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.

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

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**.

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]

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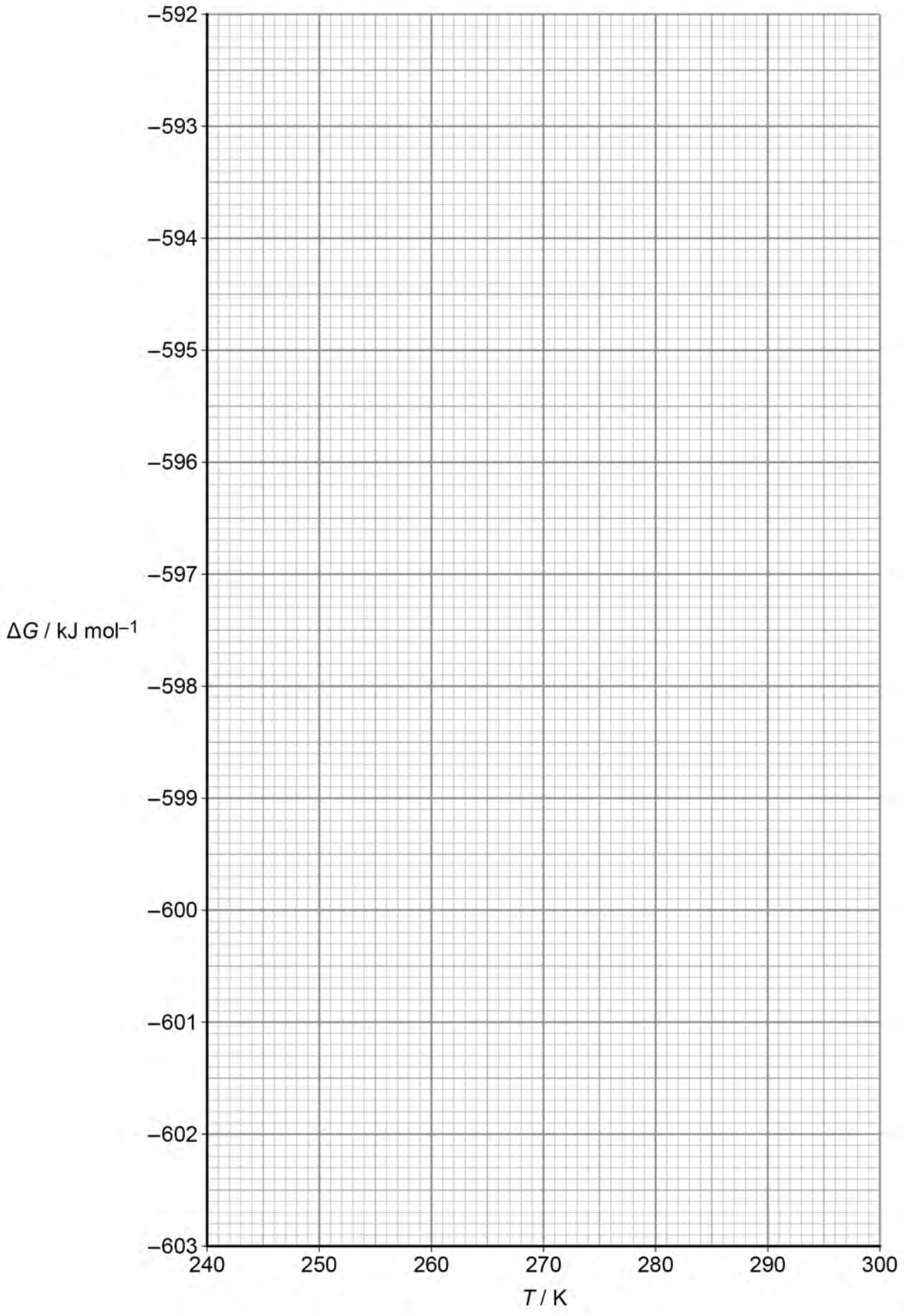


ΔS _____ J K^{-1} mol^{-1}

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]

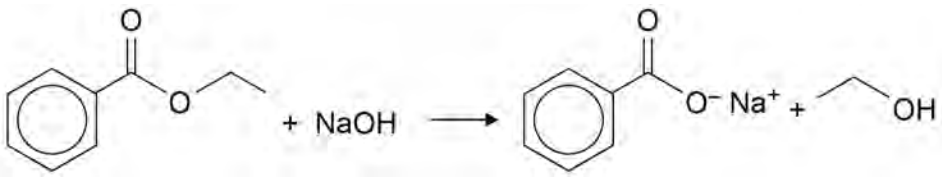
Black solid _____

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

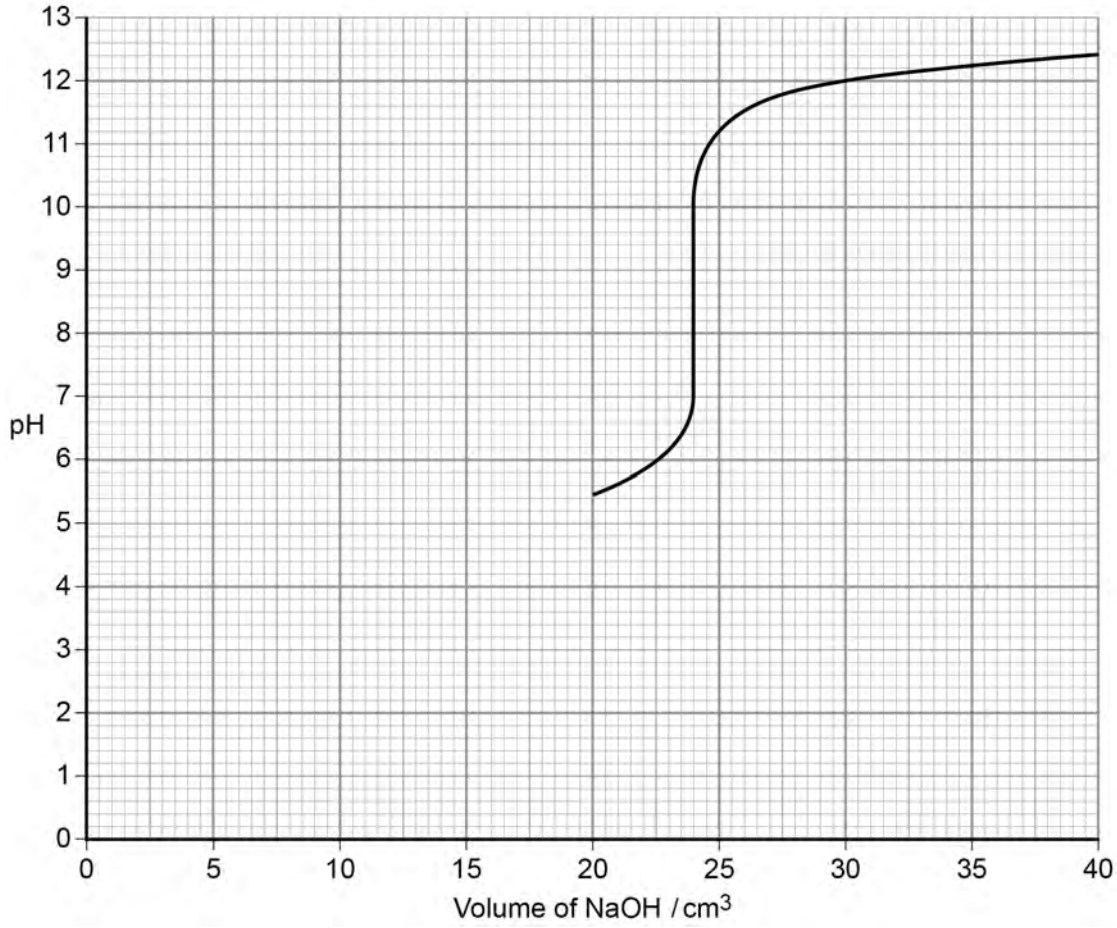
0 4 A 0.100 mol dm^{-3} solution of sodium hydroxide was gradually added to 25.0 cm^3 of a solution of a weak acid, HX, in the presence of a suitable indicator.

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} ⬭

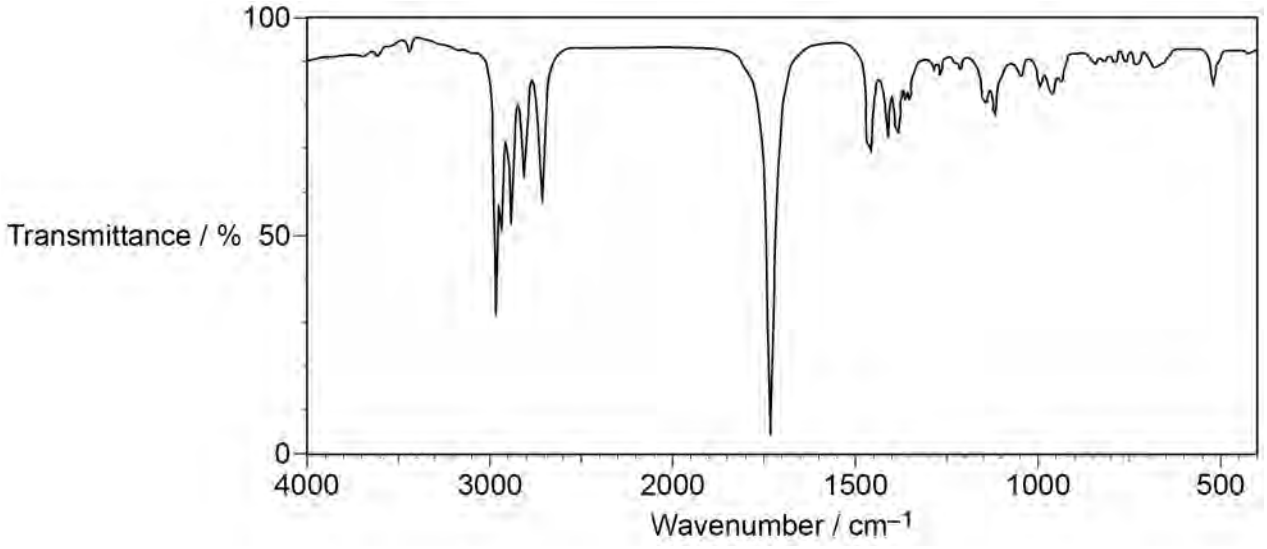
C 1.08×10^{2} ⬭

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

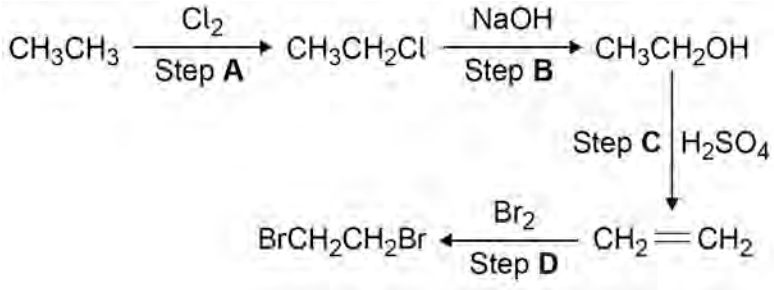
A ⬭

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** ⬭

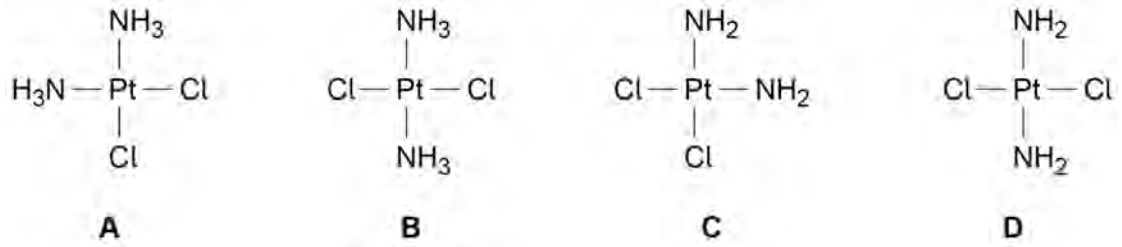
D Step **D** ⬭

Turn over for the next question

1 5 Cisplatin is an anti-cancer drug.

Which structure represents a stereoisomer of cisplatin?

[1 mark]



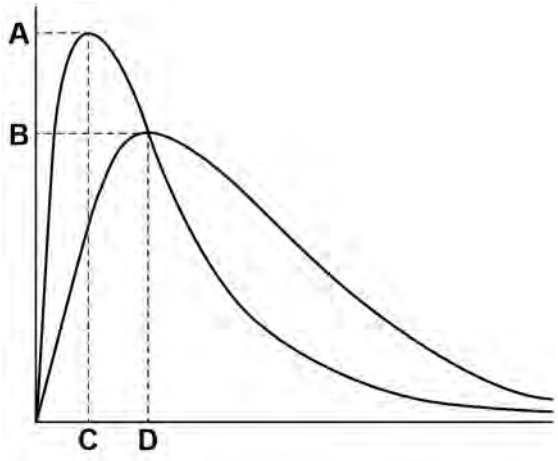
A ⬭

B ⬭

C ⬭

D ⬭

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]

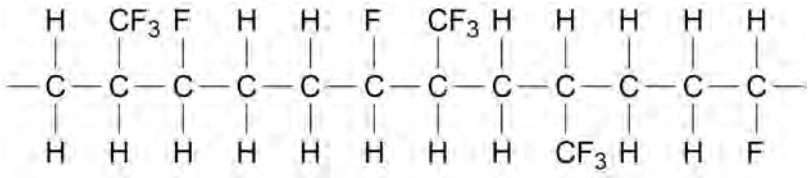
A $SO_2 + V_2O_5 \rightarrow SO_3 + 2VO_2$ ⬭

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]

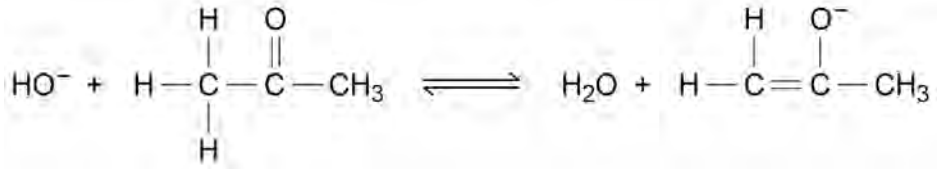
A The mole fraction of carbon monoxide ⬭

B The partial pressure of chlorine ⬭

C The total pressure of the mixture ⬭

D The value of the equilibrium constant, K_p ⬭

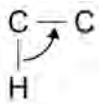
2 1 In concentrated alkali, propanone reacts with hydroxide ions to form an equilibrium mixture as shown.



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

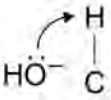
[1 mark]

A

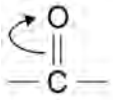


B

C

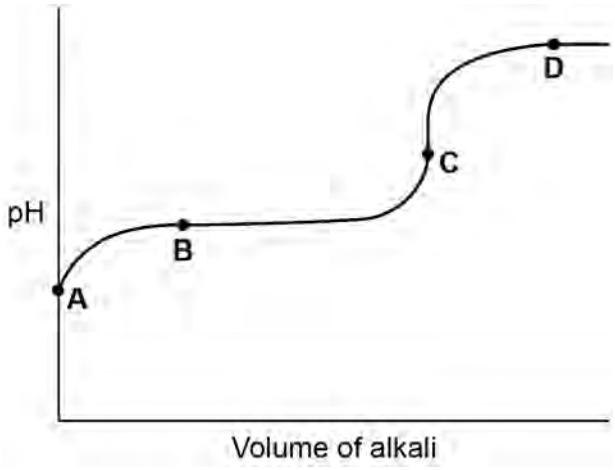


D



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 ⬭

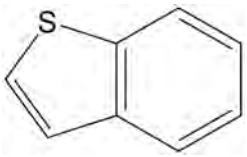
B 0.46 ⬭

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]

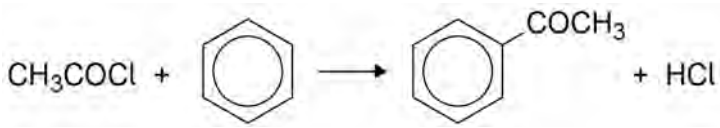
A The reaction is always feasible ⬭

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 ⬭

Do not write outside the box

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

There are no questions printed on this page

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