SECTION A

1 10.0 cm^3 of 0.250 mol dm^{-3} potassium hydroxide solution was placed in a conical flask and titrated with 0.200 mol dm^{-3} hydrochloric acid solution, using phenolphthalein as an indicator.

(a) What colour would phenolphthalein turn at the end-point in this titration?

(1)

☒ **A** Colourless

☒ **B** Pink

☒ **C** Yellow

☒ **D** Orange

(b) The best piece of apparatus to accurately measure out 10.0 cm^3 is a

(1)

☒ **A** pipette.

☒ **B** burette.

☒ **C** syringe.

☒ **D** measuring cylinder.

(c) What volume of 0.200 mol dm^{-3} hydrochloric acid solution was added by the end-point?

(1)

☒ **A** 8.00 cm^3

☒ **B** 10.00 cm^3

☒ **C** 12.50 cm^3

☒ **D** 25.00 cm^3

(Total for Question 1 = 3 marks)

Use this space for any rough working. Anything you write in this space will gain no credit.

2 Which of these metal hydroxides is the most soluble in water?

- ☒ **A** Barium hydroxide
- ☒ **B** Calcium hydroxide
- ☒ **C** Magnesium hydroxide
- ☒ **D** Strontium hydroxide

(Total for Question 2 = 1 mark)

3 Which of these metals will give a lilac flame colour?

- ☒ **A** Sodium
- ☒ **B** Calcium
- ☒ **C** Potassium
- ☒ **D** Magnesium

(Total for Question 3 = 1 mark)

4 Which of these is a tertiary alcohol?

- ☒ **A** 3-methylpentan-2-ol
- ☒ **B** Pentan-2-ol
- ☒ **C** Pentan-3-ol
- ☒ **D** 2-methylpentan-2-ol

(Total for Question 4 = 1 mark)

5 Which of these statements about fluorine is **not** correct?

- ☒ **A** It is a gaseous element at room temperature and pressure.
- ☒ **B** It can react with chloride ions to form chlorine.
- ☒ **C** It forms salts with Group 1 metals.
- ☒ **D** It is less electronegative than chlorine.

(Total for Question 5 = 1 mark)

Use this space for any rough working. Anything you write in this space will gain no credit.

Turn over ▶

6 What is the oxidation number of oxygen in dioxygen difluoride, O_2F_2?

- ☒ **A** –1
- ☒ **B** –2
- ☒ **C** +1
- ☒ **D** +2

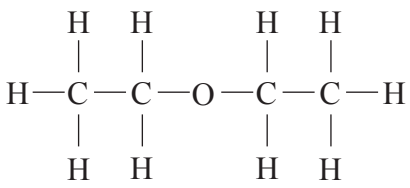
(Total for Question 6 = 1 mark)

7 Which of these four molecules, PCl_3, CO, CO_2 and CCl_4, are polar?

- ☒ **A** All four
- ☒ **B** PCl_3 and CO
- ☒ **C** CO and CCl_4
- ☒ **D** PCl_3 and CO_2

(Total for Question 7 = 1 mark)

8 Which intermolecular forces exist between molecules of ethoxyethane?



- ☒ **A** Instantaneous dipole – induced dipole only
- ☒ **B** Permanent dipole – permanent dipole only
- ☒ **C** Instantaneous dipole – induced dipole and hydrogen bonds
- ☒ **D** Instantaneous dipole – induced dipole and permanent dipole – permanent dipole

(Total for Question 8 = 1 mark)

9 The following liquids all have the same number of electrons in each molecule. Which one is likely to have the lowest boiling point?

- ☒ **A** $CH_3CH_2CH_2CH_2OH$
- ☒ **B** $CH_3CH_2CH_2CH_2CH_3$
- ☒ **C** $CH_3C(CH_3)_2CH_3$
- ☒ **D** $CH_3CH(CH_3)CH_2CH_3$

(Total for Question 9 = 1 mark)

10 Which of these is likely to be the best solvent for cyclohexanol?

- ☒ **A** $H_2O(l)$
- ☒ **B** $CH_3COCH_3(l)$
- ☒ **C** NaCl(aq)
- ☒ **D** $CH_3CH_2CH_2CH_2CH_2CH_3(l)$

(Total for Question 10 = 1 mark)

11 The ability of a liquid to flow is linked to the strength of its intermolecular forces. Suggest which of these liquids flows the slowest when poured.

- ☒ **A** Propane-1,2,3-triol
- ☒ **B** Propane-1,2-diol
- ☒ **C** Pentane
- ☒ **D** Butane

(Total for Question 11 = 1 mark)

12 What type of species forms when a bond breaks homolytically?

- ☒ **A** Nucleophile
- ☒ **B** Electron
- ☒ **C** Electrophile
- ☒ **D** Free radical

(Total for Question 12 = 1 mark)

Turn over ▶

13 In the reaction between $Ag^+(aq)$ ions and $Fe^{2+}(aq)$ ions, what would be the effect of increasing the concentration of $Ag^+(aq)$ ions?

$$Ag^+(aq) + Fe^{2+}(aq) \rightleftharpoons Fe^{3+}(aq) + Ag(s)$$

☒ **A** Rate of reaction increases, yield of $Fe^{3+}(aq)$ stays the same.

☒ **B** Rate of reaction increases, yield of $Fe^{3+}(aq)$ decreases.

☒ **C** Rate of reaction decreases, yield of $Fe^{3+}(aq)$ stays the same.

☒ **D** Rate of reaction increases, yield of $Fe^{3+}(aq)$ increases.

(Total for Question 13 = 1 mark)

14 Which one of these reactions is **not** a disproportionation reaction?

☒ **A** $2H_2O_2(aq) \rightarrow O_2(g) + 2H_2O(l)$

☒ **B** $S_2O_3^{2-}(aq) + 2H^+(aq) \rightarrow SO_2(g) + S(s) + H_2O(l)$

☒ **C** $Cl_2(aq) + 2Br^-(aq) \rightarrow 2Cl^-(aq) + Br_2(aq)$

☒ **D** $2Cu^+(aq) \rightarrow Cu(s) + Cu^{2+}(aq)$

(Total for Question 14 = 1 mark)

15 Molecules absorb IR radiation because

☒ **A** they change their polarity when they vibrate.

☒ **B** they change their velocity when they vibrate.

☒ **C** they change their magnetic field when they vibrate.

☒ **D** they change their direction of rotation when they vibrate.

(Total for Question 15 = 1 mark)

16 How many of the following molecules will absorb IR radiation?

H_2O N_2 CH_4 O_2 CO_2

☒ **A** Two

☒ **B** Three

☒ **C** Four

☒ **D** Five

(Total for Question 16 = 1 mark)

17 Infrared (IR) spectra can be used to follow the progress of reactions involving propan-1-ol and propan-2-ol. Some absorption ranges by chemical bonds in the IR spectrum are given below.

1 O—H stretching in alcohols at 3750 − 3200 cm^{-1}

2 C═O stretching in aldehydes at 1740 − 1720 cm^{-1}

3 C═O stretching in ketones at 1700 − 1680 cm^{-1}

4 C═O stretching in carboxylic acids at 1725 − 1700 cm^{-1}

(a) To identify the formation of the product when propan-1-ol has been partially oxidized, you can look for absorptions in the IR spectrum at absorption range

(1)

☒ **A** 1

☒ **B** 2

☒ **C** 3

☒ **D** 4

(b) To monitor whether all of the sample of propan-2-ol has been oxidized, you can look for

(1)

☒ **A** a lack of absorptions in the IR spectrum at 1.

☒ **B** a lack of absorptions in the IR spectrum at 2.

☒ **C** absorptions in the IR spectrum at 3.

☒ **D** absorptions in the IR spectrum at 4.

(Total for Question 17 = 2 marks)

TOTAL FOR SECTION A = 20 MARKS

SECTION B

18 This question is about the reactions and properties of some halogenoalkanes.

(a) State the reagents and conditions needed to convert the following halogenoalkanes into the named product.

(i) 1-bromobutane into butan-1-ol

(2)

(ii) 1-iodobutane into butylamine

(2)

(iii) 2-chloropropane into propene

(2)

(b) Chloroethane can be prepared by reacting ethanol with potassium chloride in the presence of concentrated sulfuric acid.

Explain why a similar reaction using potassium iodide and concentrated sulfuric acid should **not** be used to prepare iodoethane.

(2)

(c) Two gaseous halogenoalkanes that could be used as fire retardants have the structural formulae CF_2ClBr and CF_3CHF_2.

(i) Give the systematic name of CF_2ClBr.

(1)

(ii) Draw the **skeletal** formula of CF_3CHF_2.

(1)

(iii) Suggest TWO reasons to explain how these compounds can help put out fires.

(2)

*(iv) Explain why fire retardants containing some halogenoalkanes, such as CF_2ClBr, are being phased out.

Suggest a reason why the scientific community still supports the use of fire retardants containing CF_3CHF_2.

(4)

(Total for Question 18 = 16 marks)

19 10.0 cm^3 of a solution containing $Cu^{2+}(aq)$ ions was added to excess potassium iodide solution and the following reaction occurred.

$$2Cu^{2+}(aq) + 4I^{-}(aq) \rightarrow 2CuI(s) + I_2(aq)$$

(a) What happens to the $Cu^{2+}(aq)$ during this reaction? Justify your answer.

(2)

(b) All of the mixture containing iodine was titrated using sodium thiosulfate solution of concentration 0.200 mol dm^{-3}. The volume of sodium thiosulfate solution added at the end-point was 12.75 cm^3.

The equation for the reaction is

$$I_2(aq) + 2Na_2S_2O_3(aq) \rightarrow Na_2S_4O_6(aq) + 2NaI(aq)$$

(i) The end-point is shown most effectively using an indicator. State a suitable indicator and the colour change you would expect to see at the end-point.

(2)

Indicator

Colour change at end-point

(ii) Calculate the number of moles of iodine in the solution.

(2)

*(iii) Use your answer from (ii), and the equation for the reaction between $Cu^{2+}(aq)$ and $I^{-}(aq)$, to calculate the concentration of the $Cu^{2+}(aq)$ in the original sample of solution.

Give your answer to **three** significant figures and justify why this is an appropriate level of accuracy.

(3)

(iv) The whole of the solution containing iodine was used in one titration. Explain how this affects the reliability of your answer to (iii).

(1)

(Total for Question 19 = 10 marks)

20 This question is about boron and nitrogen compounds.

(a) Draw and name the shape of a boron trifluoride, BF_3, molecule. Suggest the FBF bond angle.

(3)

Name of shape

FBF bond angle

(b) Ammonia has the formula NH_3. Its HNH bond angle is less than the FBF bond angle in boron trifluoride.

(i) Estimate the HNH bond angle in NH_3.

(1)

(ii) Explain why the HNH bond angle is less than that for FBF.

(1)

(iii) Name the strongest intermolecular force between BF_3 molecules.

(1)

(iv) Name the strongest intermolecular force between NH_3 molecules.

(1)

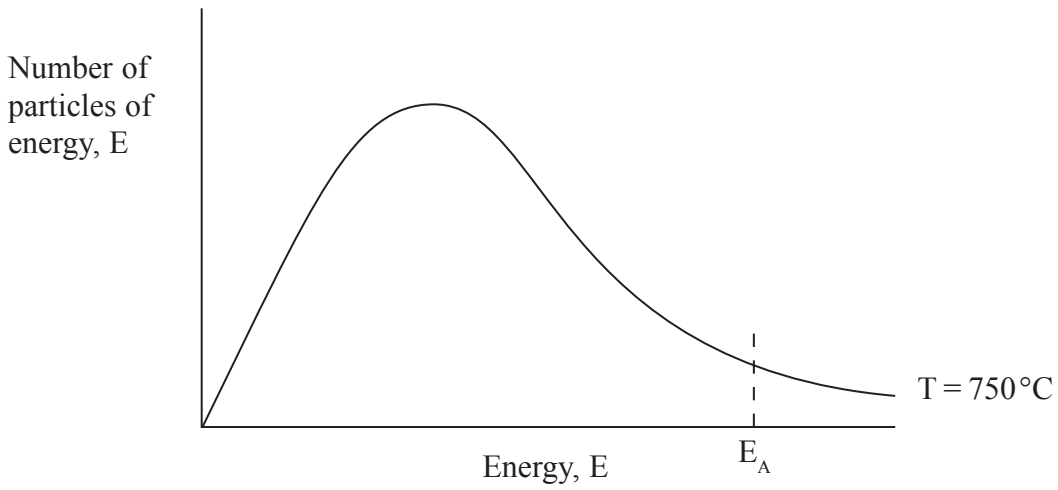
(c) Ammonia will react with oxygen in the presence of a platinum catalyst at 750 °C forming water and nitrogen(II) oxide, NO.

(i) What is the oxidation number of nitrogen in ammonia, NH_3?

(1)

(ii) The diagram below shows the distribution of molecular energies in the reaction at 750 °C. On the same diagram, draw a curve to show the distribution at 500 °C and explain what effect this change in temperature would have on the rate of the reaction.

(3)



Turn over ▶

*(d) Explain how a catalyst speeds up the rate of a reaction.

(3)

(Total for Question 20 = 14 marks)

TOTAL FOR SECTION B = 40 MARKS

SECTION C

21 Ethanoic acid is used industrially in the manufacture of polymers and glues and also in the food industry as an acidity regulator.

It can be synthesized in the laboratory by the reaction of ethanol with excess sodium dichromate(VI) solution, acidified with concentrated sulfuric acid. Ethanol is placed in a suitable flask along with some anti-bumping beads. The concentrated sulfuric acid is then added a drop at a time. The sodium dichromate(VI) solution is then added a drop at a time causing the mixture to boil spontaneously. When the addition of the sodium dichromate(VI) solution is complete, the mixture is heated under reflux for approximately 15 minutes. The ethanoic acid formed can then be separated from the reaction mixture.

$$CH_3CH_2OH \xrightarrow[\text{heat, 1 atm}]{\substack{Na_2Cr_2O_7 \\ H_2SO_4}} CH_3COOH$$

Ethanoic acid can be produced industrially by the Cativa™ process. Methanol, which can be obtained from wood, is reacted with carbon monoxide in the presence of an iridium catalyst.

$$CH_3OH(g) + CO(g) \underset{\text{190 °C}}{\overset{\text{Iridium catalyst, 20–30 atm}}{\rightleftharpoons}} CH_3COOH(g)$$

(a) (i) Balance the half-equation for the reduction of dichromate(VI) ions.

(1)

$Cr_2O_7^{2-}$ + ... H^+ + ... e^- → ..... Cr^{3+} + ... H_2O

(ii) The half-equation for the oxidation of ethanol is

$$CH_3CH_2OH + H_2O \rightarrow CH_3COOH + 4H^+ + 4e^-$$

Use this and your answer to (a)(i) to write a full equation for the overall reaction between acidified dichromate(VI) ions and ethanol. State symbols are **not** required.

(2)

(b) (i) Why are the concentrated sulfuric acid and sodium dichromate(VI) added a drop at a time in the laboratory process?

(1)

.....

.....

(ii) Draw a labelled diagram of the apparatus that could be used to heat the mixture under reflux.

(3)

(iii) What colour would the mixture be after it was heated under reflux?

(1)

.....

(c) A solution containing both water and ethanoic acid is produced by distillation of the final reaction mixture.

(i) Explain why the other products and any excess reactants are left behind in the distillation flask.

(1)

(ii) Suggest a method to separate pure ethanoic acid, boiling temperature 118 °C, from the water.

(1)

(d) (i) In the Cativa™ process what effect, if any, would increasing the pressure have on the yield of ethanoic acid? Justify your answer.

(2)

(ii) Suggest TWO reasons why it might be difficult, or undesirable, to produce ethanoic acid in industry by scaling up the laboratory process.

(2)

*(e) An alternative industrial process for the production of ethanoic acid is the oxidation of butane using a transition metal catalyst at 150 °C and 55–60 atm.

$$2C_4H_{10}(l) + 5O_2(g) \rightarrow 4CH_3COOH(aq) + 2H_2O(l)$$

Evaluate the 'greenness' and sustainability of the two industrial processes.

Suggest TWO additional pieces of information that would help you make a more informed decision.

(6)

(Total for Question 21 = 20 marks)

TOTAL FOR SECTION C = 20 MARKS
TOTAL FOR PAPER = 80 MARKS

mock papers 2

SECTION A

1 What is the oxidation number of chlorine in the ClO_3^- ion?

☒ **A** –1

☒ **B** +4

☒ **C** +5

☒ **D** +6

(Total for Question 1 = 1 mark)

2 Which of these reactions is **not** a redox reaction?

☒ **A** $Mg(NO_3)_2(s) \rightarrow MgO(s) + 2NO_2(g) + ½O_2(g)$

☒ **B** $HCl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(l)$

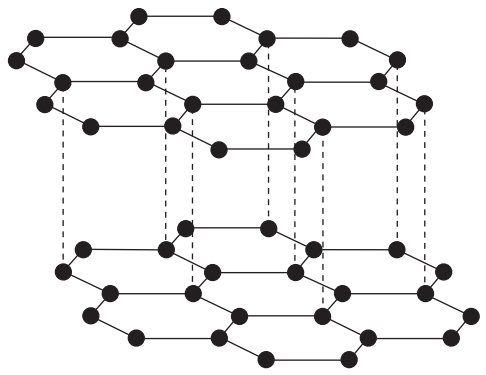
☒ **C** $Fe(s) + CuSO_4(aq) \rightarrow FeSO_4(aq) + Cu(s)$

☒ **D** $Cl_2(aq) + 2Br^-(aq) \rightarrow 2Cl^-(aq) + Br_2(aq)$

(Total for Question 2 = 1 mark)

Use this space for any rough working. Anything you write in this space will gain no credit.

3 Which of these carbon structures is represented by the diagram below?



☒ **A** Graphite

☒ **B** Diamond

☒ **C** A fullerene

☒ **D** A carbon nanotube

(Total for Question 3 = 1 mark)

4 What colour precipitate would you expect to see if 1-bromopropane was heated with a solution of silver nitrate?

☒ **A** Orange

☒ **B** White

☒ **C** Yellow

☒ **D** Cream

(Total for Question 4 = 1 mark)

5 Which of these bond angles is the smallest?

☒ **A** HNH in NH_3

☒ **B** HCH in CH_4

☒ **C** HOH in H_2O

☒ **D** OCO in CO_2

(Total for Question 5 = 1 mark)

6 Which statement best describes the shape and bond angles in the molecule SF_6?

☒ **A** Octahedral, 90° and 180°

☒ **B** Trigonal bipyramidal, 90° and 180°

☒ **C** Octahedral, 90° and 120°

☒ **D** Trigonal bipyramidal, 90° and 120°

(Total for Question 6 = 1 mark)

7 Which of the following values for the mass/charge ratio for singly charged ions would be present in the mass spectrum of propanal, CH_3CH_2CHO, but not of propanone, CH_3COCH_3?

☒ **A** 15

☒ **B** 29

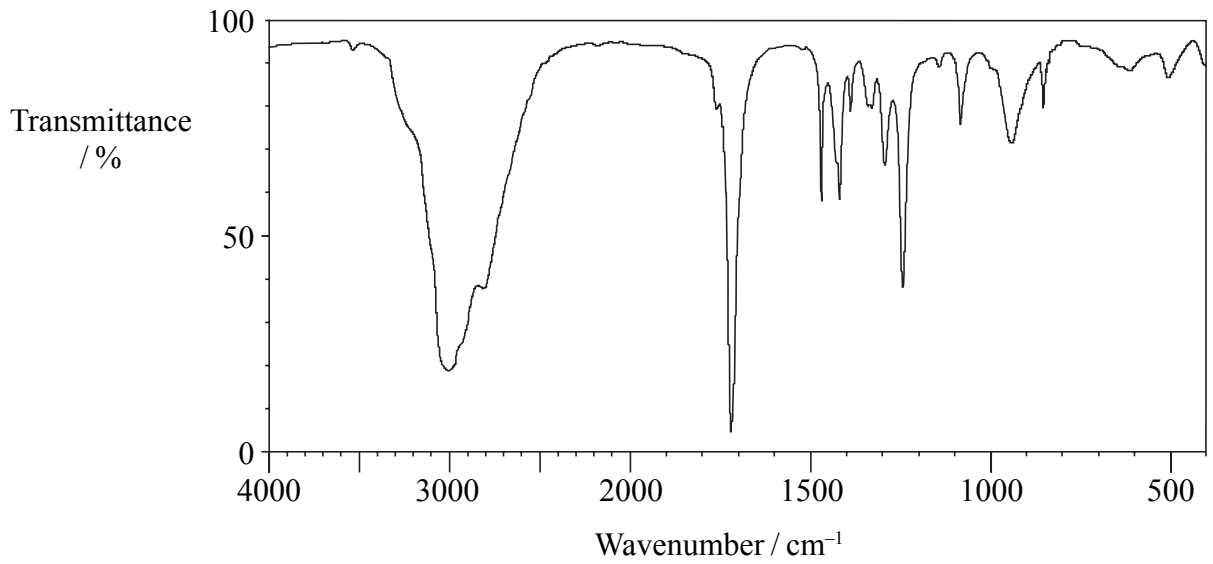
☒ **C** 43

☒ **D** 58

(Total for Question 7 = 1 mark)

Use this space for any rough working. Anything you write in this space will gain no credit.

8 The infrared spectrum below is most likely to be that of a member of which homologous series?



C—Cl stretching vibrations 600 – 800 cm^{-1}
O—H stretching vibrations 2500 – 3300 cm^{-1}
C═O stretching vibrations 1680 – 1740 cm^{-1}

☒ **A** Alcohol

☒ **B** Chloroalkane

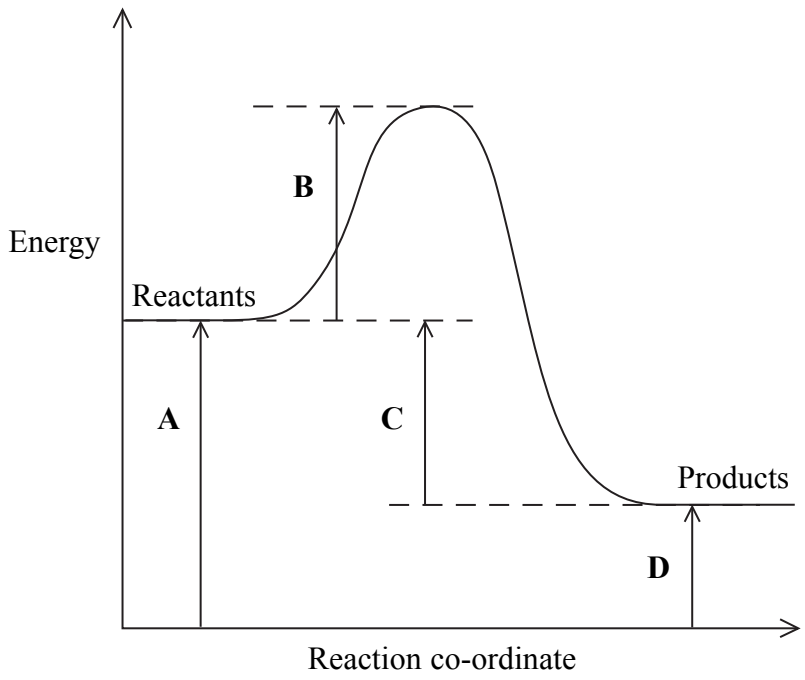
☒ **C** Aldehyde

☒ **D** Carboxylic acid

(Total for Question 8 = 1 mark)

Use this space for any rough working. Anything you write in this space will gain no credit.

9 In the reaction profile below, which energy change would alter if a catalyst was added to the reaction?



☒ **A**

☒ **B**

☒ **C**

☒ **D**

(Total for Question 9 = 1 mark)

Use this space for any rough working. Anything you write in this space will gain no credit.

10 In the equilibrium below, what effect would the changes described have on the system?

$$2H_2S(g) + SO_2(g) \rightleftharpoons 3S(s) + 2H_2O(g) \qquad \Delta H \text{ is negative}$$

(a) Increase in temperature

(1)

☒ **A** increase rate, decrease yield

☒ **B** increase rate, increase yield

☒ **C** decrease rate, decrease yield

☒ **D** decrease rate, increase yield

(b) Decrease in pressure

(1)

☒ **A** increase rate, decrease yield

☒ **B** increase rate, increase yield

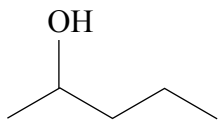
☒ **C** decrease rate, decrease yield

☒ **D** decrease rate, increase yield

(Total for Question 10 = 2 marks)

Use this space for any rough working. Anything you write in this space will gain no credit.

11 What is the correct systematic name for the alcohol shown below?



☒ **A** hexan-4-ol

☒ **B** hexan-2-ol

☒ **C** pentan-4-ol

☒ **D** pentan-2-ol

(Total for Question 11 = 1 mark)

12 Which of these compounds is a secondary halogenoalkane?

☒ **A** $CH_3CH(OH)CH_3$

☒ **B** $CH_3CCl(CH_3)CH_3$

☒ **C** $CH_3CHClCH_3$

☒ **D** $CH_3CH_2CH_2Cl$

(Total for Question 12 = 1 mark)

13 The bonding in **gaseous** hydrogen halides is best described as

☒ **A** mainly covalent with an increasing tendency towards ionic as you go down the group.

☒ **B** mainly covalent with an increasing tendency towards ionic as you go up the group.

☒ **C** mainly ionic with an increasing tendency towards covalent as you go down the group.

☒ **D** mainly ionic with an increasing tendency towards covalent as you go up the group.

(Total for Question 13 = 1 mark)

14 What would be the colour of the solution when iodine is dissolved in a hydrocarbon solvent?

☒ **A** Grey

☒ **B** Brown

☒ **C** Yellow

☒ **D** Purple

(Total for Question 14 = 1 mark)

15 Starch is often used as an indicator in titrations between sodium thiosulfate and iodine solutions. What colour change would you see at the end-point as sodium thiosulfate is added to iodine solution in the presence of starch?

☒ **A** Yellow to colourless

☒ **B** Colourless to yellow

☒ **C** Blue-black to colourless

☒ **D** Colourless to blue-black

(Total for Question 15 = 1 mark)

16 An electric field can affect the direction of a stream of some liquids. Which of these liquids would be affected by an electric field?

☒ **A** 1-chloropropane

☒ **B** Pentane

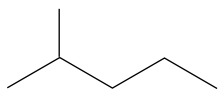
☒ **C** Tetrachloromethane

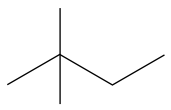
☒ **D** Cyclopentane

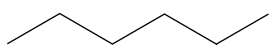
(Total for Question 16 = 1 mark)

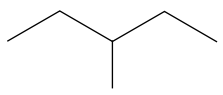
Use this space for any rough working. Anything you write in this space will gain no credit.

17 Which of these isomers has the highest boiling temperature?

☒ **A** 

☒ **B** 

☒ **C** 

☒ **D** 

(Total for Question 17 = 1 mark)

18 Which of the following statements is **true**?

☒ **A** Calcium hydroxide is more soluble in water than magnesium hydroxide.

☒ **B** Chlorine is more electronegative than fluorine.

☒ **C** Iodine is a stronger oxidizing agent than bromine.

☒ **D** The first ionization energy of barium is greater than that of strontium.

(Total for Question 18 = 1 mark)

19 Iodine can react with sodium hydroxide solution to form $NaIO_3(aq)$, according to the equation below.

$$3I_2(aq) + 6NaOH(aq) \rightarrow 5NaI(aq) + NaIO_3(aq) + 3H_2O(l)$$

Which of the statements about the reaction is **false**?

☒ **A** The oxidation number of some iodine atoms goes up.

☒ **B** At high temperatures NaIO(aq) also forms.

☒ **C** Sodium ions are spectator ions.

☒ **D** The oxidation number of some iodine atoms goes down.

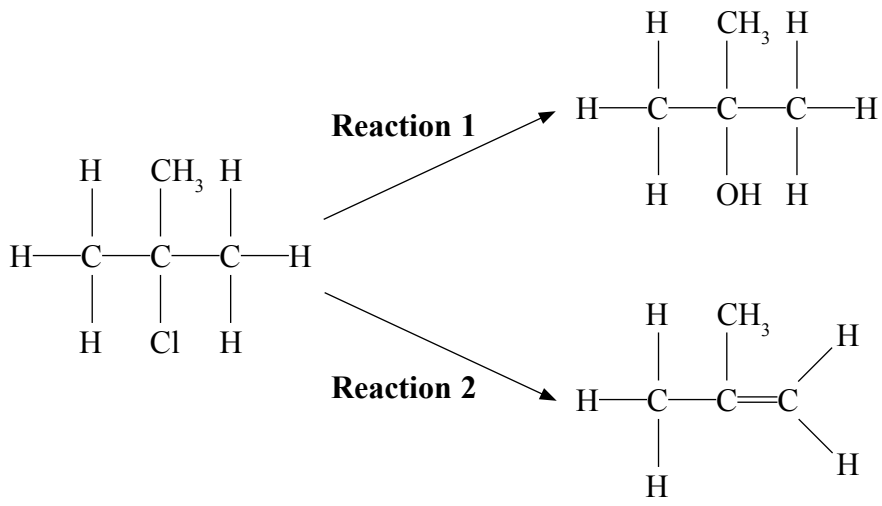
(Total for Question 19 = 1 mark)

TOTAL FOR SECTION A = 20 MARKS

SECTION B

Answer ALL the questions. Write your answers in the spaces provided.

20 When 2-chloro-2-methylpropane is heated in a mixture of water and ethanol at 65 °C, two types of reaction occur. A mixture of two organic products, 2-methylpropan-2-ol and 2-methylpropene, is formed.



(a) (i) Name the two reaction types that are taking place.

(2)

Reaction 1 .....

Reaction 2 .....

*(ii) Explain how the two products form, by describing the role of the water in each case.

(4)

Reaction 1 .....

.....

.....

.....

Reaction 2 .....

.....

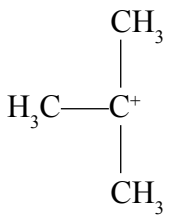
.....

.....

.....

Turn over ▶

(b) A proposed mechanism for **Reaction 1** involved the formation of the carbocation,



(i) What type of bond breaking must have occurred during the carbocation formation?

(1)

(ii) Suggest why 1-chlorobutane reacts with water via a different mechanism.

(2)

(c) Another halogenoalkane, 2-chlorobutane, behaves in a similar way to 2-chloro-2-methylpropane but in **Reaction 2** can form three different alkenes. Suggest how **three** different alkenes can form and give their displayed formulae.

(4)

(d) Suggest why 2-fluoro-2-methylpropane would react more slowly than 2-chloro-2-methylpropane in **Reaction 1**.

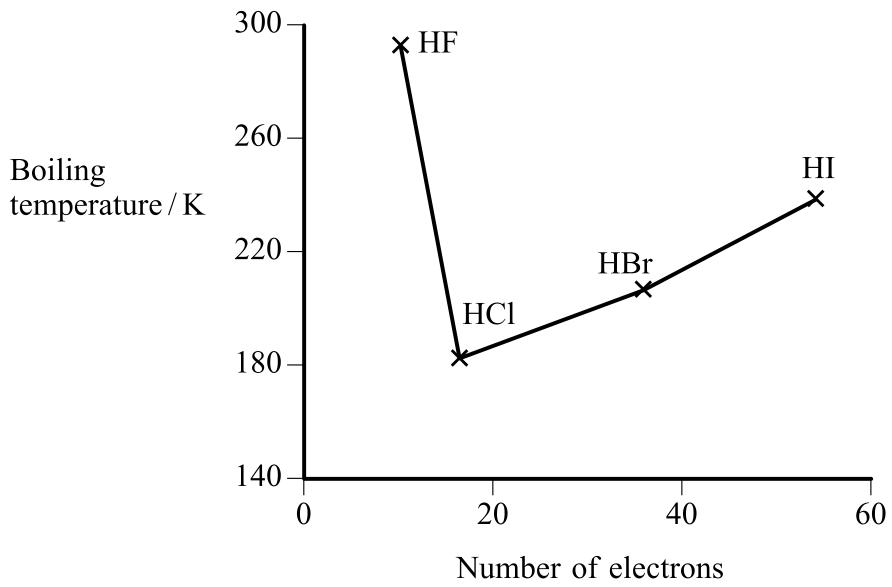
What reagent could you use instead of water to increase the rate of this reaction involving 2-fluoro-2-methylpropane? Explain why the reagent would have this effect.

(3)

(Total for Question 20 = 16 marks)

Turn over ▶

21 The graph below shows the boiling temperatures of the hydrides of Group 7.



(a) (i) Identify the type of intermolecular force that gives rise to the unusually high boiling temperature of hydrogen fluoride.

(1)

(ii) State and explain whether the electronegativity of fluorine is greater than, similar to or less than, that of bromine.

Hence explain why hydrogen fluoride can form the type of intermolecular force named in (a)(i) but hydrogen bromide cannot.

(3)

(iii) Use the graph to predict what the boiling temperature of hydrogen fluoride would be without the presence of the type of intermolecular force named in (a)(i).

(1)

(b) Propanone, CH_3COCH_3, is a useful solvent for cleaning glassware in laboratories.

(i) Why is propanone able to dissolve a wide range of substances?

(1)

(ii) Propanone can be used to remove both water and octane from glassware.

For each of these substances, identify the strongest intermolecular force formed with propanone and the feature of the propanone molecule involved.

(2)

Water

Octane

(Total for Question 21 = 8 marks)

22 Calcium oxide, known as quicklime, is produced by the thermal decomposition of calcium carbonate, found naturally in limestone.

(a) (i) Explain what is meant by the term **thermal decomposition**.

(2)

(ii) Write an equation for the thermal decomposition of calcium carbonate, including state symbols.

(1)

(iii) Other Group 2 carbonates can also undergo thermal decomposition. Describe and explain the trend in thermal stability of carbonates down Group 2.

(3)

(b) 0.121 g of an impure sample of quicklime was dissolved in 50.0 cm^3 of hydrochloric acid, concentration 0.100 mol dm^{-3}. The excess hydrochloric acid was titrated with sodium hydroxide solution, concentration 0.100 mol dm^{-3}, and 18.0 cm^3 was needed to just neutralize the acid. The indicator used was methyl orange.

The equations for the reactions involved are shown below.

$$CaO(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2O(l)$$

$$HCl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(l)$$

(i) What colour would the indicator be at the end-point?

(1)

(ii) Calculate the number of moles of hydrochloric acid that reacted with the sodium hydroxide solution.

(1)

(iii) Calculate the number of moles of hydrochloric acid originally added to the quicklime. Use this answer and your answer to (b)(ii) to calculate the number of moles of quicklime that reacted with the hydrochloric acid.

(2)

(iv) Calculate the percentage purity of the sample of quicklime. Give your answer to **three** significant figures.

(2)

(c) (i) Describe how to carry out a flame test on the impure sample of quicklime to confirm that it contains calcium ions.

(3)

(ii) If the flame test gave a green colour, in addition to the expected brick red flame, which Group 2 metal is also likely to be present?

(1)

(Total for Question 22 = 16 marks)

TOTAL FOR SECTION B = 40 MARKS

SECTION C

23

As levels of fossil fuel resources are getting lower, society is increasingly looking at the use of biofuels as alternatives to coal, oil and gas. Biofuels are derived from plants and examples include bioethanol, biodiesel and *Miscanthus*, a plant more commonly known as elephant grass. These fuels have the advantage of being renewable and the plants take in carbon dioxide as they grow.

Bioethanol is produced from crops such as sugar cane or corn. The raw plant material is treated to produce a sugary solution which is then fermented to produce ethanol, water and carbon dioxide gas. The ethanol is removed by distillation. The resulting solution contains about 96 % ethanol. The remaining water has to be removed by absorption using a suitable drying agent so that the ethanol can burn efficiently. The bioethanol can then be burnt alone or mixed with petrol in vehicle engines.

Biodiesel is formed by the hydrolysis of vegetable oils using sodium hydroxide solution, followed by esterification with methanol and a sodium hydroxide catalyst. Biodiesel can then be used on its own in diesel-engined vehicles or mixed with diesel derived from crude oil. Plants which are used to produce the vegetable oils include rapeseed in the UK, soya bean in the USA and palm oil in Asia.

Miscanthus, or elephant grass, is a quick growing, high-yield plant that grows up to four metres in height. After harvesting, the grass is left to dry and then burnt in power stations designed to run on solid fuels such as coal. In the United Kingdom, farms that produce elephant grass are normally situated within 50 miles of such a power station.

In an experiment to simulate the production of bioethanol, a student produced a water/ethanol mixture by fermentation of sucrose solution using yeast. It was then proposed to separate the ethanol from water by carrying out a distillation on the mixture. The mixture would then be dried using a suitable drying agent.

(a) Draw a diagram to show the most significant intermolecular force between an ethanol molecule and a water molecule. Label the bond angle between the molecules and state its value.

(2)

Turn over ▶

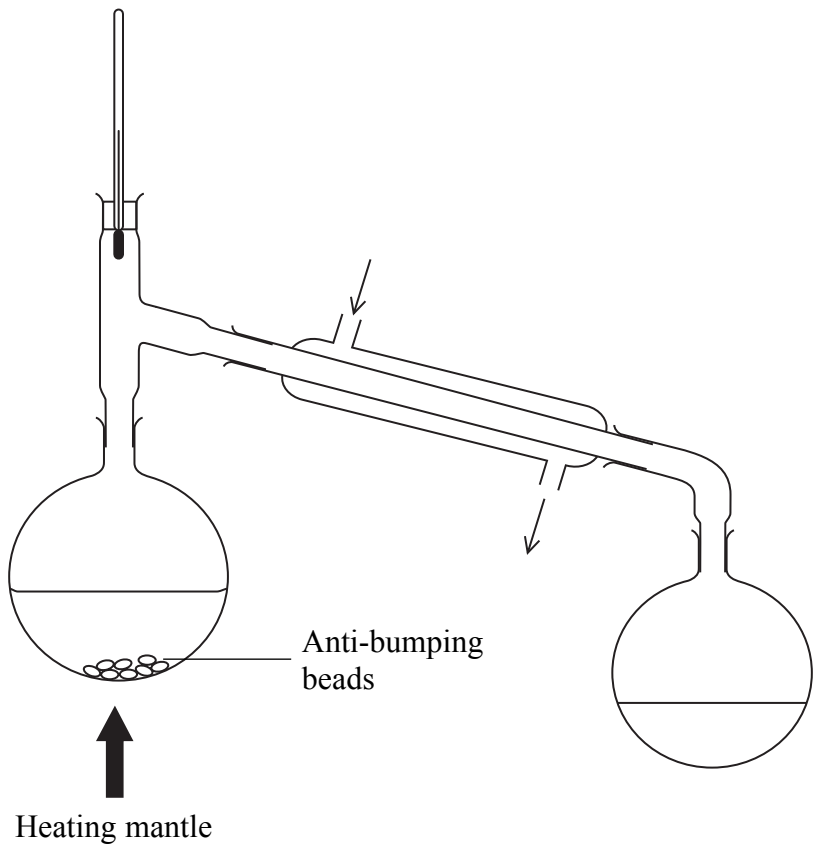
(b) The student proposed to set up the apparatus as shown below to carry out the distillation to try to separate the ethanol from water.

There are **three** errors with the set-up. Draw a circle around each error.

Describe what effect these errors would have if the student attempted to carry out the separation as shown.

[Clamps are not shown in the diagram but you can assume the apparatus is supported adequately.]

(6)



(c) If a balance accurate to two decimal places was used to record the mass of ethanol collected, what would be the percentage error due to the balance readings if the total mass of ethanol collected was 20.10 g?

(1)

(d) Suggest a suitable drying agent to absorb the water remaining with the ethanol after distillation. Describe how you would use it to produce a dry sample of ethanol.

(2)

Turn over ▶

(e) Describe a chemical test you could carry out to confirm the presence of the –OH group in ethanol. What result would you expect to see?

(2)

Test .....

.....

Result .....

(f) *(i) Explain what is meant by a **carbon neutral fuel**.

(2)

*(ii) Suggest TWO reasons why these biofuels may **not** be carbon neutral and describe TWO effects that large scale production of biofuels may have on society. Which of the three biofuels do you think is the most sustainable? Justify your choice.

(5)

(Total for Question 23 = 20 marks)

TOTAL FOR SECTION C = 20 MARKS
TOTAL FOR PAPER = 80 MARKS

mock papers 3

SECTION A

1 Which of the following bond angles occur in a molecule of ethanol, C_2H_5OH?

☒ **A** 90° and 180°

☒ **B** 104.5° and 180°

☒ **C** 104.5° and 109.5°

☒ **D** 109.5° and 120°

(Total for Question 1 = 1 mark)

2 Which of the following molecules is linear?

☒ **A** Carbon dioxide, CO_2

☒ **B** Sulfur dioxide, SO_2

☒ **C** Water, H_2O

☒ **D** Methanal, HCHO

(Total for Question 2 = 1 mark)

3 Which of the following molecules contains polar bonds but is **not** a polar molecule?

☒ **A** Chlorine, Cl_2

☒ **B** Hydrogen chloride, HCl

☒ **C** Trichloromethane, $CHCl_3$

☒ **D** Tetrachloromethane, CCl_4

(Total for Question 3 = 1 mark)

4 Which of the following has dipole-dipole interactions between its molecules, but no hydrogen bonding?

☒ **A** Methane, CH_4

☒ **B** Methanol, CH_3OH

☒ **C** Ammonia, NH_3

☒ **D** Hydrogen iodide, HI

(Total for Question 4 = 1 mark)

5 Which list below shows the compounds in order of **increasing** boiling temperature?

☒ **A** CH_4, HCl, HF

☒ **B** HF, CH_4, HCl

☒ **C** HCl, HF, CH_4

☒ **D** HF, HCl, CH_4

(Total for Question 5 = 1 mark)

6 Which of the following has the highest boiling temperature?

☒ **A** Pentane, $CH_3CH_2CH_2CH_2CH_3$

☒ **B** Hexane, $CH_3CH_2CH_2CH_2CH_2CH_3$

☒ **C** 2-methylbutane, $CH_3CH(CH_3)CH_2CH_3$

☒ **D** 2-methylpentane, $CH_3CH(CH_3)CH_2CH_2CH_3$

(Total for Question 6 = 1 mark)

7 Which of the following could **not** be an element in Group 2?

☒ **A** An element with an oxide which forms a solution of pH 10.

☒ **B** An element with an insoluble sulfate.

☒ **C** An element with a chloride which is liquid at room temperature.

☒ **D** An element with a carbonate which decomposes on heating.

(Total for Question 7 = 1 mark)

8 Chlorides of Group 1 elements produce coloured flames when

☒ **A** electrons become excited to a higher energy level.

☒ **B** excited electrons move from a higher to a lower energy level.

☒ **C** an outer electron leaves the atom.

☒ **D** electrons move between the negative and positive ions.

(Total for Question 8 = 1 mark)

Turn over ▶

9 This question is about the following compounds.

A Barium carbonate

B Lithium nitrate

C Potassium bromide

D Potassium nitrate

(a) Which compound gives a green colour in a flame test?

(1)

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(b) Which compound gives a lilac colour in a flame test and does **not** decompose on heating?

(1)

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(Total for Question 9 = 2 marks)

Use this space for any rough working. Anything you write in this space will gain no credit.

10 20 cm^3 of sulfuric acid, concentration 0.25 mol dm^{-3}, was neutralized in a titration with barium hydroxide, concentration 0.50 mol dm^{-3}. The equation for the reaction is

$$Ba(OH)_2(aq) + H_2SO_4(aq) \rightarrow BaSO_4(s) + 2H_2O(l)$$

(a) The volume of barium hydroxide required was

(1)

☒ **A** 10 cm^3

☒ **B** 20 cm^3

☒ **C** 25 cm^3

☒ **D** 40 cm^3

(b) During the titration, the barium hydroxide was added until it was present in excess. The electrical conductivity of the titration mixture

(1)

☒ **A** increased steadily.

☒ **B** decreased steadily.

☒ **C** increased and then decreased.

☒ **D** decreased and then increased.

(Total for Question 10 = 2 marks)

11 Which of the following trends occurs going down the elements in Group 2?

☒ **A** The solubility of the hydroxides increases.

☒ **B** The first ionization energy increases.

☒ **C** The solubility of the sulfates increases.

☒ **D** The stability of the carbonates to heat decreases.

(Total for Question 11 = 1 mark)

12 Which of the following is **not** a true statement about hydrogen iodide?

☒ **A** It forms steamy fumes in moist air.

☒ **B** It dissolves in water to form an acidic solution.

☒ **C** It forms a cream precipitate with silver nitrate solution.

☒ **D** It forms dense white smoke with ammonia.

(Total for Question 12 = 1 mark)

13 Chemical reactions may involve

A oxidation

B reduction

C no change in oxidation number

D disproportionation

Which of the terms above best describes what happens to the **chlorine** in the following reactions?

(a) $Cl_2(g) + H_2O(l) \rightarrow HCl(aq) + HOCl(aq)$

(1)

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(b) $Cl_2(g) + 2Na(s) \rightarrow 2NaCl(s)$

(1)

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(c) $NaCl(s) + H_2SO_4(l) \rightarrow HCl(g) + NaHSO_4(s)$

(1)

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(Total for Question 13 = 3 marks)

14 When chloroethane is heated with a concentrated solution of potassium hydroxide in **ethanol**, the reaction which occurs is

- ☒ **A** substitution.
- ☒ **B** elimination.
- ☒ **C** hydrolysis.
- ☒ **D** redox.

(Total for Question 14 = 1 mark)

Use this space for any rough working. Anything you write in this space will gain no credit.

15 Chloroethane reacts with **aqueous** potassium hydroxide solution, producing ethanol as the organic product.

(a) The hydroxide ion is acting as

(1)

☒ **A** an electrophile.

☒ **B** a nucleophile.

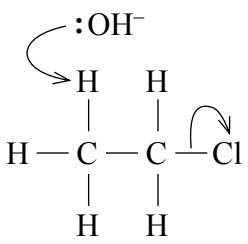
☒ **C** an oxidizing agent.

☒ **D** a reducing agent.

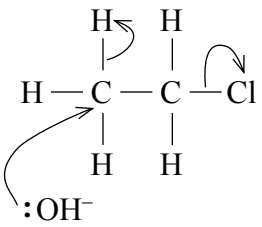
(b) Which of the following shows the correct electron-pair movements in this reaction?

(1)

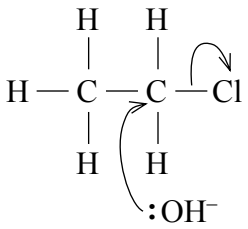
☒ **A**



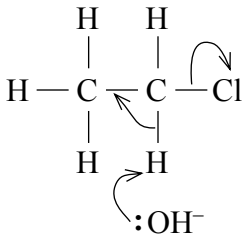
☒ **B**



☒ **C**



☒ **D**



(Total for Question 15 = 2 marks)

TOTAL FOR SECTION A = 20 MARKS

SECTION B

16 Magnesium nitrate, $Mg(NO_3)_2$, decomposes when it is heated. One product is the brown gas, nitrogen dioxide.

(a) (i) Write an equation for this reaction. State symbols are **not** required.

(2)

(ii) Calcium nitrate decomposes in a similar way to magnesium nitrate, but at a higher temperature.

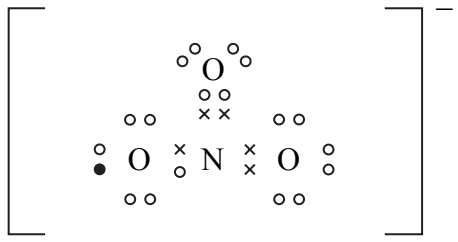
Explain why the two nitrates have different stability to heat.

(2)

(b) Sodium nitrate decomposes to give different products to magnesium nitrate. Write an equation for the decomposition of sodium nitrate. State symbols are **not** required.

(1)

(c) A student suggested that the structure of the nitrate ion, NO_3^-, is



Scientists have found that the bonds between nitrogen and oxygen in the nitrate ion are all the same length. Is the student's suggestion supported by this evidence? Explain your answer.

(1)

(d) Nitrogen dioxide gas can dimerize to dinitrogen tetroxide, N_2O_4, a very pale yellow gas, as shown in the equation below.

$$2NO_2(g) \rightleftharpoons N_2O_4(g) \qquad \Delta H = -58 \text{ kJ mol}^{-1}$$

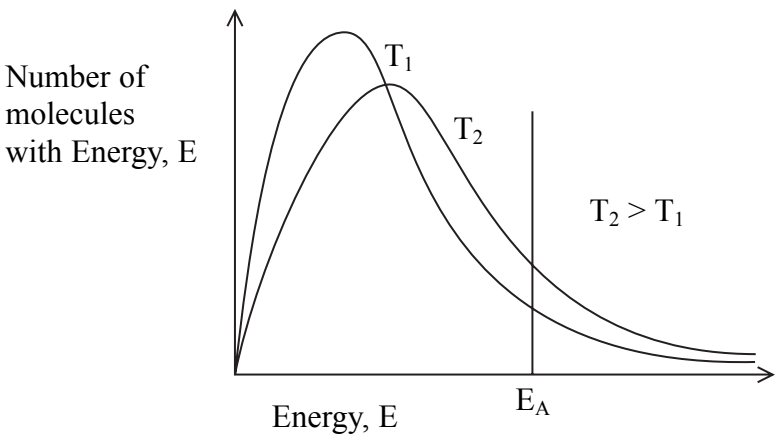
(i) What would you see when an equilibrium mixture of these gases is warmed gently? Explain your answer.

(2)

(ii) Explain why an equilibrium mixture of these gases eventually becomes paler in colour when the pressure on it is increased.

(2)

(e) Two Maxwell-Boltzmann distributions showing the energy of particles in a gas at different temperatures, T_1 and T_2, are shown below. The activation energy for the reaction is labelled E_A.



Use the distributions to explain why gases react faster when the temperature is increased.

(2)

(Total for Question 16 = 12 marks)

Turn over ▶

17 This question is about some reactions of halogens and halide ions.

(a) (i) When chlorine is added to a solution containing bromide or iodide ions, a colour change occurs. What solvent would you add to the mixture to confirm the identity of the halogen produced?

(1)

(ii) Give the result for the test with this solvent in a reaction in which bromine is produced.

(1)

(b) (i) Solid potassium bromide and potassium iodide can be distinguished by their reactions with concentrated sulfuric acid.

Potassium bromide reacts with concentrated sulfuric acid initially to produce hydrogen bromide. This reacts further, as shown below, to produce a sharp smelling gas and a brown fuming liquid.

$$2HBr(g) + H_2SO_4(l) \rightarrow SO_2(g) + Br_2(l) + 2H_2O(l)$$

Show, by use of oxidation numbers for sulfur, that the sulfuric acid has been reduced.

(2)

(ii) State TWO observations, which would differ from those with potassium bromide, when potassium iodide reacts with concentrated sulfuric acid.

(2)

(iii) One product of the reaction with potassium iodide is hydrogen sulfide, H_2S.
How does this show that iodide ions are more powerful reducing agents than bromide ions?

(1)

.....

.....

.....

.....

.....

.....

(c) In areas where the natural concentration of fluoride ions in rocks is low, some water authorities add fluoride to the water supply to improve the dental health of children. An alternative would be to supply free fluoride tablets.

Give ONE reason why it could be considered more ethical to supply free fluoride tablets rather than to add fluoride compounds to the water supply.

(1)

.....

.....

.....

.....

(Total for Question 17 = 8 marks)

18 Butan-1-ol and three other alcohols, **X**, **Y** and **Z**, are isomers.

(a) (i) Give TWO observations you would make when any one of the alcohols reacts with sodium.

(2)

.....

.....

.....

.....

(ii) Give the molecular formula of the organic product of the reaction.

(1)

.....

(b) Isomer **X** does **not** react with a mixture of potassium dichromate(VI) and sulfuric acid.

Draw the displayed formula of **X** and name it.

(2)

Name .....

(c) When isomer **Y** is heated under reflux with a mixture of potassium dichromate(VI) and sulfuric acid, it forms 2-methylpropanoic acid.

Deduce the structural formula of the alcohol **Y**.

(1)

(d) (i) Isomer **Z** reacts with a mixture of potassium dichromate(VI) and sulfuric acid to form a compound **Q**, which does **not** react with Fehling's or Benedict's solution.

Deduce the structural formula of the alcohol **Z**.

(1)

(ii) What would be the principal difference between the infrared spectrum of **Q** and the infrared spectrum of 2-methylpropanoic acid?

You are **not** expected to quote absorption values.

(1)

(e) One of the isomers, **X**, **Y** or **Z** can be converted to 2-chlorobutane.

What reagent would you use to carry out this conversion?

(1)

(f) (i) 2-chlorobutane reacts with silver nitrate in a mixture of ethanol and water as a solvent. What would you see when the reaction occurred?

(1)

*(ii) Both ethanol and water contain hydrogen bonds. By considering the hydrogen bonding on these two solvents, suggest why 2-chlorobutane is more soluble in ethanol than in water.

(2)

(Total for Question 18 = 12 marks)

19 The concentration of iodine in solution can be measured by titration with sodium thiosulfate solution.

$$I_2(aq) + 2S_2O_3^{2-}(aq) \rightarrow 2I^-(aq) + S_4O_6^{2-}(aq)$$

(a) Name a suitable indicator which could be used for this titration.

(1)

.....

(b) The amount of sulfur dioxide in the atmosphere can be measured by passing a known volume of air through iodine solution. Sulfur dioxide converts iodine to iodide ions.

$$SO_2(g) + I_2(aq) + 2H_2O(l) \rightarrow SO_4^{2-}(aq) + 4H^+(aq) + 2I^-(aq)$$

In an experiment, 100 m^3 of air were passed through 100 cm^3 of iodine, concentration 0.0100 mol dm^{-3}. The remaining iodine was titrated with sodium thiosulfate solution and reacted with 12.60 cm^3 of sodium thiosulfate, concentration 0.100 mol dm^{-3}.

(i) How many moles of iodine were present in the solution of the iodine at the start of the experiment?

(1)

(ii) How many moles of iodine remained in the solution at the end of the experiment?

(2)

(iii) Calculate the number of moles of iodine which **reacted** with the sulfur dioxide, and hence the number of moles of sulfur dioxide in 100 m^3 of air.

(2)

(iv) The European Commission recommend exposure to sulfur dioxide in air should be less than 350 micrograms (350×10^{-6} g) per cubic metre.

Calculate whether the sulfur dioxide in this sample of air was within this limit. One mole of sulfur dioxide has mass 64.1 g.

(2)

(c) Explain whether the changes below would or would not improve the experimental procedure for measuring the concentration of sulfur dioxide in air used in (b).

(i) The 100 cm^3 of iodine was divided into 25 cm^3 samples before titration.

(1)

(ii) The concentration of sodium thiosulfate used to titrate the iodine was changed from 0.100 mol dm^{-3} to 0.050 mol dm^{-3}.

(2)

(iii) 150 m^3 of air was passed through the iodine. The solutions used were of the same concentrations as in the original experiment.

(2)

(Total for Question 19 = 13 marks)

TOTAL FOR SECTION B = 45 MARKS

SECTION C

20

Fuel from the air?

A new catalyst that can break down carbon dioxide gas could allow us to use carbon from the atmosphere as a fuel source in a similar way to plants.

Plants break the stable bonds in carbon dioxide during photosynthesis. In the natural process, the carbon dioxide molecule is initially bonded to nitrogen atoms, making reactive compounds called carbamates. Carbamates are derivatives of carbamic acid, NH_2CO_2H. These compounds can then be broken down, allowing the carbon to be used in the synthesis of other plant products such as sugars and proteins.

A new catalyst produced by scientists is a graphite-like compound made from flat layers of carbon and nitrogen atoms arranged in hexagons. Carbon dioxide binds to the catalyst and takes part in the following reaction, which occurs at 150 °C and at about three times atmospheric pressure.

$$\underset{\text{benzene}}{C_6H_6} + CO_2 \rightarrow \underset{\text{phenol}}{C_6H_5OH} + CO$$

Carbon monoxide can then be used to make liquid fuels such as methanol.

The energy required for photosynthesis comes from light, and experiments are now going on to develop a light activated catalyst which could break down carbon dioxide in a new process.

(Source: adapted from an article from the *NewScientist.com* by Tom Simonite, March 2007)

*(a) Why are the bonds **within** a layer of carbon atoms in graphite stronger than the bonds **between** the layers of carbon atoms?

(2)

.....

.....

.....

.....

(b) The data below gives the relative electrical conductivity of a pure graphite crystal.

Relative conductivity in plane of carbon hexagons	Relative conductivity perpendicular to plane of carbon hexagons
3.7	0.0017

Explain why the relative electrical conductivity of graphite differs with direction.

(2)

(c) Suggest why the strength of the bond between the layers in graphite would increase if some carbon atoms were replaced with nitrogen atoms.

(2)

(d) Suggest ONE benefit of using a light activated catalyst for the new process.

(1)

(e) The liquid fuel, methanol, is made by reacting carbon monoxide with hydrogen.

Write an equation for this reaction. State symbols are **not** required.

(1)

*(f) Benzene, which is needed for the new process of breaking down carbon dioxide, can be made from coal. It is now usually made by catalytic treatment of one fraction of crude oil at temperatures of around 500 °C and 20 atmospheres pressure.

Suggest the benefits and disadvantages of breaking down carbon dioxide using benzene and the catalyst as described in the passage. You should consider

- the energy and resources needed
- the effects on the atmosphere
- whether it is a beneficial method for producing energy compared to direct use of fossil fuels.

(6)

(g) Carbon exists in forms other than graphite. Nanotubes are rolls of graphite layers, and fullerenes are cages of carbon atoms. Both nanotubes and fullerenes can trap other substances in their structures, and fullerenes can be coated with other substances.

Give ONE application of carbon nanotubes or fullerenes which exploits this behaviour.

(1)

.....

(Total for Question 20 = 15 marks)

TOTAL FOR SECTION C = 15 MARKS
TOTAL FOR PAPER = 80 MARKS

mock papers 4

SECTION A

1 This question is about bond angles.

A 90°

B 104°

C 107°

D 109.5°

Select, from A to D above, the most likely value for the bond angle of

(a) HCH in methane, CH_4.

(1)

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(b) FSF in sulfur hexafluoride, SF_6.

(1)

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(c) FOF in oxygen difluoride, OF_2.

(1)

☒ **A**

☒ **B**

☒ **C**

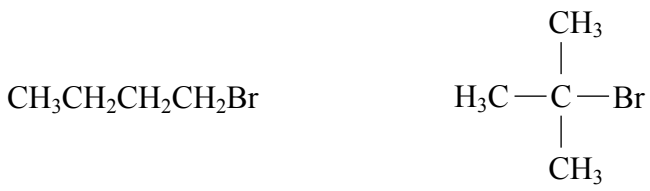
☒ **D**

(Total for Question 1 = 3 marks)

2 Consider the following compounds, **P**, **Q**, **R** and **S**.

Compound P

Compound Q



Compound R

Compound S

The boiling temperatures of compounds P, Q, R and S **increase** in the order

☒ **A** P Q R S

☒ **B** R S P Q

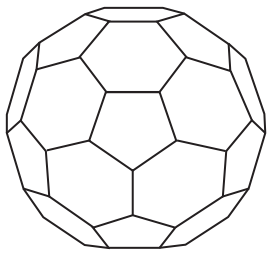
☒ **C** Q S P R

☒ **D** Q P S R

(Total for Question 2 = 1 mark)

Turn over ▶

3 Buckminsterfullerene has the formula C_{60}. Its structure is shown below.



The bonding in buckminsterfullerene is similar to the bonding in graphite.

Which of the following is true?

☒ **A** All the bond angles in buckminsterfullerene are 120°.

☒ **B** The melting temperature of buckminsterfullerene is higher than that of graphite.

☒ **C** There are delocalized electrons in buckminsterfullerene.

☒ **D** On complete combustion, buckminsterfullerene forms carbon dioxide and water.

(Total for Question 3 = 1 mark)

4 When concentrated sulfuric acid is added to solid sodium bromide, bromine is produced.

When concentrated sulfuric acid is added to solid sodium chloride, **no** chlorine is produced.

The reason for this difference is

☒ **A** sulfuric acid is a strong acid.

☒ **B** hydrogen chloride is a weak acid.

☒ **C** the chloride ion is a weaker reducing agent than the bromide ion.

☒ **D** bromine is less volatile than chlorine.

(Total for Question 4 = 1 mark)

Use this space for any rough working. Anything you write in this space will gain no credit.

5 Compound **X** is a white solid. On heating this compound, a colourless, acidic gas is the only gaseous product. A flame test is carried out on the solid residue and a reddish flame is observed.

Compound **X** is

☒ **A** calcium nitrate.

☒ **B** calcium carbonate.

☒ **C** magnesium carbonate.

☒ **D** strontium nitrate.

(Total for Question 5 = 1 mark)

6 Which of the following does **not** apply to the elements Mg, Ca, Sr and Ba in Group 2 of the Periodic Table?

☒ **A** Their oxides, MO, are all basic.

☒ **B** Their metal hydroxides, $M(OH)_2$, become more soluble down the group.

☒ **C** Their oxides, MO, react with water to form the metal hydroxide, $M(OH)_2$.

☒ **D** Their carbonates, MCO_3, all decompose on gentle heating.

(Total for Question 6 = 1 mark)

7 Which of the following compounds shows hydrogen bonding in the liquid state?

☒ **A** Hydrogen bromide, HBr

☒ **B** Hydrogen sulfide, H_2S

☒ **C** Silane, SiH_4

☒ **D** Ammonia, NH_3

(Total for Question 7 = 1 mark)

Use this space for any rough working. Anything you write in this space will gain no credit.

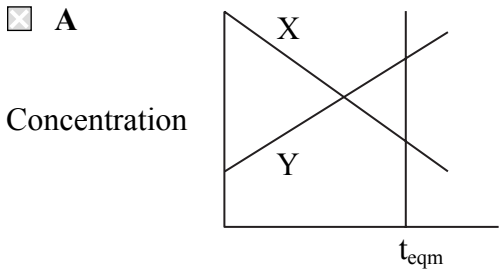
Turn over ▶

8 For the reversible reaction

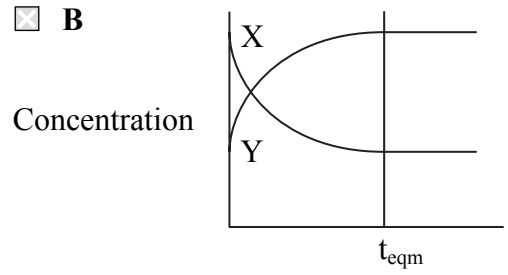
$$X \rightleftharpoons Y$$

which of the following could represent the change in the concentrations of X and Y with time, starting with a mixture of both X and Y? Equilibrium is reached at time t_{eqm}.

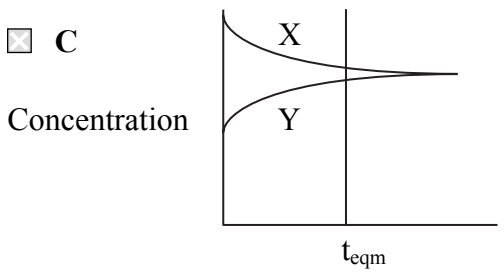
☒ **A**



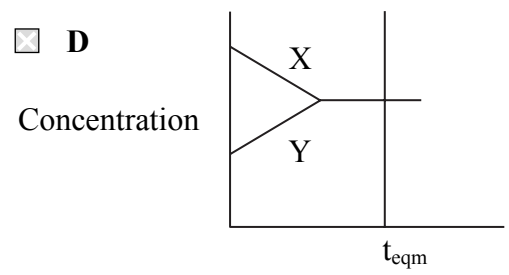
☒ **B**



☒ **C**



☒ **D**



(Total for Question 8 = 1 mark)

9 Which of the following molecules is polar?

☒ **A** Carbon dioxide, CO_2

☒ **B** Beryllium chloride, $BeCl_2$

☒ **C** Ammonia, NH_3

☒ **D** Boron trifluoride, BF_3

(Total for Question 9 = 1 mark)

Use this space for any rough working. Anything you write in this space will gain no credit.

10 The electronegativities of four pairs of elements are given below. Which pair would form the compound with the greatest ionic character?

☒ **A** 0.7 and 4.0

☒ **B** 0.7 and 3.5

☒ **C** 1.0 and 4.0

☒ **D** 0.8 and 2.8

(Total for Question 10 = 1 mark)

11 Which of the following statements about the elements in Group 7 is **incorrect**?

☒ **A** They all show variable oxidation states in their compounds.

☒ **B** They all form acidic hydrides.

☒ **C** Electronegativity decreases as the group is descended.

☒ **D** They all exist as diatomic molecules.

(Total for Question 11 = 1 mark)

12 What are the products, other than water, when chlorine is passed through cold, dilute aqueous sodium hydroxide solution?

☒ **A** NaCl and NaClO

☒ **B** NaClO and $NaClO_3$

☒ **C** NaCl and $NaClO_3$

☒ **D** NaClO and $NaClO_4$

(Total for Question 12 = 1 mark)

Use this space for any rough working. Anything you write in this space will gain no credit.

13 When solutions of iodine are titrated with aqueous sodium thiosulfate solution, $Na_2S_2O_3(aq)$, the thiosulfate ions are oxidized to

☒ **A** $S_2O_4^{2-}$

☒ **B** $S_2O_6^{2-}$

☒ **C** $S_2O_8^{2-}$

☒ **D** $S_4O_6^{2-}$

(Total for Question 13 = 1 mark)

14 The best method of converting ethanol, C_2H_5OH, into iodoethane, C_2H_5I, is to

☒ **A** heat iodine and ethanol under reflux.

☒ **B** react ethanol and potassium iodide in the presence of dilute acid.

☒ **C** heat potassium iodide and ethanol with concentrated sulfuric acid.

☒ **D** heat red phosphorus, ethanol and iodine under reflux.

(Total for Question 14 = 1 mark)

15 The use of poly(ethene) packaging has been criticised mainly because

☒ **A** the complete combustion of poly(ethene) produces dangerous fumes.

☒ **B** large amounts of oil are consumed in producing the monomer, ethene.

☒ **C** poly(ethene) degrades to form toxic products.

☒ **D** the catalyst used in the polymerization of ethene is expensive.

(Total for Question 15 = 1 mark)

16 Which of the following is essential if a species is to act as a nucleophile?

☒ **A** A lone pair of electrons.

☒ **B** A negative charge.

☒ **C** An unpaired electron.

☒ **D** A strongly polar bond.

(Total for Question 16 = 1 mark)

17 Calculate the volume of dilute sulfuric acid, concentration 0.500 mol dm^{-3}, required to neutralize 20.0 cm^3 aqueous sodium hydroxide, concentration 0.100 mol dm^{-3}.

$$H_2SO_4 + 2NaOH \rightarrow Na_2SO_4 + 2H_2O$$

☒ **A** 2.0 cm^3

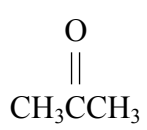
☒ **B** 4.0 cm^3

☒ **C** 8.0 cm^3

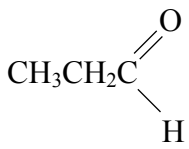
☒ **D** 20.0 cm^3

(Total for Question 17 = 1 mark)

18 Which of the following features is shown by the mass spectra of propanone and propanal?



propanone



propanal

		m/e of the molecular ion	Fragmentation pattern
☒	**A**	same	same
☒	**B**	same	different
☒	**C**	different	same
☒	**D**	different	different

(Total for Question 18 = 1 mark)

TOTAL FOR SECTION A = 20 MARKS

SECTION B

19 A student carried out an experiment to determine the concentration of ethanoic acid in a solution of vinegar.

- The student used a measuring cylinder to measure out 25.0 cm^3 of the vinegar solution.
- This solution was then transferred to a 250 cm^3 volumetric flask and the liquid level was carefully made up to the mark with distilled water.
- A pipette was used to transfer 25.0 cm^3 portions of the acidic solution to conical flasks.
- The solution was then titrated with sodium hydroxide solution, concentration 0.100 mol dm^{-3}, using phenolphthalein as the indicator.

$$CH_3COOH(aq) + NaOH(aq) \rightarrow CH_3COONa(aq) + H_2O(l)$$

Results

Titration number	1	2	3	4
Burette reading (final) / cm^3	28.55	28.00	40.35	28.05
Burette reading (initial) / cm^3	0.00	0.05	12.30	0.05
Volume of NaOH used / cm^3	28.55	27.95	28.05	28.00

(a) In this titration, what is the colour change of the phenolphthalein indicator?

(2)

From ..... **to** .....

(b) Explain why the mean titre should be based only on titrations 2, 3 and 4.

(1)

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.....

.....

(c) Calculate the mean titre in cm^3.

(1)

(d) (i) Using your answer to (c), calculate the number of moles of sodium hydroxide in the mean titre.

(1)

(ii) Hence state the number of moles of ethanoic acid, CH_3COOH, in 25.0 cm^3 of the **diluted** solution used in the titration.

(1)

(iii) Calculate the concentration of the **diluted** acid solution in mol dm^{-3}.

(1)

(iv) Hence calculate the concentration of the ethanoic acid in the **original** vinegar solution in mol dm^{-3}.

(1)

(v) Use your answer from (d)(iv) to state the concentration of the ethanoic acid in the **original** vinegar solution in units of g dm^{-3}.

[The molar mass of the ethanoic acid is 60 g mol^{-1}.]

(1)

(e) Suggest, with a reason, how the student's method of preparing the diluted solution could be improved.

(2)

Improvement

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Reason

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(f) The burette used in the titration had an uncertainty for each reading of ±0.05 cm^3.

(i) Identify, by letter, which ONE of the following should be regarded as the true value of the titre in titration number **2**?

X Between 27.90 and 28.00 cm^3

Y Between 27.925 and 27.975 cm^3

Z Between 27.85 and 28.05 cm^3

(1)

.....

(ii) Suggest ONE reason why a student may obtain volumes outside the uncertainty of the burette when performing a titration.

(1)

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(Total for Question 19 = 13 marks)

20 (a) Propene, C_3H_6, reacts with hydrogen bromide, HBr, in an electrophilic addition reaction.

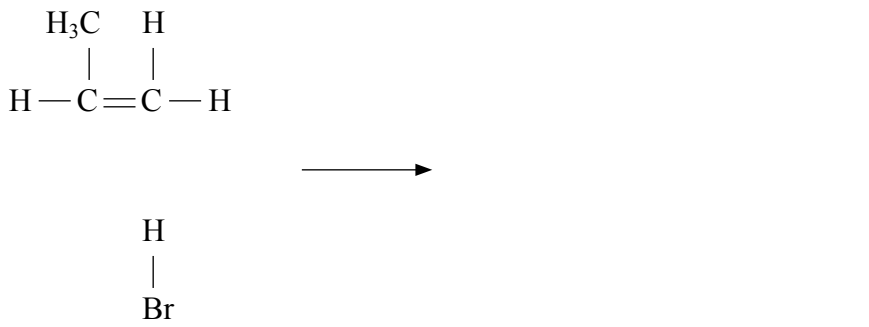
2-bromopropane is formed as the major product.

$$H_3CCH{=}CH_2 + HBr \rightarrow H_3CCH(Br)CH_3$$

(i) Complete the mechanism for the reaction, using 'curly arrows' where appropriate. Show clearly the structure of the intermediate carbocation formed.

(3)

Mechanism



(ii) Draw the structure of the alternative carbocation that can be formed in the reaction between propene and hydrogen bromide.

(1)

(b) Four isomers, each with the molecular formula $C_4H_{10}O$, are shown below.

Isomer **A**: $CH_3CH_2CH_2CH_2OH$

Isomer **B**: $CH_3CH_2CH(OH)CH_3$

Isomer **C**: $(CH_3)_3COH$

Isomer **D**: $CH_3CH(CH_3)CH_2OH$

(i) Which isomer is a secondary alcohol? Justify your answer.

(2)

(ii) Which isomer is resistant to oxidation when heated with acidified potassium dichromate(VI)? Justify your answer in terms of the structure of the isomer.

(2)

(iii) Which isomer can be oxidized to a ketone? Draw the displayed formula of the ketone produced.

(1)

(iv) Which isomers can be oxidized to an aldehyde?

(1)

(v) Phosphorus(V) chloride (phosphorus pentachloride), PCl_5, is used to test for the presence of an –OH group.

What would you expect to see when any of the above four isomers, A, B, C or D, are reacted with phosphorus(V) chloride?

(1)

(vi) Complete the equation for the reaction shown below. State symbols are **not** required.

(2)

$C_4H_9OH + PCl_5 \rightarrow$

(Total for Question 20 = 13 marks)

21 (a) In the catalytic converter of a car engine's exhaust system, the following reaction occurs.

$2NO(g) + 2CO(g) \rightleftharpoons N_2(g) + 2CO_2(g)$ $\Delta H = -745$ kJ mol^{-1}

The temperature in a catalytic converter is high.

(i) State the effect, if any, on the position of equilibrium if the temperature is lowered. Give a reason for your answer.

(2)

Effect .....

Reason .....

.....

(ii) The gases from the engine are **not** cooled before entering the converter. Explain why this is so.

(2)

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(iii) State the effect, if any, on the position of equilibrium if the pressure on the reacting gases is increased. Give a reason for your answer.

(2)

Effect .....

Reason .....

.....

(b) Nitrogen monoxide, NO, is formed when nitrate ions, NO_3^-, in acidic solution are reduced by silver metal.

(i) Calculate the oxidation number of nitrogen in NO and in NO_3^-.

(2)

In NO .....

In NO_3^- .....

(ii) Balance the half-equation for the reduction of nitrate ions, NO_3^-, in acidic solution.

(1)

$$NO_3^- + \text{.....}H^+ + \text{.....}e^- \rightarrow NO + \text{.....}H_2O$$

(iii) Write the half-equation for the oxidation of silver metal, Ag, to silver ions, Ag^+.

(1)

(iv) Hence deduce the full ionic equation for the reaction between silver metal and nitrate ions in acidic solution. State symbols are **not** required.

(2)

(Total for Question 21 = 12 marks)

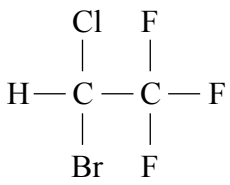
TOTAL FOR SECTION B = 38 MARKS

SECTION C

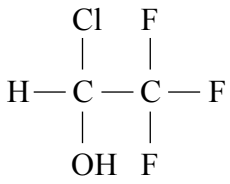
22 This question is about the chemistry of some halogenoalkanes.

Halothane is a colourless and sweet-smelling liquid. It has a boiling temperature of 50 °C. Halothane vapour was used as a general anaesthetic in hospitals during the mid to late 20th Century. Patients inhaled the halothane vapour under medical supervision. However, halothane was found to have some adverse side-effects and was therefore replaced by other halogenoalkane anaesthetics.

Halothane has the structure



In an experiment, halothane was heated in a test tube with aqueous silver nitrate and ethanol, using a water bath. Compound **X** and bromide ions were formed. The structure of compound **X** is shown below.



Compound **X**

(a) (i) Give the systematic name of halothane.

(1)

(ii) Suggest the types of intermolecular force present between molecules of liquid halothane.

(2)

Turn over ▶

(iii) In the above experiment, suggest ONE reason why a water bath was used rather than heating the test tube containing the reaction mixture directly over a Bunsen flame.

(1)

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(iv) Suggest why ethanol was used in this experiment.

(1)

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(v) What would be seen in the test tube as the reaction progressed?

(1)

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(vi) Write an ionic equation to show the reaction between aqueous silver ions and aqueous bromide ions. Include state symbols in your equation.

(1)

(b) Chloroethane, C_2H_5Cl, can also be used as an anaesthetic. In an experiment, chloroethane was hydrolysed by aqueous sodium hydroxide, NaOH.

(i) Name, and give the structural formula of, the organic product of the hydrolysis of chloroethane.

(2)

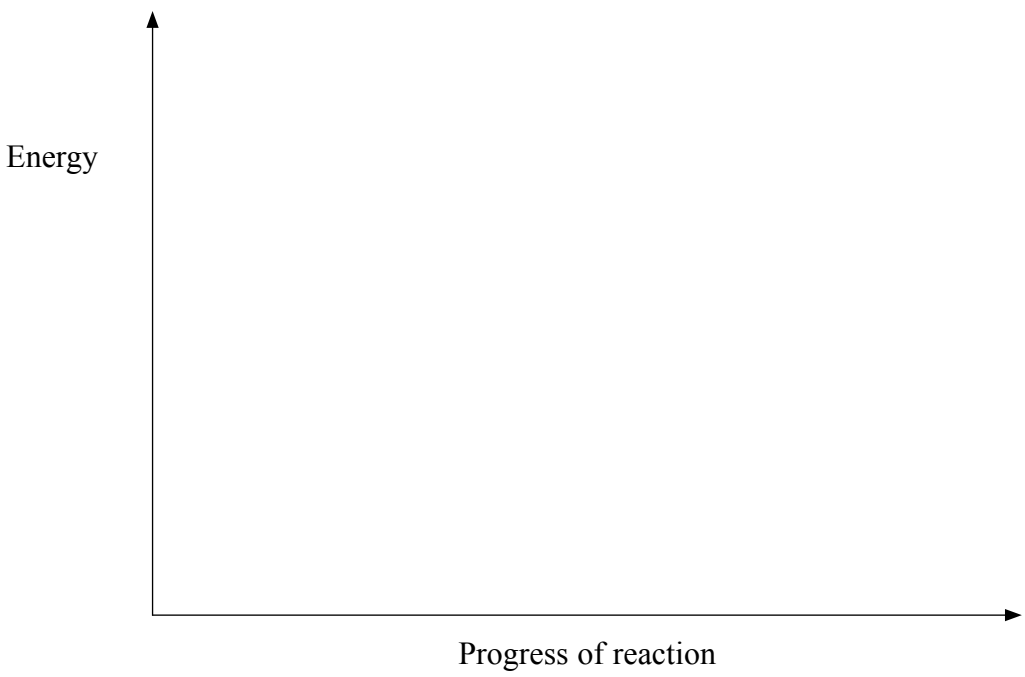
Name .....

Structural formula .....

(ii) The hydrolysis of chloroethane is an exothermic reaction which takes place in a single step.

On the diagram below, draw the energy profile for the reaction. Label clearly the activation energy for the reaction.

(3)



(c) In the early 1900s, the CFC with formula CCl_2F_2, was identified as a refrigerant which was both non-flammable and non-toxic.

(i) What does the term **CFC** stand for?

(1)

.....

(ii) Suggest ONE use for CFCs other than as a refrigerant.

(1)

.....

*(iii) In the stratosphere, CFCs are broken down by absorption of UV radiation to form chlorine free radicals.

The following two reactions occur.

$$Cl\bullet + O_3 \rightarrow ClO\bullet + O_2$$

$$ClO\bullet + O \rightarrow Cl\bullet + O_2$$

Combine these two equations to give the overall equation for the reaction of ozone in the stratosphere. State the role played by the chlorine free radical in the overall reaction. Hence explain why many scientists consider the effect of CFCs on ozone to be harmful.

(5)

(d) The compound of formula CH_2F_2 has replaced several CFCs for commercial use. If molecules of CH_2F_2 reach the stratosphere, they do not break down to produce fluorine free radicals.

(i) Suggest why C–F bonds are **not** broken in the stratosphere.

(1)

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*(ii) The compound CH_2F_2 acts as a greenhouse gas when it absorbs a particular type of radiation.

Name the type of radiation and explain why a molecule of CH_2F_2 is able to absorb this radiation.

(2)

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(Total for Question 22 = 22 marks)

TOTAL FOR SECTION C = 22 MARKS
TOTAL FOR PAPER = 80 MARKS