
D Step **D** ⬭

Turn over for the next question

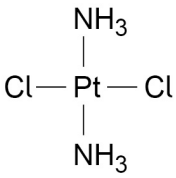
1 5 Cisplatin is an anti-cancer drug.

Which structure represents a stereoisomer of cisplatin?

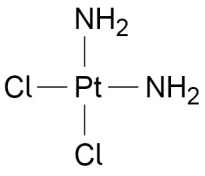
[1 mark]



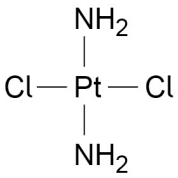
A



B



C



D

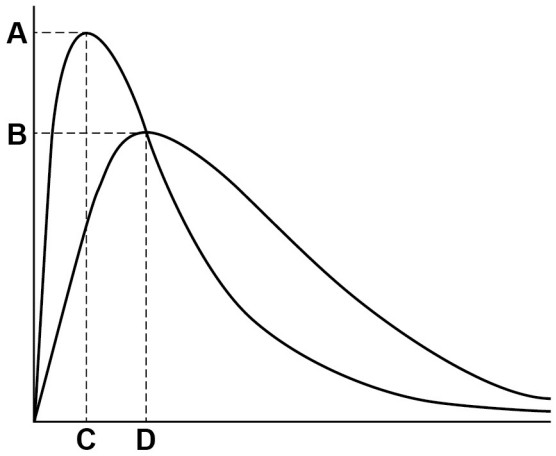
A ⬭

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]

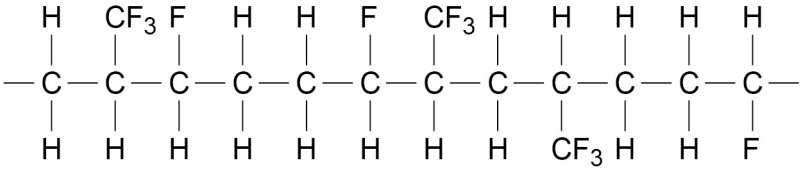
A $SO_2 + V_2O_5 \rightarrow SO_3 + 2VO_2$ ⬭

B $SO_3 + 2VO_2 \rightarrow SO_2 + V_2O_5$ ⬭

C $2VO_2 + \frac{1}{2}O_2 \rightarrow V_2O_5$ ⬭

D $V_2O_5 \rightarrow 2VO_2 + \frac{1}{2}O_2$ ⬭

1 8 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]

A $CH_2=CHF$ and $CH_2=CHCF_3$ ⬭

B $CH_2=CH_2$ and $CHF=CHCF_3$ ⬭

C $CH_2=CH_2$ and $CH_2=CHCF_3$ ⬭

D $CH_2=CHF$ and $CHCF_3=CHF$ ⬭

Turn over for the next question

1 9 The equation for the reaction between zinc and hydrochloric acid is

$$Zn + 2HCl \rightarrow ZnCl_2 + H_2$$

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.

$$CO(g) + Cl_2(g) \rightleftharpoons COCl_2(g) \qquad \Delta H = -108 \text{ kJ mol}^{-1}$$

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]

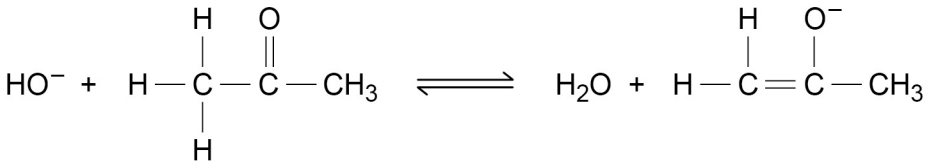
A The mole fraction of carbon monoxide ⬭

B The partial pressure of chlorine ⬭

C The total pressure of the mixture ⬭

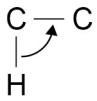
D The value of the equilibrium constant, K_p ⬭

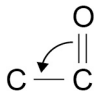
2 1 In concentrated alkali, propanone reacts with hydroxide ions to form an equilibrium mixture as shown.

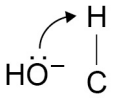


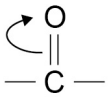
Which curly arrow does **not** appear in the mechanism of this reaction?

[1 mark]

A  ⬭

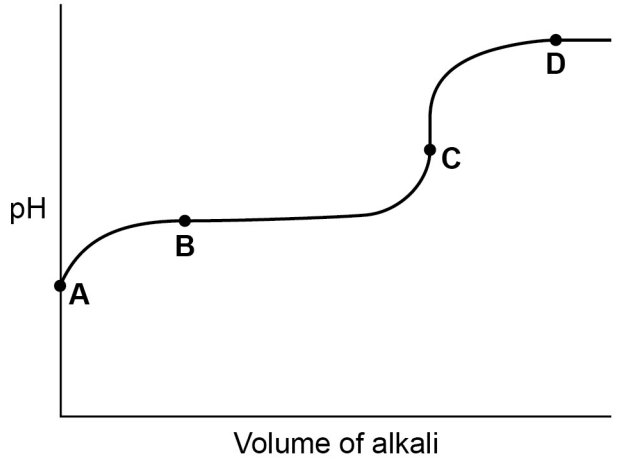
B  ⬭

C  ⬭

D  ⬭

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 4 Which 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 $HOCH_2CH_2OH$ ⬭

B $HOOCCH_2CH_2COOH$ ⬭

C $HOCH_2CH_2COCl$ ⬭

D $ClCH_2CH_2COOH$ ⬭

2 6 A solution of lead(II) chloride (M_r = 278.2) contains 1.08 g of $PbCl_2$ in 100 cm^3 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 3.88×10^{-3} mol dm^{-3} ⬭

B 7.76×10^{-3} mol dm^{-3} ⬭

C 3.88×10^{-2} mol dm^{-3} ⬭

D 7.76×10^{-2} mol dm^{-3} ⬭

Turn over for the next question

2 7 The rate equation for the acid-catalysed reaction between iodine and propanone is:

$$\text{rate} = k\,[H^+]\,[C_3H_6O]$$

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 2.89×10^{-2} mol of argon. The gas constant, R = 8.31 J K^{-1} mol^{-1}

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

[1 mark]

A 0.35 ⬭

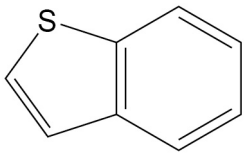
B 0.46 ⬭

C 0.54 ⬭

D 0.65 ⬭

2 9 How 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 $Cr_2O_7^{2-}(aq)$ ⬭

B $Fe^{2+}(aq)$ ⬭

C $Fe^{3+}(aq)$ ⬭

D $Cu^{2+}(aq)$ ⬭

Turn over for the next question

3 2 A reaction is exothermic and has a negative entropy change.

Which statement is correct?

[1 mark]

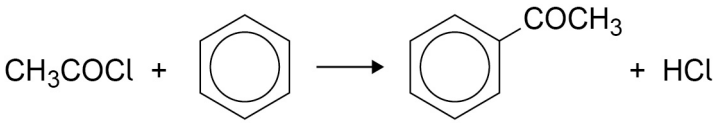
A The reaction is always feasible ⬭

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 cm^3 of oxygen and 40 cm^3 of nitrogen, each at 298 K and 100 kPa, were placed into an evacuated flask of volume 0.50 dm^3.

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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