UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS
General Certificate of Education
Advanced Subsidiary Level and Advanced Level

CHEMISTRY **9701/11**

Paper 1 Multiple Choice **October/November 2011**

1 hour

Additional Materials: Multiple Choice Answer Sheet
Soft clean eraser
Soft pencil (type B or HB is recommended)
Data Booklet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
Do not use staples, paper clips, highlighters, glue or correction fluid.
Write your name, Centre number and candidate number on the Answer Sheet in the spaces provided unless this has been done for you.

There are **forty** questions on this paper. Answer **all** questions. For each question there are four possible answers **A**, **B**, **C** and **D**.
Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Answer Sheet.

Read the instructions on the Answer Sheet very carefully.

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This document consists of **14** printed pages and **2** blank pages.

Section A

For each question there are four possible answers, **A**, **B**, **C**, and **D**. Choose the **one** you consider to be correct.

1 Three elements, **X**, **Y** and **Z**, have the physical properties shown in the table.

element	melting point / °C	boiling point / °C	density / g cm^{3}
X	–7	59	3.12
Y	98	883	0.97
Z	649	1107	1.74

What could be the identities of **X**, **Y** and **Z**?

	X	**Y**	**Z**
A	Br_2	A*l*	Si
B	Br_2	Na	Mg
C	I_2	Mg	Na
D	I_2	Si	K

2 *Use of the Data Booklet is relevant to this question.*

Lead(IV) chloride will oxidise bromide ions to bromine. The Pb^{4+} ions are reduced to Pb^{2+} ions in this reaction.

If 6.980 g of lead(IV) chloride is added to an excess of sodium bromide solution, what mass of bromine would be produced?

A 0.799 g **B** 1.598 g **C** 3.196 g **D** 6.392 g

3 Which element has an equal number of electron pairs and of unpaired electrons within orbitals of principal quantum number 2?

A beryllium

B carbon

C nitrogen

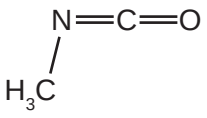
D oxygen

4 Methyl isocyanate, CH_3NCO, is a toxic liquid which is used in the manufacture of some pesticides.

In the methyl isocyanate molecule, the sequence of atoms is $H_3C—N=C=O$.

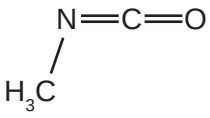
What is the approximate angle between the bonds formed by the N atom?

A



104°

B



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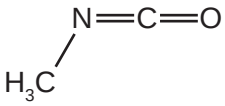
C



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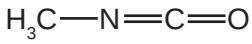
D



180°

5 At room temperature and pressure chlorine does not behave as an ideal gas.

At which temperature and pressure would the behaviour of chlorine become more ideal?

	pressure / kPa	temperature / K
A	50	200
B	50	400
C	200	200
D	200	400

6 The standard enthalpy change for the reaction

$$2NF_3(g) \rightarrow 2N(g) + 6F(g) \qquad \text{is } \Delta H^{\ominus} = +1668\,\text{kJ}$$

What is the bond energy of the N–F bond?

A $-556\,\text{kJ mol}^{-1}$

B $-278\,\text{kJ mol}^{-1}$

C $+278\,\text{kJ mol}^{-1}$

D $+556\,\text{kJ mol}^{-1}$

[Turn over

7 When chlorine and aqueous sodium hydroxide are heated together the following overall reaction occurs.

$$3Cl_2(aq) + 6NaOH(aq) \rightarrow 5NaCl(aq) + NaClO_3(aq) + 3H_2O(l)$$

What are the oxidation numbers for chlorine in each of the following species?

	Cl_2	$NaCl$	$NaClO_3$
A	0	+1	–5
B	+2	–1	+3
C	0	–1	+5
D	–2	+1	–3

8 Sulfur dioxide is used as a preservative in wine making.

The following equations describe how sulfur dioxide dissolves.

$$H_2O + SO_2 \rightleftharpoons HSO_3^- + H^+$$

$$HSO_3^- + H^+ \rightleftharpoons SO_3^{2-} + 2H^+$$

Which statement about these two reactions is correct?

A HSO_3^- acts as a base.

B SO_2 acts as an oxidising agent.

C SO_3^{2-} acts as an acid.

D SO_3^{2-} acts as a reducing agent.

9 An aqueous solution was prepared containing 1.0 mol of $AgNO_3$ and 1.0 mol of $FeSO_4$ in 1.00 dm^3 of water. When equilibrium was established, there was 0.44 mol of $Ag^+(aq)$ in the mixture.

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

What is the numerical value of K_c?

A 0.35 **B** 0.62 **C** 1.62 **D** 2.89

10 When gaseous iodine is heated with hydrogen at 450 °C, an equilibrium is established.

$$\underset{\text{colourless}}{H_2(g)} + \underset{\text{purple}}{I_2(g)} \rightleftharpoons \underset{\text{colourless}}{2HI(g)} \qquad \Delta H = +53\,\text{kJ mol}^{-1}$$

Which change of conditions will cause the purple colour of the equilibrium mixture to become paler?

A decrease in pressure

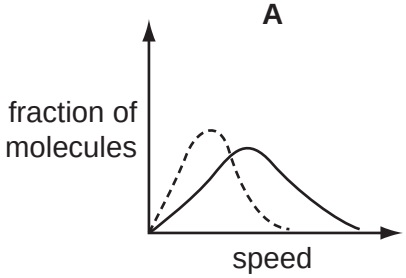
B decrease in temperature

C increase in pressure

D increase in temperature

11 Which solid-line curve most accurately represents the distribution of molecular speeds in a gas at 500 K if the dotted-line curve represents the corresponding distribution for the same gas at 300 K?

A



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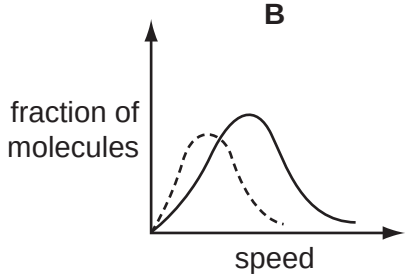

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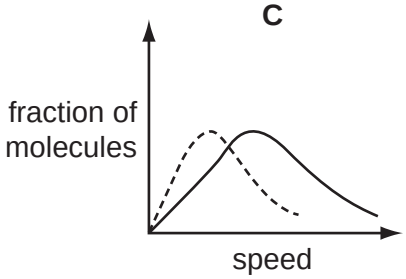
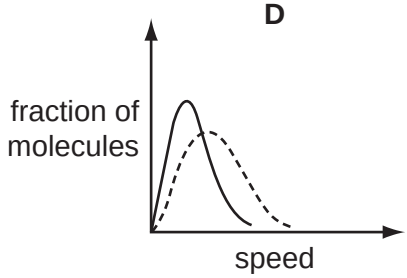


D



12 Butanedioate ions can be dehydrogenated to form *trans*-butenedioate ions. The enzyme fumarase speeds up this reaction.

Why does fumarase speed up this reaction?

A Fumarase is a protein.

B Fumarase is effective at body temperature.

C Fumarase lowers the activation energy of the dehydrogenation reaction.

D The enzyme fumarase is specific for this dehydrogenation reaction.

[Turn over

13 Which element shows the greatest tendency to form some covalent compounds?

A aluminium

B magnesium

C neon

D potassium

14 *Use of the Data Booklet is relevant to this question.*

A significant contribution to atmospheric carbon dioxide levels comes from the thermal decomposition of limestone, in the manufacture of cement and of lime for agricultural purposes.

Cement works roast 1000 million tonnes of limestone per year and a further 200 million tonnes is roasted in kilns to make lime.

What is the total annual mass output of carbon dioxide (in million tonnes) from these two processes?

A 440 **B** 527 **C** 660 **D** 880

15 *Use of the Data Booklet is relevant to this question.*

A 5.00 g sample of an anhydrous Group II metal nitrate loses 3.29 g in mass when heated strongly.

Which metal is present?

A magnesium

B calcium

C strontium

D barium

16 Aqueous sodium chloride (brine) is electrolysed by using inert electrodes in a cell which is stirred so that products of electrolysis react with each other. The cell is kept cold.

Which pair of substances is among the major products?

A hydrogen and chlorine

B hydrogen and sodium chlorate(I)

C hydrogen and sodium chlorate(V)

D sodium hydroxide and chlorine

17 Why do the halogens become less volatile as Group VII is descended?

A The halogen-halogen bond energy decreases.

B The halogen-halogen bond length increases.

C The number of electrons in each molecule increases.

D The van der Waals' forces between molecules become weaker.

18 Total removal of the pollutant sulfur dioxide, SO_2, is difficult, both for economic and technical reasons. The quantities emitted from furnace chimneys can be lowered by using desulfurisation plants. The gases are scrubbed (washed) with calcium hydroxide to remove the SO_2.

What is the main product formed **initially**?

A $Ca(HSO_4)_2$ **B** CaS **C** $CaSO_3$ **D** $CaSO_4$

19 Which reaction is endothermic?

A $2HBr \rightarrow H_2 + Br_2$

B $N_2 + 3H_2 \rightarrow 2NH_3$

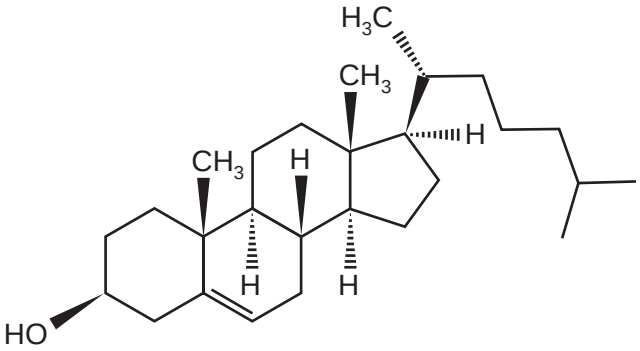
C $2SO_2 + O_2 \rightarrow 2SO_3$

D $SO_3 + H_2O \rightarrow H_2SO_4$

[Turn over

20 This question should be answered by considering the reactions of $KMnO_4$ with different functional groups under the stated conditions.

The diagram shows the structure of the naturally-occurring molecule cholesterol.



cholesterol

Separate oxidation reactions are carried out using different conditions.

- cold, dilute acidified $KMnO_4$
- hot, concentrated acidified $KMnO_4$

Which statements about the **products** formed are correct?

	cold, dilute acidified $KMnO_4$: number of hydroxy groups present	hot, concentrated acidified $KMnO_4$: number of 6-membered rings remaining
A	1	2
B	1	3
C	3	2
D	3	3

21 Many different compounds have been used in aerosol sprays, refrigerators and in making foamed plastics.

Which compound will cause the **most** ozone depletion?

A CCl_3F

B $CH_2FCHClF$

C $CH_3CH_2CH_2CH_3$

D N_2O

22 In the general formula of which class of compound, is the ratio of hydrogen atoms to carbon atoms the highest?

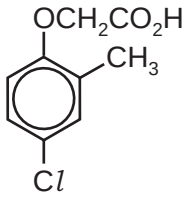
A alcohols

B aldehydes

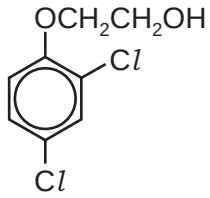
C carboxylic acids

D halogenoalkanes

23 **Y** and **Z** are two widely-used selective weed killers.



Y



Z

Which reagent will distinguish **Y** from **Z**?

A acidified $AgNO_3(aq)$

B Fehling's solution

C Na

D $Na_2CO_3(aq)$

24 What is involved in the mechanism of the reaction between aqueous sodium hydroxide and 1-bromobutane?

A attack by a nucleophile on a carbon atom with a partial positive charge

B heterolytic bond fission and attack by a nucleophile on a carbocation

C homolytic bond fission and attack by an electrophile on a carbanion

D homolytic bond fission and attack by a nucleophile on a carbocation

25 *Use of the Data Booklet is relevant to this question.*

2.76 g of ethanol were mixed with an excess of aqueous acidified potassium dichromate(VI). The reaction mixture was then boiled under reflux for one hour. The organic product was then collected by distillation.

The yield of product was 75.0 %.

What mass of product was collected?

A 1.98 g **B** 2.07 g **C** 2.70 g **D** 4.80 g

[Turn over

26 Energy is released in the human body by the oxidation of glucose in a complex sequence of reactions. Part of this sequence is the Krebs cycle. One reaction in the Krebs cycle is the conversion of fumaric acid into malic acid.

$$HO_2CCH{=}CHCO_2H \rightarrow HO_2CCH(OH)CH_2CO_2H$$

fumaric acid malic acid

Which reagents could achieve this transformation in the laboratory?

A acidified $KMnO_4$

B $Br_2(aq)$ followed by hot NaOH(aq)

C H_2O with Pt catalyst

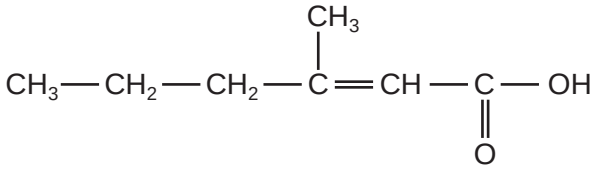
D steam with H_2SO_4

27 A reaction between chlorine and propane in ultraviolet light produces two isomeric monochloropropanes, C_3H_7Cl, as products.

Which information about this reaction is correct?

	type of bond fission in initiation step	expected ratio of 1-chloropropane to 2-chloropropane produced
A	heterolytic	1 : 1
B	heterolytic	3 : 1
C	homolytic	1 : 1
D	homolytic	3 : 1

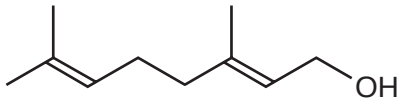
28 An unpleasant smelling chemical produced in the human armpit is 3-methylhex-2-enoic acid.



If this compound is reacted with a cold, dilute, acidified solution of potassium manganate(VII), how many chiral centres will be produced?

A 0 **B** 1 **C** 2 **D** 3

29 Geraniol is a constituent of some perfumes.



geraniol

Which statement about geraniol is **not** correct?

A Geraniol causes hot acidified potassium dichromate(VI) to change colour from orange to green.

B Geraniol decolourises bromine water.

C There are three methyl groups and three methylene (CH_2) groups in geraniol.

D There are two pairs of *cis-trans* isomers of geraniol.

30 Which pair of substances could react to give the ester $CH_3CH_2CO_2CH_3$?

A ethanol and ethanoic acid

B methanol and ethanoic acid

C methanol and propanoic acid

D propan-1-ol and methanoic acid

[Turn over

Section B

For each of the questions in this section, one or more of the three numbered statements **1** to **3** may be correct.

Decide whether each of the statements is or is not correct (you may find it helpful to put a tick against the statements that you consider to be correct).

The responses **A** to **D** should be selected on the basis of

A	B	C	D
1, 2 and **3** are correct	**1** and **2** only are correct	**2** and **3** only are correct	**1** only is correct

No other combination of statements is used as a correct response.

31 The definitions of many chemical terms can be illustrated by chemical equations.

Which terms can be illustrated by an equation that shows the formation of a positive ion?

1 first ionisation energy

2 heterolytic fission

3 enthalpy change of atomisation

32 Why does aluminium chloride, Al_2Cl_6, sublime at the relatively low temperature of 180 °C?

1 The intermolecular forces between the Al_2Cl_6 molecules are weak.

2 The co-ordinate bonds between aluminium and chlorine are weak.

3 The covalent bonds between aluminium and chlorine are weak.

33 The three statements that follow are all true.

Which of these can be explained, at least in part, by reference to hydrogen bonding?

1 At 0 °C ice floats on water.

2 The boiling point of propan-2-ol is 82 °C. The boiling point of propanone is 56 °C.

3 At 20 °C propanone and propanal mix completely.

34 A farmer spreads lime on land which has already been treated with an ammonium nitrate fertiliser.

Which reactions will occur in the treated soil?

1 $Ca(OH)_2 + 2NH_4^+(aq) \rightarrow Ca^{2+}(aq) + 2NH_3 + 2H_2O$

2 $Ca(OH)_2 + 2H^+(aq) \rightarrow Ca^{2+}(aq) + 2H_2O$

3 $Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + H_2O$

35 Which of the halide ions, chloride, bromide or iodide, acts as a reducing agent when its sodium salt reacts with concentrated sulfuric acid?

1 at least one of Cl , Br and I

2 at least two of Cl , Br and I

3 all three of Cl , Br and I

36 In a car engine, non-metallic element X forms a pollutant oxide Y.

Further oxidation of Y to Z occurs spontaneously in the atmosphere. In this further oxidation, 1 mol of Y reacts with 0.5 mol of gaseous oxygen.

Which statements about X, Y and Z are correct?

1 X forms a basic hydride.

2 Y is a diatomic molecule.

3 Z is a polar molecule.

37 Disaccharides, $C_{12}H_{22}O_{11}$, are important in the human diet. For example, sucrose is found in pastries and lactose occurs in milk products.

Both of these compounds can be hydrolysed.

$$\underset{}{\text{sucrose}} + H_2O \rightarrow \underset{\text{glucose}}{CH_2OH(CHOH)_4CHO} + \underset{\text{fructose}}{CH_2OH(CHOH)_3COCH_2OH}$$

$$\underset{}{\text{lactose}} + H_2O \rightarrow \underset{\text{glucose}}{CH_2OH(CHOH)_4CHO} + \underset{\text{galactose}}{CH_2OH(CHOH)_4CHO}$$

Which statements about these hydrolysis products are correct?

1 Glucose and fructose have structural isomers.

2 Glucose and galactose are optical isomers.

3 Glucose and galactose are ketones.

[Turn over

The responses **A** to **D** should be selected on the basis of

A	B	C	D
1, 2 and **3** are correct	**1** and **2** only are correct	**2** and **3** only are correct	**1** only is correct

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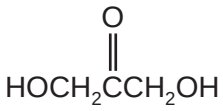
38 DHA is a colourless liquid which reacts with protein in skin to cause it to darken. It has the structure shown.



DHA

Which observations would be made when testing this substance?

1 Hydrogen is produced when sodium is added.

2 A coloured precipitate is produced when 2,4-dinitrophenylhydrazine reagent is added.

3 A silver precipitate is produced when Tollens' reagent is added.

39 On acid hydrolysis, which compounds produce propanoic acid?

1 $CH_3CH_2CO_2CH_3$

2 $CH_3CH_2CH_2CN$

3 $CH_3CH_2CH_2Cl$

40 **X** is an organic compound. **X** gives a precipitate with aqueous silver nitrate. Some or all of this precipitate remains undissolved when an excess of dilute aqueous ammonia is added.

What could be the identity of **X**?

1 2-chlorobutane

2 2-bromobutane

3 iodomethane

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1 hour

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Section A

For each question there are four possible answers, **A**, **B**, **C**, and **D**. Choose the **one** you consider to be correct.

1 In the Haber process for the manufacture of ammonia, why is the heterogeneous catalyst iron in a finely divided state?

A to increase its surface area

B to produce the maximum reduction in the activation energy

C to reduce its loss during the reaction

D to reduce its surface area

2 The following equations the letters **W**, **X**, **Y** and **Z** all represent whole numbers.

When correctly balanced, which equation requires one of letters **W**, **X**, **Y** or **Z** to be 5?

A $\mathbf{W}C_3H_7COOH + \mathbf{X}O_2 \rightarrow \mathbf{Y}CO_2 + \mathbf{Z}H_2O$

B $\mathbf{W}C_4H_8 + \mathbf{X}O_2 \rightarrow \mathbf{Y}CO_2 + \mathbf{Z}H_2O$

C $\mathbf{W}H_3PO_4 + \mathbf{X}NaOH \rightarrow \mathbf{Y}Na_2HPO_4 + \mathbf{Z}H_2O$

D $\mathbf{W}NH_3 + \mathbf{X}O_2 \rightarrow \mathbf{Y}N_2 + \mathbf{Z}H_2O$

3 *Use of the Data Booklet is relevant to this question.*

From which particle is the removal of an electron the most difficult?

A Cl (g) **B** F (g) **C** K^+(g) **D** Na^+(g)

4 *Use of the Data Booklet is relevant to this question.*

560 kg of nitrogen and 120 kg of hydrogen are pressurised, heated and passed over an iron catalyst. When the mixture of gases reaches equilibrium, it contains 96 kg of hydrogen.

Which mass of ammonia does it contain?

A 24 kg **B** 68 kg **C** 136 kg **D** 680 kg

5 The presence of dipoles helps to explain why the element Br_2 and the compound $CHCl_3$ exist as liquids at room temperature.

Which types of dipole are involved?

	Br_2	$CHCl_3$
A	induced dipoles and permanent dipoles	induced dipoles and permanent dipoles
B	induced dipoles and permanent dipoles	induced dipoles only
C	induced dipoles only	induced dipoles and permanent dipoles
D	induced dipoles only	induced dipoles only

6 Three compounds have the physical properties shown in the table.

compound	**P**	**Q**	**R**
melting point / °C	2852	993	–119
boiling point / °C	3600	1695	39
conductivity (solid)	poor	poor	poor
conductivity (liquid)	good	good	poor
conductivity (aqueous)	insoluble	good	insoluble

What might be the identities of **P**, **Q** and **R**?

	P	**Q**	**R**
A	MgO	KCl	NH_3
B	MgO	NaF	C_2H_5Br
C	SiO_2	KCl	C_2H_5Br
D	SiO_2	NaF	HCl

7 For the equilibrium $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$, what will change the value of K_p?

A adding a catalyst

B adding more O_2

C increasing the pressure

D increasing the temperature

8 Which pollutant, present in the exhaust fumes of an internal combustion engine, has an element in the +2 oxidation state and an odd number of electrons in one molecule of the pollutant?

A CO **B** H_2S **C** NO **D** NO_2

[Turn over

9 The use of sucrose in food processing depends in part on osmotic pressure, symbol Π.

In dilute solution, Π varies with concentration in a similar way to gas behaviour. The equation $\Pi V = nRT$ can be used, where n is the number of moles of solute molecules contained in volume V at temperature T. The number of moles of solvent molecules should be ignored.

Under aqueous acidic conditions sucrose is hydrolysed.

$$\underset{\text{sucrose}}{C_{12}H_{22}O_{11}} + H_2O \rightarrow \underset{\text{glucose}}{CH_2OH(CHOH)_4CHO} + \underset{\text{fructose}}{CH_2OH(CHOH)_3COCH_2OH}$$

What can be deduced from this hydrolysis equation?

	the osmotic pressure	glucose and fructose are
A	decreases	optical isomers
B	decreases	structural isomers
C	increases	optical isomers
D	increases	structural isomers

10 Hess's Law can be used to calculate the average C-H bond energy in methane.

$\Delta H^{\ominus}_{at}$ = standard enthalpy change of atomisation

$\Delta H^{\ominus}_{f}$ = standard enthalpy change of formation

$\Delta H^{\ominus}_{c}$ = standard enthalpy change of combustion

Which data values are needed in order to perform the calculation?

A $\Delta H^{\ominus}_{at}$ (C), $\Delta H^{\ominus}_{at}$ (H), $\Delta H^{\ominus}_{f}$ (CH_4)

B $\Delta H^{\ominus}_{c}$ (C), $\Delta H^{\ominus}_{c}$ (H_2), $\Delta H^{\ominus}_{c}$ (CH_4)

C $\Delta H^{\ominus}_{c}$ (C), $\Delta H^{\ominus}_{c}$ (H_2), $\Delta H^{\ominus}_{f}$ (CH_4)

D $\Delta H^{\ominus}_{f}$ (CH_4) only, as $\Delta H^{\ominus}_{f}$ (C), and $\Delta H^{\ominus}_{f}$ (H_2), are defined as zero

11 The amount of titanium dioxide in an ore can be determined by using the following reaction.

$$3TiO_2 + 4BrF_3 \rightarrow 3TiF_4 + 2Br_2 + 3O_2$$

Which element increases in oxidation number in this reaction?

A bromine

B fluorine

C oxygen

D titanium

12 For the reaction

$$W(aq) + 2X(aq) \rightleftharpoons 2Y(aq) + 3Z(aq)$$

what are the correct units for the equilibrium constant K_c?

A $mol\,dm^{-3}$ **B** $mol^2\,dm^{-6}$ **C** $mol^{-1}\,dm^3$ **D** $mol^{-2}\,dm^6$

13 Methyl mercaptan, CH_3SH, has a foul smell and is often used to impart a smell to natural gas.

What will be formed when CH_3SH is burned in an excess of air?

A CO H_2O SO_2

B CO_2 H_2O H_2S

C CO_2 H_2O SO_2

D CO_2 H_2O SO_3

14 Nitrogenous fertilisers are used extensively in modern farming. If rainwater washes excess fertiliser into a nearby lake, a process called eutrophication may occur.

Three of the stages of eutrophication are described below.

P Water plants growing on the lake bed die due to lack of sunlight.

Q An excessive growth of algae occurs.

R Excessive bacterial activity causes a reduction in oxygen levels.

In which order do these three stages occur?

A P → Q → R

B P → R → Q

C Q → P → R

D Q → R → P

15 Chlorine can be manufactured from brine in a diaphragm cell.

Which row represents the correct electrodes?

	nature of anode	nature of cathode
A	graphite	titanium
B	steel	titanium
C	titanium	graphite
D	titanium	steel

[Turn over

16 Sodium iodide reacts with concentrated sulfuric acid. The equation which represents one of the reactions that takes place is shown.

$$8NaI + 9H_2SO_4 \rightarrow 8NaHSO_4 + 4I_2 + H_2S + 4H_2O$$

Which species has been oxidised in this reaction?

A H^+ **B** I **C** Na^+ **D** SO_4^{2}

17 The standard enthalpy changes of formation of HCl and HI are –92 kJ mol ^{1} and +26 kJ mol ^{1} respectively.

Which statement is **most** important in explaining this difference?

A Chlorine is more electronegative than iodine.

B The activation energy for the $H_2 + Cl_2$ reaction is much less than that for the $H_2 + I_2$ reaction.

C The bond energy of HI is smaller than the bond energy of HCl.

D The bond energy of I_2 is smaller than the bond energy of Cl_2.

18 Lime mortar is made from quicklime, water and sand. Over a period of time, lime mortar changes into a much harder form. Both fresh and old lime mortar react with aqueous hydrochloric acid but only the old lime mortar effervesces during the reaction.

Which equation describes the change from fresh to old lime mortar?

A $CaO + CO_2 \rightarrow CaCO_3$

B $CaO + H_2O \rightarrow Ca(OH)_2$

C $Ca(OH)_2 \rightarrow CaO + H_2O$

D $Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + H_2O$

19 Ar, Ca^{2+} and K^+, contain the same number of electrons.

In which order do their radii increase?

	smallest radius ⟶		largest radius
A	Ar	K^+	Ca^{2+}
B	Ca^{2+}	Ar	K^+
C	Ca^{2+}	K^+	Ar
D	K^+	Ar	Ca^{2+}

20 Bromine and propene undergo an addition reaction.

Which is a property of the product?

A It exists in *cis-trans* isomers.

B It is more volatile than propene.

C It possesses a chiral centre.

D It possesses hydrogen bonding.

21 Buta-1,3-diene is currently obtained from fossil fuel sources. In future it may be obtained from ethanol, which can be produced from non-food agricultural crops. The sequence of reactions is as follows.

$$CH_3CH_2OH \xrightarrow{\text{step 1}} CH_3CHO \xrightarrow{\text{step 2}} CH_3CH(OH)CH_2CHO \xrightarrow{\text{step 3}} CH_2{=}CHCH{=}CH_2$$

buta-1,3-diene

Which term could be used to describe step 1?

A condensation

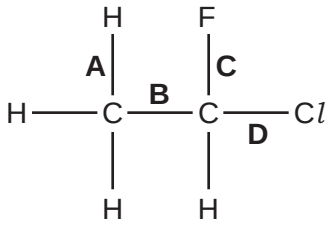
B dehydration

C dehydrogenation

D hydrogenation

22 *Use of the Data Booklet is relevant to this question.*

Which bond in the structure below has the lowest bond energy?



23 Ethanal, CH_3CHO, can be reduced using $NaBH_4$ in aqueous ethanol.

This is a nucleophilic addition reaction.

What could be the first step of this mechanism?

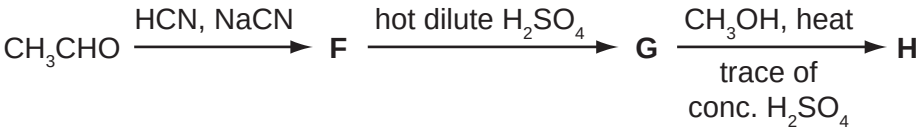
A attack of an H ion at the carbon atom of the carbonyl group

B attack of an H ion at the oxygen atom of the carbonyl group

C attack of an H^+ ion at the carbon atom of the carbonyl group

D attack of an H^+ ion at the oxygen atom of the carbonyl group

24 In a sequence of reactions, ethanal is converted into a compound **H**.



What could **H** be?

A $CH_3CH_2COOCH_3$

B $CH_3CH(OH)COOCH_3$

C $CH_3CH(OH)OCOCH_3$

D $CH_3CH(OCH_3)COOH$

25 What is involved in the mechanism of the reaction between aqueous sodium hydroxide and 2-bromo-2-methylbutane?

A heterolytic bond fission, attack by an electrophile on a carbanion

B heterolytic bond fission, attack by a nucleophile on a carbocation

C homolytic bond fission, attack by an electrophile on a carbanion

D homolytic bond fission, attack by a nucleophile on a carbocation

26 *Use of the Data Booklet is relevant to this question.*

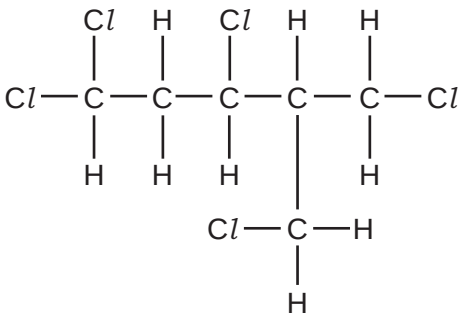
2.30 g of ethanol were mixed with aqueous acidified potassium dichromate(VI). The desired product was collected by immediate distillation under gentle warming.

The yield of product was 70.0 %.

What mass of product was collected?

A 1.54 g **B** 1.61 g **C** 2.10 g **D** 3.14 g

27 The molecule shown is optically active.



How many chiral carbon atoms are present in this molecule?

A 1 **B** 2 **C** 3 **D** 4

28 Which reagent could best be used to distinguish between cyclohexene and cyclohexanol?

A $Ag(NH_3)_2^+$ in H_2O

B Br_2 in CCl_4

C 2,4-dinitrophenylhydrazine in CH_3OH

D $NaBH_4$ in CH_3OH

29 Compound X, molecular formula C_4H_8, undergoes the following reactions.

$$\underset{\textbf{X}}{C_4H_8} \xrightarrow{Br_2} \underset{\textbf{Y}}{C_4H_8Br_2} \xrightarrow{\text{aq.NaOH / heat}} \underset{\textbf{Z}}{C_4H_{10}O_2}$$

$$\underset{\textbf{X}}{C_4H_8} \xrightarrow{H_2 / Ni} \text{methylpropane}$$

What is the formula of compound Z?

A $CH_3CH_2CH(OH)CH_2OH$

B $CH_3CH(OH)CH(OH)CH_3$

C $CH_3CH(CH_2OH)CH_2OH$

D $(CH_3)_2C(OH)CH_2OH$

30 How many of the isomeric alcohols with the formula C_4H_9OH will produce an alkene that has cis and trans isomers, on treatment with conc. H_2SO_4?

A 1 **B** 2 **C** 3 **D** 4

[Turn over

Section B

For each of the questions in this section, one or more of the three numbered statements **1** to **3** may be correct.

Decide whether each of the statements is or is not correct (you may find it helpful to put a tick against the statements that you consider to be correct).

The responses **A** to **D** should be selected on the basis of

A	B	C	D
1, 2 and **3** are correct	**1** and **2** only are correct	**2** and **3** only are correct	**1** only is correct

No other combination of statements is used as a correct response.

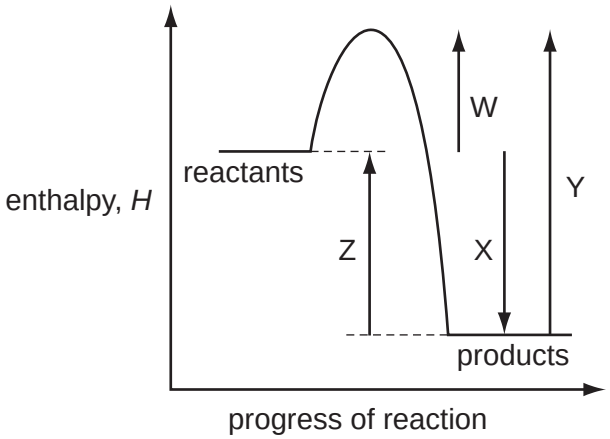
31 Which statements about bond angles are correct?

1 The bond angle in SO_2 is smaller than the bond angle in CO_2.

2 The bond angle in H_2O is smaller than the bond angle in CH_4.

3 The bond angle in NH_3 is smaller than the bond angle in BF_3.

32 An energy profile diagram is shown.



What do the labels on the diagram represent?

1 W = ΔH of the forward reaction, Y = E_a of the backward reaction

2 Z = ΔH of the backward reaction, Y = E_a of the backward reaction

3 X = ΔH of the forward reaction, W = E_a of the forward reaction

33 Which are assumptions of the kinetic theory of gases and hence of the ideal gas equation, $PV = nRT$?

1 Molecules move without interacting with one another except for collisions.

2 Intermolecular forces are negligible.

3 Intermolecular distances are much greater than the molecular size.

34 *Use of the Data Booklet is relevant to this question.*

Which properties would be expected for radium, $_{88}Ra$, or its compounds?

1 Radium carbonate would not decompose at the temperature of a Bunsen flame.

2 Radium hydroxide is very insoluble.

3 Radium does not react with cold water.

35 When a firework is lit, a fuel and an oxidising agent react together.

In one such firework, magnesium is the fuel and barium nitrate is the oxidising agent.

Which solids are produced when the firework is lit?

1 BaO

2 MgO

3 $Mg(NO_3)_2$

36 In a car engine, non-metallic element ***X*** forms a pollutant oxide ***Y***.

Further oxidation of ***Y*** to ***Z*** occurs spontaneously in the atmosphere. In this further oxidation, 1 mol of ***Y*** reacts with 0.5 mol of gaseous oxygen.

Which statements about ***X***, ***Y*** and ***Z*** are correct?

1 The oxidation number of ***X*** increases by 2 from ***Y*** to ***Z***.

2 The molecule of ***Y*** has no unpaired electrons.

3 The molecule of ***Z*** contains three oxygen atoms.

[Turn over

The responses **A** to **D** should be selected on the basis of

A	B	C	D
1, 2 and **3** are correct	**1** and **2** only are correct	**2** and **3** only are correct	**1** only is correct

No other combination of statements is used as a correct response.

37 Compound **X** has molecular formula $C_4H_{10}O$. Separate samples of **X** are tested with three different reagents.

Which results could **not** be obtained?

	Tollens' reagent	2,4-dinitrophenylhydrazine reagent	warm acidified potassium dichromate(VI) solution
1	silver mirror forms	orange precipitate forms	colour changes from orange to green
2	no change	no change	no change
3	no change	no change	colour changes from orange to green

38 **Y** is an organic compound. **Y** gives a precipitate with aqueous silver nitrate. All of this precipitate dissolves when concentrated aqueous ammonia is added.

What is a possible identity for **Y**?

1 1-bromopropane

2 chloroethane

3 2-iodo-2-methylpropane

39 Which compounds will produce ethanoic acid when boiled under reflux with dilute alkali followed by acidification?

1 CH_3CH_2Cl

2 $CH_3CO_2CH_3$

3 CH_3CN

40 Which pairs of homologous series have the same C:H ratio in their general formulae?

1 aldehydes and ketones

2 carboxylic acids and esters

3 alkenes and ketones

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UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS
General Certificate of Education
Advanced Subsidiary Level and Advanced Level

CHEMISTRY **9701/13**

Paper 1 Multiple Choice **October/November 2011**

1 hour

Additional Materials: Multiple Choice Answer Sheet
Soft clean eraser
Soft pencil (type B or HB is recommended)
Data Booklet

3160072507

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
Do not use staples, paper clips, highlighters, glue or correction fluid.
Write your name, Centre number and candidate number on the Answer Sheet in the spaces provided unless this has been done for you.

There are **forty** questions on this paper. Answer **all** questions. For each question there are four possible answers **A**, **B**, **C** and **D**.
Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Answer Sheet.

Read the instructions on the Answer Sheet very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this booklet.

This document consists of **13** printed pages and **3** blank pages.

Section A

For each question there are four possible answers, **A**, **B**, **C**, and **D**. Choose the **one** you consider to be correct.

1 *Use of the Data Booklet is relevant to this question.*

Lead(IV) chloride will oxidise bromide ions to bromine. The Pb^{4+} ions are reduced to Pb^{2+} ions in this reaction.

If 6.980 g of lead(IV) chloride is added to an excess of sodium bromide solution, what mass of bromine would be produced?

A 0.799 g **B** 1.598 g **C** 3.196 g **D** 6.392 g

2 Which element has an equal number of electron pairs and of unpaired electrons within orbitals of principal quantum number 2?

A beryllium

B carbon

C nitrogen

D oxygen

3 Three elements, **X**, **Y** and **Z**, have the physical properties shown in the table.

element	melting point / °C	boiling point / °C	density / g cm^{-3}
X	–7	59	3.12
Y	98	883	0.97
Z	649	1107	1.74

What could be the identities of **X**, **Y** and **Z**?

	X	**Y**	**Z**
A	Br_2	A*l*	Si
B	Br_2	Na	Mg
C	I_2	Mg	Na
D	I_2	Si	K

4 At room temperature and pressure chlorine does not behave as an ideal gas.

At which temperature and pressure would the behaviour of chlorine become more ideal?

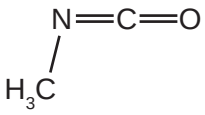
	pressure /kPa	temperature /K
A	50	200
B	50	400
C	200	200
D	200	400

5 Methyl isocyanate, CH_3NCO, is a toxic liquid which is used in the manufacture of some pesticides.

In the methyl isocyanate molecule, the sequence of atoms is $H_3C—N=C=O$.

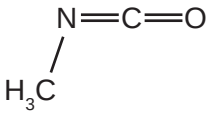
What is the approximate angle between the bonds formed by the N atom?

A



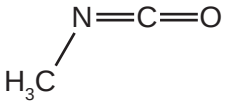
104°

B



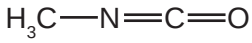
109°

C



120°

D



180°

6 When chlorine and aqueous sodium hydroxide are heated together the following overall reaction occurs.

$$3Cl_2(aq) + 6NaOH(aq) \rightarrow 5NaCl(aq) + NaClO_3(aq) + 3H_2O(l)$$

What are the oxidation numbers for chlorine in each of the following species?

	Cl_2	$NaCl$	$NaClO_3$
A	0	+1	–5
B	+2	–1	+3
C	0	–1	+5
D	–2	+1	–3

[Turn over

7 The standard enthalpy change for the reaction

$$2NF_3(g) \rightarrow 2N(g) + 6F(g) \qquad \text{is } \Delta H^{\ominus} = +1668\,\text{kJ}$$

What is the bond energy of the N–F bond?

A –556 kJ mol^{-1}

B –278 kJ mol^{-1}

C +278 kJ mol^{-1}

D +556 kJ mol^{-1}

8 When gaseous iodine is heated with hydrogen at 450 °C, an equilibrium is established.

$$\underset{\text{colourless}}{H_2(g)} + \underset{\text{purple}}{I_2(g)} \rightleftharpoons \underset{\text{colourless}}{2HI(g)} \qquad \Delta H = +53\,\text{kJ mol}^{-1}$$

Which change of conditions will cause the purple colour of the equilibrium mixture to become paler?

A decrease in pressure

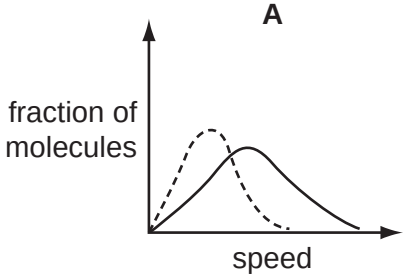
B decrease in temperature

C increase in pressure

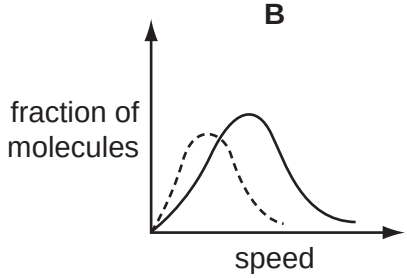
D increase in temperature

9 Which solid-line curve most accurately represents the distribution of molecular speeds in a gas at 500 K if the dotted-line curve represents the corresponding distribution for the same gas at 300 K?

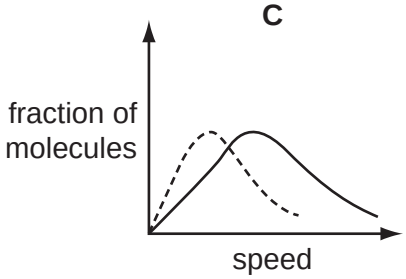
A



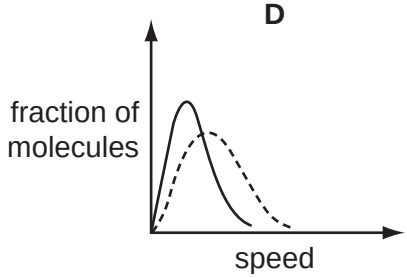
B



C



D



10 Sulfur dioxide is used as a preservative in wine making.

The following equations describe how sulfur dioxide dissolves.

$$H_2O + SO_2 \rightleftharpoons HSO_3^- + H^+$$

$$HSO_3^- + H^+ \rightleftharpoons SO_3^{2-} + 2H^+$$

Which statement about these two reactions is correct?

A HSO_3^- acts as a base.

B SO_2 acts as an oxidising agent.

C SO_3^{2-} acts as an acid.

D SO_3^{2-} acts as a reducing agent.

11 Butanedioate ions can be dehydrogenated to form *trans*-butenedioate ions. The enzyme fumarase speeds up this reaction.

Why does fumarase speed up this reaction?

A Fumarase is a protein.

B Fumarase is effective at body temperature.

C Fumarase lowers the activation energy of the dehydrogenation reaction.

D The enzyme fumarase is specific for this dehydrogenation reaction.

12 An aqueous solution was prepared containing 1.0 mol of $AgNO_3$ and 1.0 mol of $FeSO_4$ in 1.00 dm^3 of water. When equilibrium was established, there was 0.44 mol of $Ag^+(aq)$ in the mixture.

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

What is the numerical value of K_c?

A 0.35 **B** 0.62 **C** 1.62 **D** 2.89

13 Which element shows the greatest tendency to form some covalent compounds?

A aluminium

B magnesium

C neon

D potassium

[Turn over

14 *Use of the Data Booklet is relevant to this question.*

A 5.00 g sample of an anhydrous Group II metal nitrate loses 3.29 g in mass when heated strongly.

Which metal is present?

A magnesium

B calcium

C strontium

D barium

15 *Use of the Data Booklet is relevant to this question.*

A significant contribution to atmospheric carbon dioxide levels comes from the thermal decomposition of limestone, in the manufacture of cement and of lime for agricultural purposes.

Cement works roast 1000 million tonnes of limestone per year and a further 200 million tonnes is roasted in kilns to make lime.

What is the total annual mass output of carbon dioxide (in million tonnes) from these two processes?

A 440 **B** 527 **C** 660 **D** 880

16 Why do the halogens become less volatile as Group VII is descended?

A The halogen-halogen bond energy decreases.

B The halogen-halogen bond length increases.

C The number of electrons in each molecule increases.

D The van der Waals' forces between molecules become weaker.

17 Aqueous sodium chloride (brine) is electrolysed by using inert electrodes in a cell which is stirred so that products of electrolysis react with each other. The cell is kept cold.

Which pair of substances is among the major products?

A hydrogen and chlorine

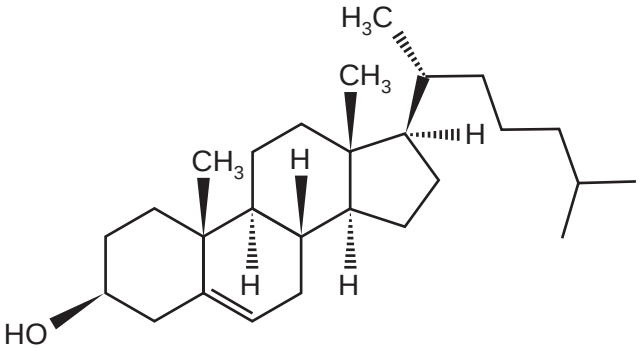
B hydrogen and sodium chlorate(I)

C hydrogen and sodium chlorate(V)

D sodium hydroxide and chlorine

18 This question should be answered by considering the reactions of $KMnO_4$ with different functional groups under the stated conditions.

The diagram shows the structure of the naturally-occurring molecule cholesterol.



cholesterol

Separate oxidation reactions are carried out using different conditions.

- cold, dilute acidified $KMnO_4$
- hot, concentrated acidified $KMnO_4$

Which statements about the **products** formed are correct?

	cold, dilute acidified $KMnO_4$: number of hydroxy groups present	hot, concentrated acidified $KMnO_4$: number of 6-membered rings remaining
A	1	2
B	1	3
C	3	2
D	3	3

19 Which reaction is endothermic?

A $2HBr \rightarrow H_2 + Br_2$

B $N_2 + 3H_2 \rightarrow 2NH_3$

C $2SO_2 + O_2 \rightarrow 2SO_3$

D $SO_3 + H_2O \rightarrow H_2SO_4$

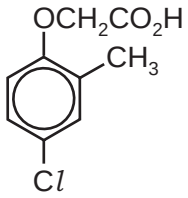
[Turn over

20 Total removal of the pollutant sulfur dioxide, SO_2, is difficult, both for economic and technical reasons. The quantities emitted from furnace chimneys can be lowered by using desulfurisation plants. The gases are scrubbed (washed) with calcium hydroxide to remove the SO_2.

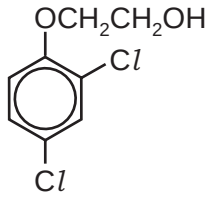
What is the main product formed **initially**?

A $Ca(HSO_4)_2$ **B** CaS **C** $CaSO_3$ **D** $CaSO_4$

21 **Y** and **Z** are two widely-used selective weed killers.



Y



Z

Which reagent will distinguish **Y** from **Z**?

A acidified $AgNO_3(aq)$

B Fehling's solution

C Na

D $Na_2CO_3(aq)$

22 What is involved in the mechanism of the reaction between aqueous sodium hydroxide and 1-bromobutane?

A attack by a nucleophile on a carbon atom with a partial positive charge

B heterolytic bond fission and attack by a nucleophile on a carbocation

C homolytic bond fission and attack by an electrophile on a carbanion

D homolytic bond fission and attack by a nucleophile on a carbocation

23 In the general formula of which class of compound, is the ratio of hydrogen atoms to carbon atoms the highest?

A alcohols

B aldehydes

C carboxylic acids

D halogenoalkanes

24 Many different compounds have been used in aerosol sprays, refrigerators and in making foamed plastics.

Which compound will cause the **most** ozone depletion?

A CCl_3F

B $CH_2FCHClF$

C $CH_3CH_2CH_2CH_3$

D N_2O

25 *Use of the Data Booklet is relevant to this question.*

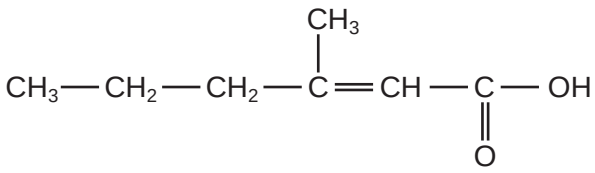
2.76 g of ethanol were mixed with an excess of aqueous acidified potassium dichromate(VI). The reaction mixture was then boiled under reflux for one hour. The organic product was then collected by distillation.

The yield of product was 75.0 %.

What mass of product was collected?

A 1.98 g **B** 2.07 g **C** 2.70 g **D** 4.80 g

26 An unpleasant smelling chemical produced in the human armpit is 3-methylhex-2-enoic acid.



If this compound is reacted with a cold, dilute, acidified solution of potassium manganate(VII), how many chiral centres will be produced?

A 0 **B** 1 **C** 2 **D** 3

27 Energy is released in the human body by the oxidation of glucose in a complex sequence of reactions. Part of this sequence is the Krebs cycle. One reaction in the Krebs cycle is the conversion of fumaric acid into malic acid.

$$HO_2CCH{=}CHCO_2H \rightarrow HO_2CCH(OH)CH_2CO_2H$$

fumaric acid malic acid

Which reagents could achieve this transformation in the laboratory?

A acidified $KMnO_4$

B Br_2(aq) followed by hot NaOH(aq)

C H_2O with Pt catalyst

D steam with H_2SO_4

28 A reaction between chlorine and propane in ultraviolet light produces two isomeric monochloropropanes, C_3H_7Cl, as products.

Which information about this reaction is correct?

	type of bond fission in initiation step	expected ratio of 1-chloropropane to 2-chloropropane produced
A	heterolytic	1 : 1
B	heterolytic	3 : 1
C	homolytic	1 : 1
D	homolytic	3 : 1

29 Which pair of substances could react to give the ester $CH_3CH_2CO_2CH_3$?

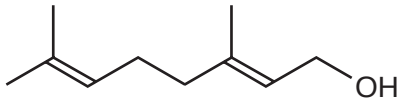
A ethanol and ethanoic acid

B methanol and ethanoic acid

C methanol and propanoic acid

D propan-1-ol and methanoic acid

30 Geraniol is a constituent of some perfumes.



geraniol

Which statement about geraniol is **not** correct?

A Geraniol causes hot acidified potassium dichromate(VI) to change colour from orange to green.

B Geraniol decolourises bromine water.

C There are three methyl groups and three methylene (CH_2) groups in geraniol.

D There are two pairs of *cis-trans* isomers of geraniol.

Section B

For each of the questions in this section, one or more of the three numbered statements **1** to **3** may be correct.

Decide whether each of the statements is or is not correct (you may find it helpful to put a tick against the statements that you consider to be correct).

The responses **A** to **D** should be selected on the basis of

A	B	C	D
1, 2 and **3** are correct	**1** and **2** only are correct	**2** and **3** only are correct	**1** only is correct

No other combination of statements is used as a correct response.

31 The definitions of many chemical terms can be illustrated by chemical equations.

Which terms can be illustrated by an equation that shows the formation of a positive ion?

1 first ionisation energy

2 heterolytic fission

3 enthalpy change of atomisation

32 The three statements that follow are all true.

Which of these can be explained, at least in part, by reference to hydrogen bonding?

1 At 0 °C ice floats on water.

2 The boiling point of propan-2-ol is 82 °C. The boiling point of propanone is 56 °C.

3 At 20 °C propanone and propanal mix completely.

33 Which of the halide ions, chloride, bromide or iodide, acts as a reducing agent when its sodium salt reacts with concentrated sulfuric acid?

1 at least one of Cl , Br and I

2 at least two of Cl , Br and I

3 all three of Cl , Br and I

34 Why does aluminium chloride, Al_2Cl_6, sublime at the relatively low temperature of 180 °C?

1 The intermolecular forces between the Al_2Cl_6 molecules are weak.

2 The co-ordinate bonds between aluminium and chlorine are weak.

3 The covalent bonds between aluminium and chlorine are weak.

The responses **A** to **D** should be selected on the basis of

A	B	C	D
1, 2 and **3** are correct	**1** and **2** only are correct	**2** and **3** only are correct	**1** only is correct

No other combination of statements is used as a correct response.

35 A farmer spreads lime on land which has already been treated with an ammonium nitrate fertiliser.

Which reactions will occur in the treated soil?

1 $Ca(OH)_2 + 2NH_4^+(aq) \rightarrow Ca^{2+}(aq) + 2NH_3 + 2H_2O$

2 $Ca(OH)_2 + 2H^+(aq) \rightarrow Ca^{2+}(aq) + 2H_2O$

3 $Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + H_2O$

36 In a car engine, non-metallic element X forms a pollutant oxide Y.

Further oxidation of Y to Z occurs spontaneously in the atmosphere. In this further oxidation, 1 mol of Y reacts with 0.5 mol of gaseous oxygen.

Which statements about X, Y and Z are correct?

1 X forms a basic hydride.

2 Y is a diatomic molecule.

3 Z is a polar molecule.

37 **X** is an organic compound. **X** gives a precipitate with aqueous silver nitrate. Some or all of this precipitate remains undissolved when an excess of dilute aqueous ammonia is added.

What could be the identity of **X**?

1 2-chlorobutane

2 2-bromobutane

3 iodomethane

38 On acid hydrolysis, which compounds produce propanoic acid?

1 $CH_3CH_2CO_2CH_3$

2 $CH_3CH_2CH_2CN$

3 $CH_3CH_2CH_2Cl$

39 Disaccharides, $C_{12}H_{22}O_{11}$, are important in the human diet. For example, sucrose is found in pastries and lactose occurs in milk products.

Both of these compounds can be hydrolysed.

$$\text{sucrose} + H_2O \rightarrow \underset{\text{glucose}}{CH_2OH(CHOH)_4CHO} + \underset{\text{fructose}}{CH_2OH(CHOH)_3COCH_2OH}$$

$$\text{lactose} + H_2O \rightarrow \underset{\text{glucose}}{CH_2OH(CHOH)_4CHO} + \underset{\text{galactose}}{CH_2OH(CHOH)_4CHO}$$

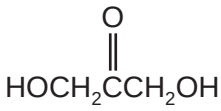
Which statements about these hydrolysis products are correct?

1 Glucose and fructose have structural isomers.

2 Glucose and galactose are optical isomers.

3 Glucose and galactose are ketones.

40 DHA is a colourless liquid which reacts with protein in skin to cause it to darken. It has the structure shown.



DHA

Which observations would be made when testing this substance?

1 Hydrogen is produced when sodium is added.

2 A coloured precipitate is produced when 2,4-dinitrophenylhydrazine reagent is added.

3 A silver precipitate is produced when Tollens' reagent is added.

[Turn over

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UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS
General Certificate of Education Advanced Subsidiary Level and Advanced Level

CANDIDATE NAME

CENTRE NUMBER

CANDIDATE NUMBER

CHEMISTRY **9701/21**

Paper 2 Structured Questions AS Core **October/November 2011**

1 hour 15 minutes

Candidates answer on the Question Paper.

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

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Use this value to calculate the amount, in moles, of carbon atoms present in 0.240 g of **A**.

(ii) Calculate the mass of hydrogen present in 0.144 g of H_2O.

Use this value to calculate the amount, in moles, of hydrogen atoms present in 0.240 g of **A**.

(iii) Use your answers to calculate the mass of oxygen present in 0.240 g of **A**.

Use this value to calculate the amount, in moles, of oxygen atoms present in 0.240 g of **A**.

[6]

(b) Use your answers to **(a)** to calculate the empirical formula of **A**.

For Examiner's Use

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(c) When a 0.148 g sample of **A** was vapourised at 60°C, the vapour occupied a volume of 67.7 cm^3 at a pressure of 101 kPa.

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M_r =.....

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[3]

(d) Compound **A** is a liquid which does **not** react with 2,4-dinitrophenylhydrazine reagent or with aqueous bromine.

Suggest **two** structural formulae for **A**.

[2]

(e) Compound **A** contains only carbon, hydrogen and oxygen.

Explain how the information on the opposite page about the reaction of **A** with CuO confirms this statement.

.....

..... [1]

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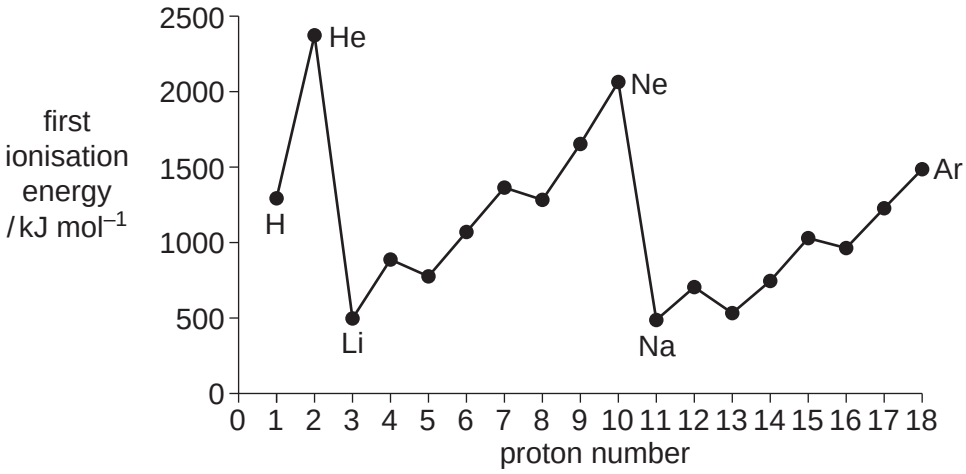
The diagram below shows the first ionisation energies of the first 18 elements of the Periodic Table.



(a) Give the equation, including state symbols, for the first ionisation energy of sulfur.

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(b) Explain why there is a **general** increase in first ionisation energies across the Period from sodium to argon.

.....

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.....

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.....

.....

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The table below refers to the elements of the third Period sodium to sulfur and is incomplete.

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conductivity			high			
melting point			high			

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For one element, **E**, he correctly predicted the following properties.

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The element **E** was in the fourth Period and was one of the elements from gallium, proton number 31, to bromine, proton number 35.

(e) By considering the properties of the third Period elements aluminium to chlorine, suggest the identity of the fourth Period element **E**.

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For Examiner's Use

In such cases, the use of Hess' Law enables the enthalpy change of reaction to be calculated from the enthalpy changes of other reactions.

(a) State Hess' Law.

.....

.....

..... [2]

In order to determine the enthalpy change for the thermal decomposition of potassium hydrogencarbonate, two separate experiments were carried out.

experiment 1

30.0 cm^3 of 2.00 mol dm^{-3} hydrochloric acid (an excess) was placed in a conical flask and the temperature recorded as 21.0 °C.
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(b) (i) Construct a balanced equation for this reaction.

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Give your answer in kJ mol^{-1} and include a sign in your answer.

(iv) Explain why the hydrochloric acid must be in an excess.

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experiment 2

For Examiner's Use

The experiment was repeated with 0.0200 mol of potassium hydrogencarbonate, $KHCO_3$.
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In the second experiment, the temperature fell from 21.0 °C to 17.3 °C.

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[3]

(d) When $KHCO_3$ is heated, it decomposes into K_2CO_3, CO_2 and H_2O.

$$2KHCO_3 \longrightarrow K_2CO_3 + CO_2 + H_2O$$

Use Hess' Law and your answers to **(b)(iii)** and **(c)(iii)** to calculate the enthalpy change for this reaction.
Give your answer in kJ mol^{-1} and include a sign in your answer.

[2]

[Total: 11]

[Turn over

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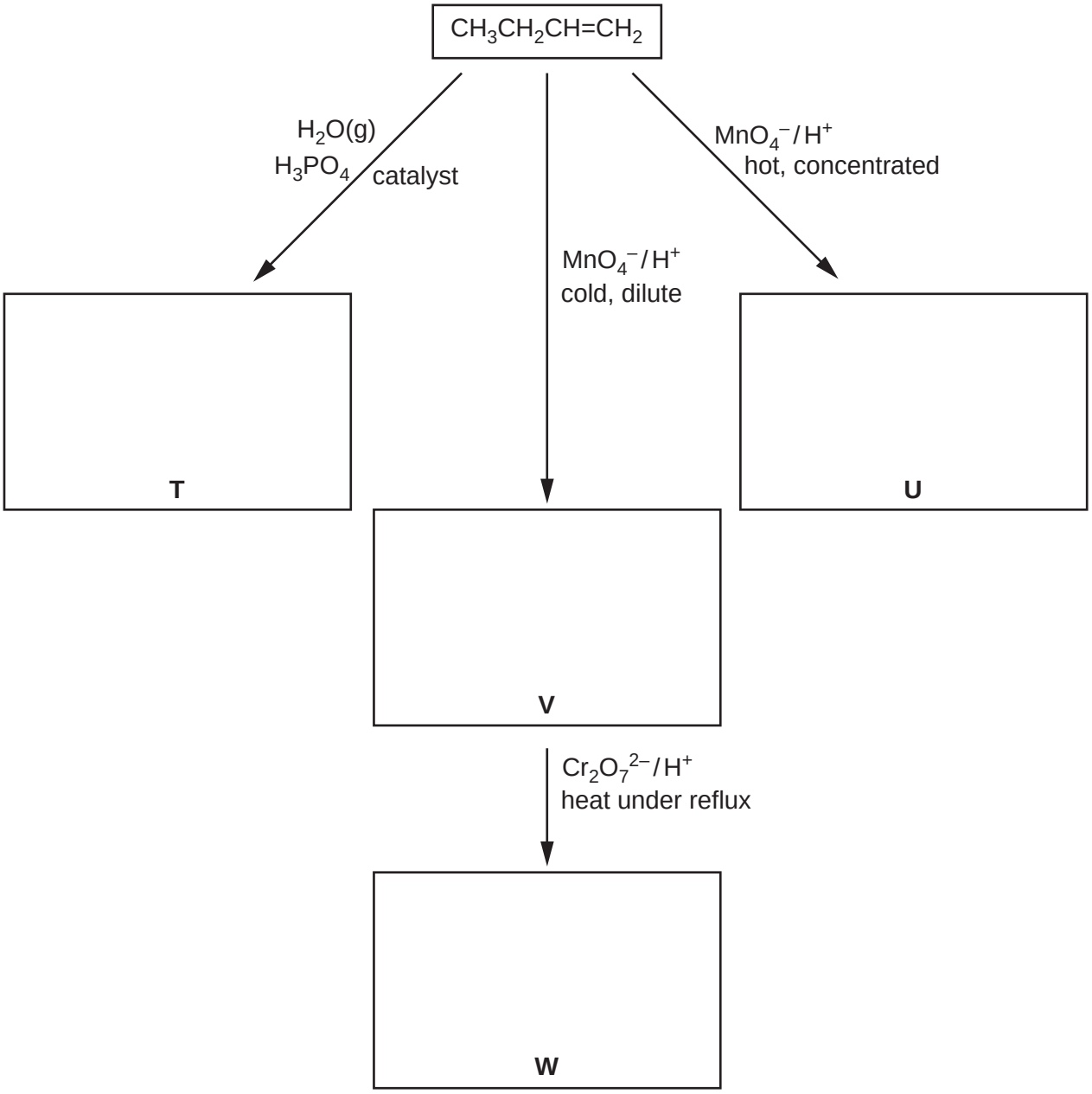
For Examiner's Use

(a) Some reactions of but-1-ene are given below.

In **each** empty box, draw the structural formula of the organic compound formed.



[5]

(b) Compound **T** reacts with compound **U**.

Draw the **displayed** formula of the organic product of this reaction.

For Examiner's Use

[2]

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One molecule that has been found in the dust clouds is hydroxyethanal, $HOCH_2CHO$.

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In a school or college laboratory, it is possible to convert a sample of hydroxyethanal into aminoethanoic acid in a three-step process.

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X	**Y**

(ii) State the reagents for **each** of the three steps you have chosen.

step 1.....

step 2.....

step 3..... [5]

[Total: 14]

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UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS
General Certificate of Education Advanced Subsidiary Level and Advanced Level

CANDIDATE NAME

CENTRE NUMBER

CANDIDATE NUMBER

7726114879

CHEMISTRY **9701/22**

Paper 2 Structured Questions AS Core **October/November 2011**

1 hour 15 minutes

Candidates answer on the Question Paper.

Additional Materials: Data Booklet

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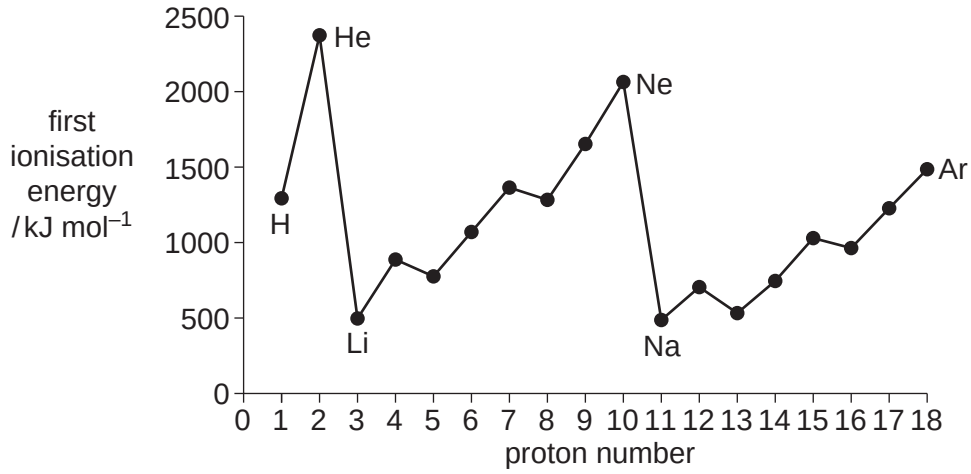

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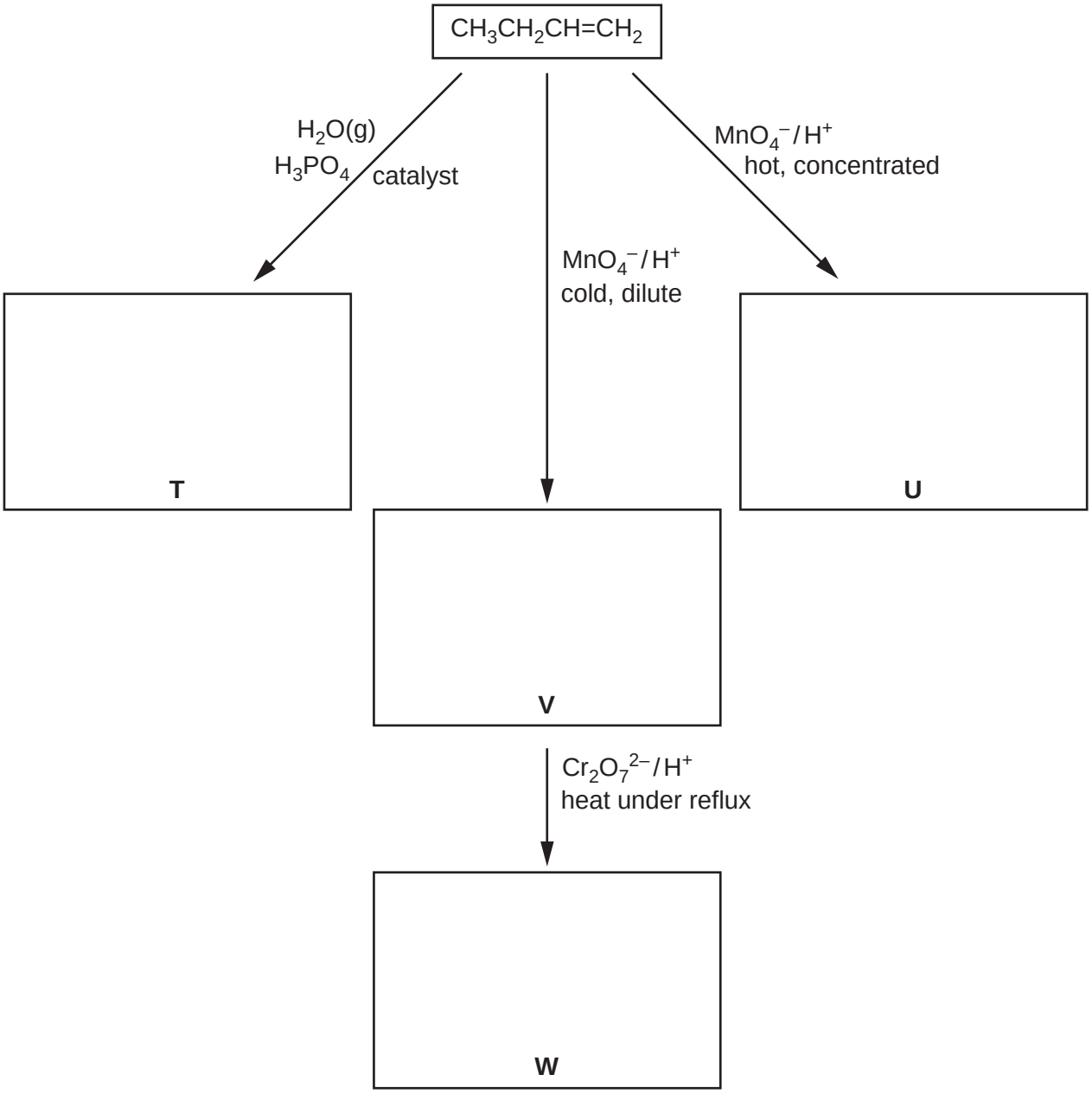

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UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS
General Certificate of Education Advanced Subsidiary Level and Advanced Level

CANDIDATE NAME

CENTRE NUMBER

CANDIDATE NUMBER

8469906161

CHEMISTRY **9701/23**

Paper 2 Structured Questions AS Core **October/November 2011**

1 hour 15 minutes

Candidates answer on the Question Paper.

Additional Materials: Data Booklet

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For Examiner's Use

1 Sulfur, S, and polonium, Po, are both elements in Group VI of the Periodic Table.

Sulfur has three isotopes.

(a) Explain the meaning of the term *isotope*.

.....

.....

..... [2]

(b) A sample of sulfur has the following isotopic composition by mass.

isotope mass	32	33	34
% by mass	95.00	0.77	4.23

Calculate the relative atomic mass, A_r, of sulfur to **two** decimal places.

A_r = ...

[2]

(c) Isotopes of polonium, proton number 84, are produced by the radioactive decay of several elements including thorium, Th, proton number 90.

The isotope ^{213}Po is produced from the thorium isotope ^{232}Th.

Complete the table below to show the atomic structures of the isotopes ^{213}Po and ^{232}Th.

	number of		
isotope	protons	neutrons	electrons
^{213}Po			
^{232}Th			

[3]

For Examiner's Use

Radiochemical reactions, such as nuclear fission and radioactive decay of isotopes, can be represented by equations in which the nucleon (mass) numbers must balance and the proton numbers must also balance.

For example, the nuclear fission of uranium-235, $^{235}_{92}U$, by collision with a neutron, $^{1}_{0}n$, produces strontium-90, xenon-143 and three neutrons.

$$^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{90}_{38}Sr + {}^{143}_{54}Xe + 3\,{}^{1}_{0}n$$

In this equation, the nucleon (mass) numbers balance because: 235 + 1 = 90 + 143 + (3x1).

The proton numbers also balance because: 92 + 0 = 38 + 54 + (3x0).

(d) In the first stage of the radioactive decay of $^{232}_{90}Th$, the products are an isotope of element *E* and an alpha-particle, $^{4}_{2}He$.

(i) By considering nucleon and proton numbers only, construct a balanced equation for the formation of the isotope of *E* in this reaction.

$$^{232}_{90}Th \rightarrow \text{.....} + {}^{4}_{2}He$$

Show clearly the nucleon number and proton number of the isotope of *E*.

nucleon number of the isotope of *E* .....

proton number of the isotope of *E* .....

(ii) Hence state the symbol of the element *E*.

..... [3]

[Total: 10]

[Turn over

2 When 0.42 g of a gaseous hydrocarbon **A** is slowly passed over a large quantity of heated copper(II) oxide, CuO, **A** is completely oxidised.

For Examiner's Use

The products are collected and it is found that 1.32 g of CO_2 and 0.54 g of H_2O are formed. Copper is the only other product of the reaction.

(a) (i) Calculate the mass of carbon present in 1.32 g of CO_2.

Use this value to calculate the amount, in moles, of carbon atoms present in 0.42 g of **A**.

(ii) Calculate the mass of hydrogen present in 0.54 g of H_2O.

Use this value to calculate the amount, in moles, of hydrogen atoms present in 0.42 g of **A**.

(iii) It is thought that **A** is an alkene rather than an alkane.

Use your answers to **(i)** and **(ii)** to deduce whether this is correct.

Explain your answer.

.....

..... [5]

(b) Analysis of another organic compound, **B**, gave the following composition by mass: C, 64.86%; H, 13.50%, O, 21.64%.

For Examiner's Use

(i) Use these values to calculate the empirical formula of **B**.

(ii) The empirical and molecular formulae of **B** are the same.

B is found to be chiral.

Draw displayed formulae of the two optical isomers of this compound, indicating with an asterisk (*) the chiral carbon atom.

(iii) There are three other structural isomers of **B** which are not chiral but which contain the same functional group as **B**.

In the boxes below, draw the structural formulae of these isomers.

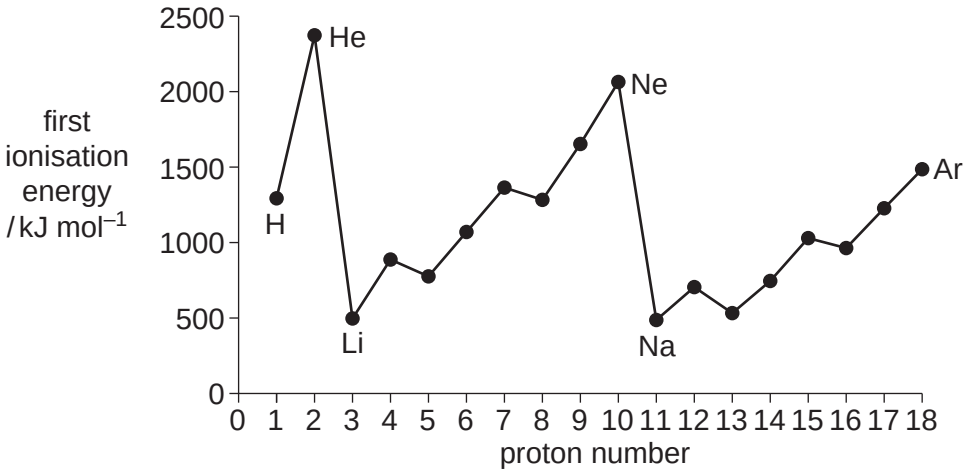
[7]

[Total: 12]

3 The Periodic Table we currently use is derived directly from that proposed in 1869 by Mendeleev who had noticed patterns in the physical and chemical properties of the elements he had studied.

For Examiner's Use

The diagram below shows the first ionisation energies of the first 18 elements of the Periodic Table.



(a) Give the equation, including state symbols, for the first ionisation energy of carbon.

..... [2]

(b) **(i)** Explain why sodium has a lower first ionisation energy than magnesium.

.....

.....

(ii) Explain why magnesium has a higher first ionisation energy than aluminium.

.....

.....

(iii) Explain why helium, He, and neon, Ne, occupy the two highest positions on the diagram.

.....

.....

(iv) Explain why the first ionisation energy of argon, Ar, is lower than that of neon, which is lower than that of helium.

.....

.....

.....

[8]

For Examiner's Use

(c) **(i)** The first ionisation energies of the elements Na to Ar show a variation. Some physical properties show similar variations.

The atomic radius of the elements decreases from Na to Cl.

Give a brief explanation of this variation.

.....

.....

(ii) The cations formed by the elements Na to Al are smaller than the corresponding atoms.

Give a brief explanation of this change.

.....

.....

[3]

(d) The oxides of the elements of the third Period behave differently with NaOH(aq) and HCl (aq). In some cases, no reaction occurs.

Complete the table below by writing a balanced equation for any reaction that occurs, with heating if necessary. If you think no reaction takes place write 'no reaction'.

You do not need to include state symbols in your answers.

.....MgO(s) + ... NaOH (aq) →
.....MgO(s) + ... HCl (aq) →
.....Al_2O_3(s) + ... NaOH (aq) + ...H_2O (l) →
.....Al_2O_3(s) + ... HCl (aq) →
.....SO_2(g) + ... NaOH (aq) →
.....SO_2(g) + ... HCl (aq) →

[6]

[Total: 19]

[Turn over

4 The structural formulae of six different compounds, **P – U**, are given below.

For Examiner's Use

$CH_3CH{=}CHCH_2CH_3$	$CH_3CH_2COCH_2CH_3$	$CH_2{=}CHCH_2CH_2CH_3$
P	**Q**	**R**
$CH_3CH_2CH_2CH_2CH_2OH$	$HOCH_2CH_2CH(OH)CH_3$	$CH_3CH_2CH_2OCH_2CH_3$
S	**T**	**U**

(a) (i) What is the empirical formula of compound **T**?

.....

(ii) Draw the skeletal formula of compound **S**.

[2]

(b) (i) Compounds **S** and **U** are isomers.

What type of isomerism do they show?

.....

(ii) Two of the six formulae **P – U** can **each** be drawn in two forms which are known as stereoisomers.

Which two compounds have formulae that can be drawn in two forms?

What type of stereoisomerism does each show?

Identify each compound by its letter.

compound	type of stereoisomerism

[3]

(c) Compound **S** can be converted into compound **R**.

For Examiner's Use

(i) What type of reaction is this?

.....

(ii) What reagent would you use for this reaction?

.....

(iii) Write the structural formula of the compound formed when **T** undergoes the same reaction using an excess of the reagent you have used in **(c)(ii)**.

..... [3]

(d) Compound **P** may be converted into compound **Q** in a two-step reaction.

$CH_3CH{=}CHCH_2CH_3$ (**P**) $\xrightarrow{\text{step 1}}$ intermediate $\xrightarrow{\text{step 2}}$ $CH_3CH_2COCH_2CH_3$ (**Q**)

(i) What is the structural formula of the intermediate compound formed in this sequence?

(ii) Outline how step 1 may be carried out to give this intermediate compound.

.....

.....

.....

(iii) What reagent would be used for step 2?

..... [4]

[Total: 12]

5 Each of the three organic compounds, **V**, **W**, and **X**, has the empirical formula CH_2O. The number of carbon atoms in each of their molecules is shown in the table.

compound	number of C atoms
V	1
W	2
X	3

V gives a brick red precipitate when warmed with Fehling's reagent; **W** and **X** do not.

W is a fruity smelling liquid.

In **X**, the carbon atoms are bonded directly to one another.

X gives an effervescence when shaken with $Na_2CO_3(aq)$; **V** and **W** do not.

(a) Give the structural formula of **V**.

[1]

(b) **(i)** What functional group is present in **W**?

.....

(ii) Give the structural formula of **W**.

[2]

(c) When **X** is heated under reflux with acidified $K_2Cr_2O_7$, the product, **Y**, gives no reaction with 2,4-dinitrophenylhydrazine reagent.

(i) Give the structural formula of **X**.

(ii) Give the structural formula of **Y**, the compound formed from **X**.

[2]

(d) When **X** is warmed with a little concentrated sulfuric acid, a small amount of a cyclic compound, **Z**, is formed.

For Examiner's Use

Z has the molecular formula $C_6H_8O_4$.

(i) Suggest a displayed formula for **Z**.

(ii) What type of reaction occurs when **Z** is formed from **X**?

..... [2]

[Total: 7]

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UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS
General Certificate of Education
Advanced Subsidiary Level and Advanced Level

CANDIDATE NAME

CENTRE NUMBER

CANDIDATE NUMBER

CHEMISTRY **9701/31**

Advanced Practical Skills 1 **October/November 2011**

2 hours

Candidates answer on the Question Paper.

Additional Materials: As listed in the Confidential Instructions

READ THESE INSTRUCTIONS FIRST

Write your Centre number, candidate number and name on all the work you hand in.
Give details of the practical session and laboratory where appropriate, in the boxes provided.
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Do not use staples, paper clips, highlighters, glue or correction fluid.
DO **NOT** WRITE IN ANY BARCODES.

Answer **all** questions.
You may lose marks if you do not show your working or if you do not use appropriate units.
Use of a Data Booklet is unnecessary.

Qualitative Analysis Notes are printed on pages 8 and 9.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

Session
Laboratory

For Examiner's Use	
1	
2	
Total	

This document consists of **9** printed pages and **3** blank pages.

1 You are to determine the enthalpy change of neutralisation of hydrochloric acid by aqueous sodium hydroxide and also the concentration of the aqueous sodium hydroxide. These can be found by measuring the temperature change when solutions of the acid and alkali are mixed.

For Examiner's Use

FA 1 is aqueous sodium hydroxide, NaOH.
FA 2 is 2.00 mol dm^{-3} hydrochloric acid, HC*l*.

(a) Method

- Fill a burette with **FA 1**. **[Care: FA 1 is corrosive]**
- Support the plastic cup in a 250 cm^3 beaker.
- Use a measuring cylinder to transfer 25 cm^3 of **FA 2** into a 100 cm^3 beaker.
- Use a measuring cylinder to add 35 cm^3 of distilled water to the acid in the beaker.
- Measure and record, in the table below, the initial temperature of the mixture in the beaker.
- Run 5.0 cm^3 of **FA 1** from the burette into the plastic cup.
- Add the mixture of acid and water from the 100 cm^3 beaker to the **FA 1** in the plastic cup.
- Stir carefully and measure the highest temperature obtained.
- Record this temperature in the table.
- Rinse the plastic cup with water.
- Repeat the experiment using 25 cm^3 of **FA 2**, 30 cm^3 of distilled water and 10.0 cm^3 of **FA 1** as shown for experiment **2** in the table.
- Carry out experiments **3** to **7** in the same way.
- Complete the table for each experiment.

Results

experiment number	**1**	**2**	**3**	**4**	**5**	**6**	**7**
volume of **FA 2** / cm^3	25	25	25	25	25	25	25
volume of water / cm^3	35	30	25	20	15	10	5
volume of **FA 1** / cm^3	5.0	10.0	15.0	20.0	25.0	30.0	35.0
initial temperature of acid mixture / °C							
highest temperature / °C							
temperature change / °C							

[7]

I	
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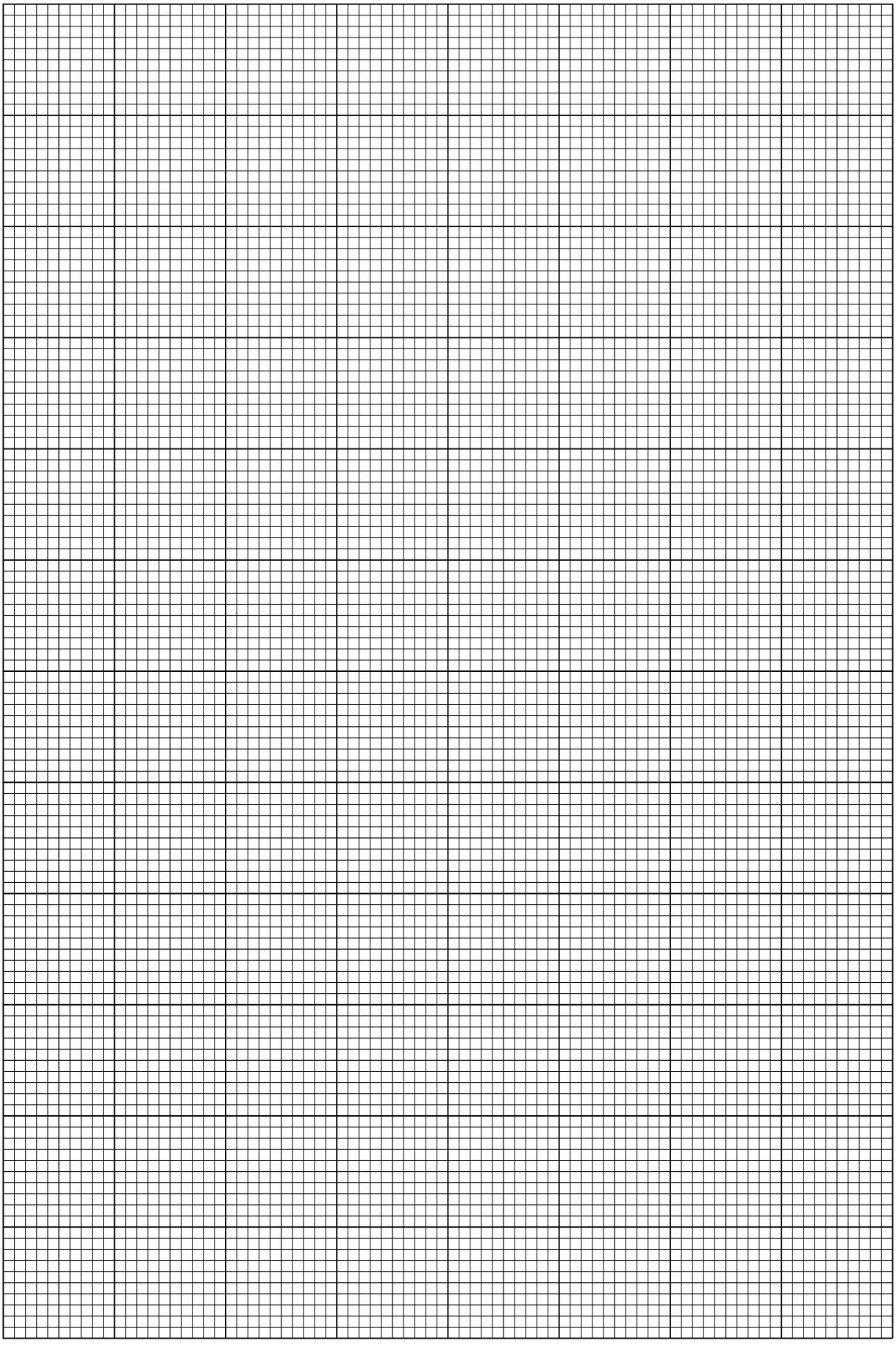
VII	

(b) On the grid below plot the temperature **change** (*y*-axis) against the volume of **FA 1** (*x*-axis). Using these points, draw two straight lines that intersect.

For Examiner's Use



I	
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III	
IV	

[4]

For Examiner's Use

(c) Reading from the intersection of the two lines on your graph,

the volume of **FA 1** is ..... cm^3,

the temperature change is ..... °C. [1]

The volume of **FA 1** at the intersection represents the volume of **FA 1** which neutralised 25.0 cm^3 of **FA 2**.

(d) The reaction between **FA 1** and **FA 2** is shown in the equation below.

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

This reaction is exothermic.

Use this information to explain the shape of the graph.

.....

.....

.....

..... [2]

(e) Calculate the amount of heat energy produced in the reaction. Use the temperature change from **(c)** in calculating your answer.

[Assume that 4.3 J are required to raise the temperature of 1 cm^3 of any solution by 1 °C]

heat energy produced = ... J [2]

(f) Calculate how many moles of hydrochloric acid are present in 25 cm^3 of **FA 2**.

mol of hydrochloric acid = ... [1]

(g) Use your answers to **(e)** and **(f)** to calculate the enthalpy change of neutralisation of hydrochloric acid by aqueous sodium hydroxide.

Give your answer in kJ mol^{-1} and include the relevant sign.

enthalpy change of neutralisation = ... kJ mol^{-1}
sign *value* [2]

(h) Explain why the **total** volume of solution used was kept constant in each of the experiments.

.....

.....

..... [1]

(i) Calculate the concentration, in mol dm^{-3}, of the aqueous sodium hydroxide, **FA 1**.

concentration of **FA 1** = ... mol dm^{-3} [2]

(j) A student thought that the experiment was not accurate because the temperature changes measured were small.

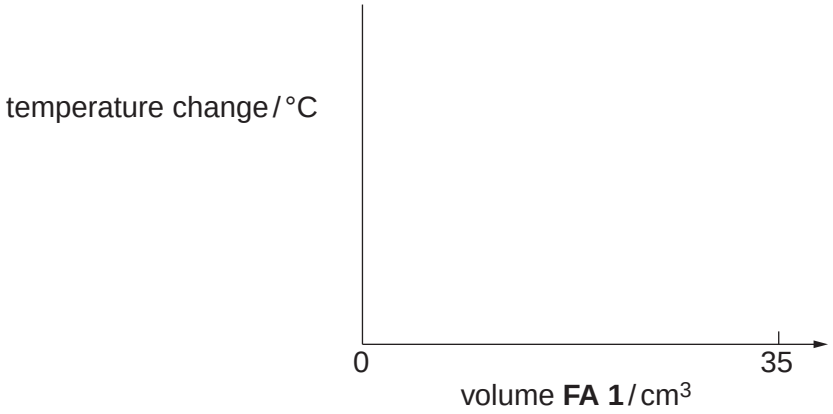
Suggest a modification to the experimental method used in order to give larger changes in temperature.

.....

..... [1]

(k) Experiments **1** to **7** were repeated using 1.00 mol dm^{-3} sulfuric acid, H_2SO_4, instead of the 2.00 mol dm^{-3} hydrochloric acid, HC*l*.

On the axes below indicate an appropriate temperature scale and sketch the graph for the temperature changes you would expect.



[2]

[Total: 25]

2 Qualitative Analysis

For Examiner's Use

At each stage of any test you are to record details of the following.

- colour changes seen
- the formation of any precipitate
- the solubility of such precipitates in an excess of the reagent added

Where gases are released they should be identified by a test, **described in the appropriate place in your observations**.

You should indicate clearly at what stage in a test a change occurs.
Marks are **not** given for chemical equations.
No additional tests for ions present should be attempted.

If any solution is warmed, a boiling tube MUST be used.

Rinse and reuse test-tubes and boiling tubes where possible.

Where reagents are selected for use in a test, the full name or correct formula of the reagents must be given.

(a) You are provided with three sodium salts **FA 3**, **FA 4** and **FA 5**. Each salt contains **one** of the ions carbonate, CO_3^{2-}, sulfite, SO_3^{2-} or sulfate, SO_4^{2-}.

(i) Using your knowledge of the reactions of these ions, suggest **one** reagent you could add to the solid to find out which ion is present in each of the solids.

.....

(ii) Use the reagent you selected in **(i)** to identify which of these ions is present in **FA 3**, **FA 4** and **FA 5**.

Carry out suitable tests on a small amount of each solid and record the results of your experiments in an appropriate form in the space below.

I	
II	
III	
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V	
VI	

Identify the anions in **FA 3**, **FA 4** and **FA 5**.

FA 3 contains the ..... ion.

FA 4 contains the ..... ion.

FA 5 contains the ..... ion. [6]

(b) (i) You are provided with **FA 6** both as a solid and in aqueous solution. Complete the following table.

For Examiner's Use

test	*observations*
To a small spatula measure of **FA 4** in a test-tube, add enough distilled water to make a solution. Add 1 cm depth of **FA 6** solution.	
To a small spatula measure of **FA 5** in a test-tube, add enough distilled water to make a solution. Add 1 cm depth of **FA 6** solution.	
To 1 cm depth of **FA 6** solution in a test-tube, add aqueous sodium hydroxide.	
Carefully heat the solid **FA 6** in the test-tube provided. Note: **two** gases are released.	

I	
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V	
VI	

[6]

(ii) From the results of the tests in **(i),** identify the cation present in **FA 6**.

Cation present in **FA 6** is …….. [1]

(iii) Suggest and use another reagent to confirm the cation present in **FA 6**.

reagent .....

observation.....[2]

[Total: 15]

[Turn over

Qualitative Analysis Notes

Key: [ppt. = precipitate]

1 Reactions of aqueous cations

ion	*reaction with*	
	NaOH(aq)	NH_3(aq)
aluminium, Al^{3+}(aq)	white ppt. soluble in excess	white ppt. insoluble in excess
ammonium, NH_4^+(aq)	no ppt. ammonia produced on heating	
barium, Ba^{2+}(aq)	no ppt. (if reagents are pure)	no ppt.
calcium, Ca^{2+}(aq)	white ppt. with high [Ca^{2+}(aq)]	no ppt.
chromium(III), Cr^{3+}(aq)	grey-green ppt. soluble in excess giving dark green solution	grey-green ppt. insoluble in excess
copper(II), Cu^{2+}(aq)	pale blue ppt. insoluble in excess	blue ppt. soluble in excess giving dark blue solution
iron(II), Fe^{2+}(aq)	green ppt. turning brown on contact with air insoluble in excess	green ppt. turning brown on contact with air insoluble in excess
iron(III), Fe^{3+}(aq)	red-brown ppt. insoluble in excess	red-brown ppt. insoluble in excess
lead(II), Pb^{2+}(aq)	white ppt. soluble in excess	white ppt. insoluble in excess
magnesium, Mg^{2+}(aq)	white ppt. insoluble in excess	white ppt. insoluble in excess
manganese(II), Mn^{2+}(aq)	off-white ppt. rapidly turning brown on contact with air insoluble in excess	off-white ppt. rapidly turning brown on contact with air insoluble in excess
zinc, Zn^{2+}(aq)	white ppt. soluble in excess	white ppt. soluble in excess

[Lead(II) ions can be distinguished from aluminium ions by the insolubility of lead(II) chloride.]

2 Reactions of anions

ion	*reaction*
carbonate, CO_3^{2-}	CO_2 liberated by dilute acids
chromate(VI), CrO_4^{2-} (aq)	yellow solution turns orange with H^+(aq); gives yellow ppt. with Ba^{2+}(aq); gives bright yellow ppt. with Pb^{2+}(aq)
chloride, Cl^- (aq)	gives white ppt. with Ag^+(aq) (soluble in NH_3(aq)); gives white ppt. with Pb^{2+}(aq)
bromide, Br^- (aq)	gives cream ppt. with Ag^+(aq) (partially soluble in NH_3(aq)); gives white ppt. with Pb^{2+}(aq)
iodide, I^- (aq)	gives yellow ppt. with Ag^+(aq) (insoluble in NH_3(aq)); gives yellow ppt. with Pb^{2+}(aq)
nitrate, NO_3^- (aq)	NH_3 liberated on heating with OH^-(aq) and Al foil
nitrite, NO_2^- (aq)	NH_3 liberated on heating with OH^-(aq) and Al foil; NO liberated by dilute acids (colourless NO → (pale) brown NO_2 in air)
sulfate, SO_4^{2-} (aq)	gives white ppt. with Ba^{2+}(aq) or with Pb^{2+}(aq) (insoluble in excess dilute strong acids)
sulfite, SO_3^{2-} (aq)	SO_2 liberated with dilute acids; gives white ppt. with Ba^{2+}(aq) (soluble in excess dilute strong acids)

3 Tests for gases

gas	*test and test result*
ammonia, NH_3	turns damp red litmus paper blue
carbon dioxide, CO_2	gives a white ppt. with limewater (ppt. dissolves with excess CO_2)
chlorine, Cl_2	bleaches damp litmus paper
hydrogen, H_2	“pops” with a lighted splint
oxygen, O_2	relights a glowing splint
sulfur dioxide, SO_2	turns acidified aqueous potassium dichromate(VI) from orange to green

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UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS
General Certificate of Education
Advanced Subsidiary Level and Advanced Level

CANDIDATE NAME

CENTRE NUMBER

CANDIDATE NUMBER

CHEMISTRY **9701/33**

Advanced Practical Skills 1 **October/November 2011**

2 hours

Candidates answer on the Question Paper.

Additional Materials: As listed in the Confidential Instructions

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Session
Laboratory

For Examiner's Use	
1	
2	
Total	

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For Examiner's Use

FA 1 is aqueous sodium hydroxide, NaOH.
FA 2 is 2.00 mol dm^{-3} hydrochloric acid, HC*l*.

(a) Method

- Fill a burette with **FA 1**. **[Care: FA 1 is corrosive]**
- Support the plastic cup in a 250 cm^3 beaker.
- Use a measuring cylinder to transfer 25 cm^3 of **FA 2** into a 100 cm^3 beaker.
- Use a measuring cylinder to add 35 cm^3 of distilled water to the acid in the beaker.
- Measure and record, in the table below, the initial temperature of the mixture in the beaker.
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- Add the mixture of acid and water from the 100 cm^3 beaker to the **FA 1** in the plastic cup.
- Stir carefully and measure the highest temperature obtained.
- Record this temperature in the table.
- Rinse the plastic cup with water.
- Repeat the experiment using 25 cm^3 of **FA 2**, 30 cm^3 of distilled water and 10.0 cm^3 of **FA 1** as shown for experiment **2** in the table.
- Carry out experiments **3** to **7** in the same way.
- Complete the table for each experiment.

Results

experiment number	**1**	**2**	**3**	**4**	**5**	**6**	**7**
volume of **FA 2** / cm^3	25	25	25	25	25	25	25
volume of water / cm^3	35	30	25	20	15	10	5
volume of **FA 1** / cm^3	5.0	10.0	15.0	20.0	25.0	30.0	35.0
initial temperature of acid mixture / °C							
highest temperature / °C							
temperature change / °C							

[7]

I	
II	
III	
IV	
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VI	
VII	

(b) On the grid below plot the temperature **change** (*y*-axis) against the volume of **FA 1** (*x*-axis). Using these points, draw two straight lines that intersect.

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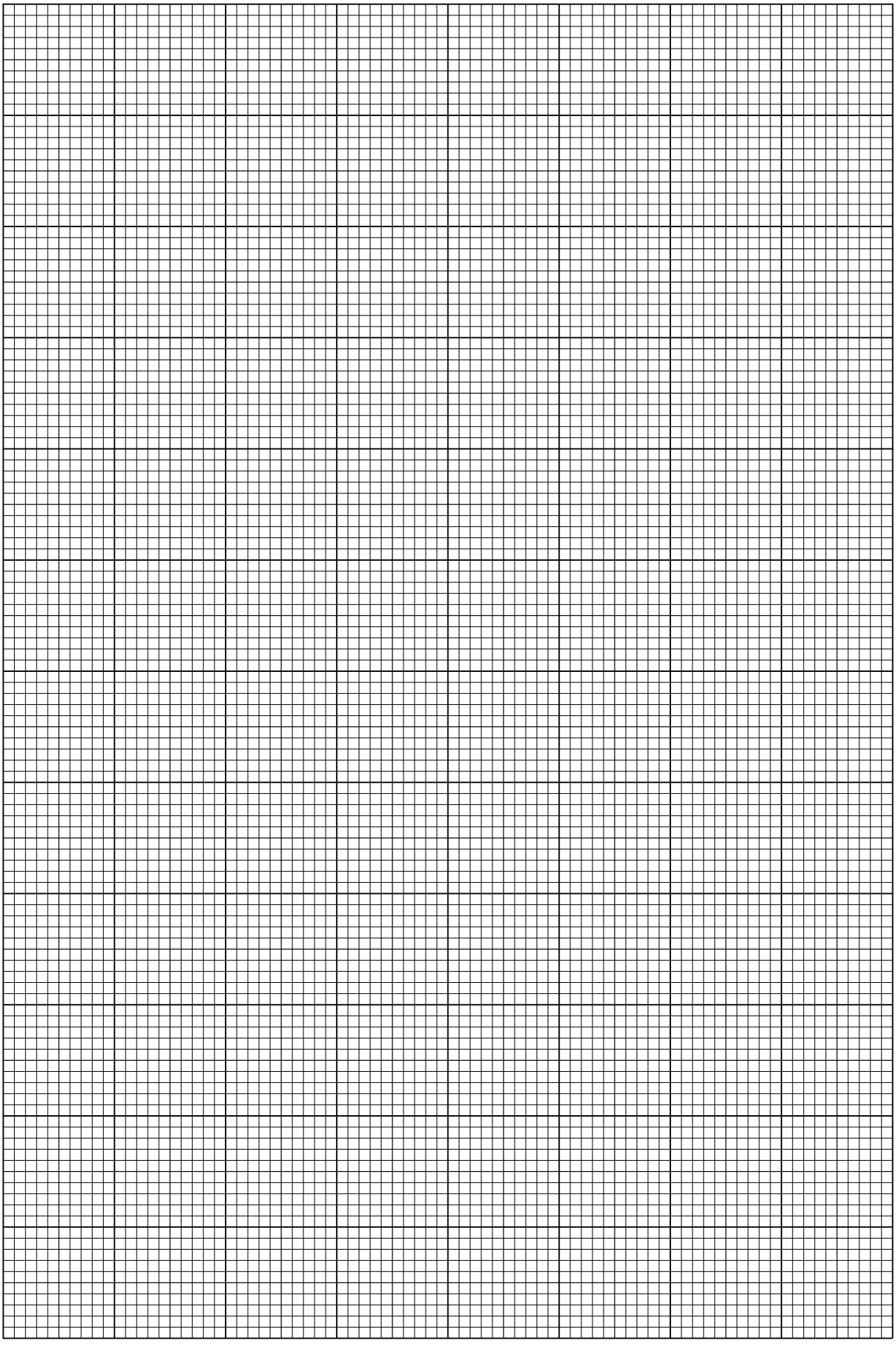

I	
II	
III	
IV	

[4]

For Examiner's Use

(c) Reading from the intersection of the two lines on your graph,

the volume of **FA 1** is ..... cm^3,

the temperature change is ..... °C. [1]

The volume of **FA 1** at the intersection represents the volume of **FA 1** which neutralised 25.0 cm^3 of **FA 2**.

(d) The reaction between **FA 1** and **FA 2** is shown in the equation below.

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

This reaction is exothermic.

Use this information to explain the shape of the graph.

.....

.....

.....

..... [2]

(e) Calculate the amount of heat energy produced in the reaction. Use the temperature change from **(c)** in calculating your answer.

[Assume that 4.3 J are required to raise the temperature of 1 cm^3 of any solution by 1 °C]

heat energy produced = ... J [2]

(f) Calculate how many moles of hydrochloric acid are present in 25 cm^3 of **FA 2**.

mol of hydrochloric acid = ... [1]

(g) Use your answers to **(e)** and **(f)** to calculate the enthalpy change of neutralisation of hydrochloric acid by aqueous sodium hydroxide.

Give your answer in kJ mol^{-1} and include the relevant sign.

enthalpy change of neutralisation = ... kJ mol^{-1}
sign *value* [2]

(h) Explain why the **total** volume of solution used was kept constant in each of the experiments.

.....

.....

..... [1]

(i) Calculate the concentration, in mol dm^{-3}, of the aqueous sodium hydroxide, **FA 1**.

concentration of **FA 1** = ... mol dm^{-3} [2]

(j) A student thought that the experiment was not accurate because the temperature changes measured were small.

Suggest a modification to the experimental method used in order to give larger changes in temperature.

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..... [1]

(k) Experiments **1** to **7** were repeated using 1.00 mol dm^{-3} sulfuric acid, H_2SO_4, instead of the 2.00 mol dm^{-3} hydrochloric acid, HC*l*.

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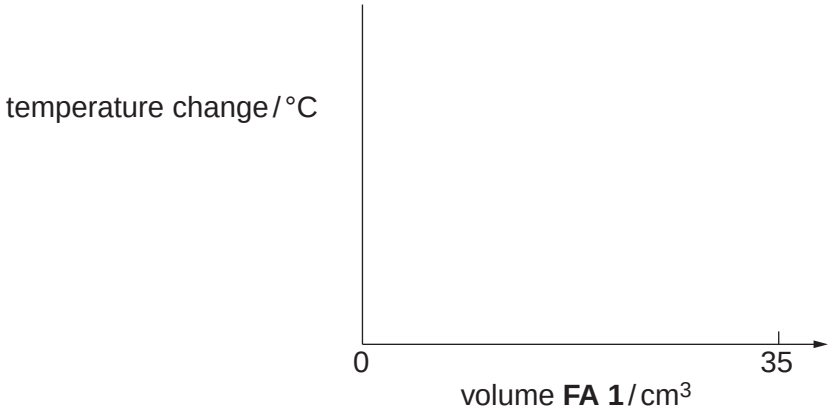

[2]

[Total: 25]

2 Qualitative Analysis

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Rinse and reuse test-tubes and boiling tubes where possible.

Where reagents are selected for use in a test, the full name or correct formula of the reagents must be given.

(a) You are provided with three sodium salts **FA 3**, **FA 4** and **FA 5**. Each salt contains **one** of the ions carbonate, CO_3^{2-}, sulfite, SO_3^{2-} or sulfate, SO_4^{2-}.

(i) Using your knowledge of the reactions of these ions, suggest **one** reagent you could add to the solid to find out which ion is present in each of the solids.

.....

(ii) Use the reagent you selected in **(i)** to identify which of these ions is present in **FA 3**, **FA 4** and **FA 5**.

Carry out suitable tests on a small amount of each solid and record the results of your experiments in an appropriate form in the space below.

I	
II	
III	
IV	
V	
VI	

Identify the anions in **FA 3**, **FA 4** and **FA 5**.

FA 3 contains the ..... ion.

FA 4 contains the ..... ion.

FA 5 contains the ..... ion. [6]

(b) (i) You are provided with **FA 6** both as a solid and in aqueous solution. Complete the following table.

For Examiner's Use

test	*observations*
To a small spatula measure of **FA 4** in a test-tube, add enough distilled water to make a solution. Add 1 cm depth of **FA 6** solution.	
To a small spatula measure of **FA 5** in a test-tube, add enough distilled water to make a solution. Add 1 cm depth of **FA 6** solution.	
To 1 cm depth of **FA 6** solution in a test-tube, add aqueous sodium hydroxide.	
Carefully heat the solid **FA 6** in the test-tube provided. Note: **two** gases are released.	

I	
II	
III	
IV	
V	
VI	

[6]

(ii) From the results of the tests in **(i),** identify the cation present in **FA 6**.

Cation present in **FA 6** is …….. [1]

(iii) Suggest and use another reagent to confirm the cation present in **FA 6**.

reagent .....

observation.....[2]

[Total: 15]

[Turn over

Qualitative Analysis Notes

Key: [ppt. = precipitate]

1 Reactions of aqueous cations

ion	*reaction with*	
	NaOH(aq)	NH_3(aq)
aluminium, Al^{3+}(aq)	white ppt. soluble in excess	white ppt. insoluble in excess
ammonium, NH_4^+(aq)	no ppt. ammonia produced on heating	
barium, Ba^{2+}(aq)	no ppt. (if reagents are pure)	no ppt.
calcium, Ca^{2+}(aq)	white ppt. with high [Ca^{2+}(aq)]	no ppt.
chromium(III), Cr^{3+}(aq)	grey-green ppt. soluble in excess giving dark green solution	grey-green ppt. insoluble in excess
copper(II), Cu^{2+}(aq)	pale blue ppt. insoluble in excess	blue ppt. soluble in excess giving dark blue solution
iron(II), Fe^{2+}(aq)	green ppt. turning brown on contact with air insoluble in excess	green ppt. turning brown on contact with air insoluble in excess
iron(III), Fe^{3+}(aq)	red-brown ppt. insoluble in excess	red-brown ppt. insoluble in excess
lead(II), Pb^{2+}(aq)	white ppt. soluble in excess	white ppt. insoluble in excess
magnesium, Mg^{2+}(aq)	white ppt. insoluble in excess	white ppt. insoluble in excess
manganese(II), Mn^{2+}(aq)	off-white ppt. rapidly turning brown on contact with air insoluble in excess	off-white ppt. rapidly turning brown on contact with air insoluble in excess
zinc, Zn^{2+}(aq)	white ppt. soluble in excess	white ppt. soluble in excess

[Lead(II) ions can be distinguished from aluminium ions by the insolubility of lead(II) chloride.]

2 Reactions of anions

ion	*reaction*
carbonate, CO_3^{2-}	CO_2 liberated by dilute acids
chromate(VI), CrO_4^{2-} (aq)	yellow solution turns orange with H^+(aq); gives yellow ppt. with Ba^{2+}(aq); gives bright yellow ppt. with Pb^{2+}(aq)
chloride, Cl^- (aq)	gives white ppt. with Ag^+(aq) (soluble in NH_3(aq)); gives white ppt. with Pb^{2+}(aq)
bromide, Br^- (aq)	gives cream ppt. with Ag^+(aq) (partially soluble in NH_3(aq)); gives white ppt. with Pb^{2+}(aq)
iodide, I^- (aq)	gives yellow ppt. with Ag^+(aq) (insoluble in NH_3(aq)); gives yellow ppt. with Pb^{2+}(aq)
nitrate, NO_3^- (aq)	NH_3 liberated on heating with OH^-(aq) and Al foil
nitrite, NO_2^- (aq)	NH_3 liberated on heating with OH^-(aq) and Al foil; NO liberated by dilute acids (colourless NO → (pale) brown NO_2 in air)
sulfate, SO_4^{2-} (aq)	gives white ppt. with Ba^{2+}(aq) or with Pb^{2+}(aq) (insoluble in excess dilute strong acids)
sulfite, SO_3^{2-} (aq)	SO_2 liberated with dilute acids; gives white ppt. with Ba^{2+}(aq) (soluble in excess dilute strong acids)

3 Tests for gases

gas	*test and test result*
ammonia, NH_3	turns damp red litmus paper blue
carbon dioxide, CO_2	gives a white ppt. with limewater (ppt. dissolves with excess CO_2)
chlorine, Cl_2	bleaches damp litmus paper
hydrogen, H_2	“pops” with a lighted splint
oxygen, O_2	relights a glowing splint
sulfur dioxide, SO_2	turns acidified aqueous potassium dichromate(VI) from orange to green

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UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS
General Certificate of Education
Advanced Subsidiary Level and Advanced Level

CANDIDATE NAME

CENTRE NUMBER

CANDIDATE NUMBER

CHEMISTRY **9701/34**

Advanced Practical Skills 2 **October/November 2011**

2 hours

Candidates answer on the Question Paper.

Additional Materials: As listed in the Confidential Instructions

READ THESE INSTRUCTIONS FIRST

Write your Centre number, candidate number and name on all the work you hand in.
Give details of the practical session and laboratory where appropriate, in the boxes provided.
Write in dark blue or black pen.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.
DO **NOT** WRITE IN ANY BARCODES.

Answer **all** questions.
You may lose marks if you do not show your working or if you do not use appropriate units.
Use of a Data Booklet is unnecessary.

Qualitative Analysis Notes are printed on pages 10 and 11.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

Session
Laboratory

For Examiner's Use	
1	
2	
Total	

This document consists of **11** printed pages and **1** blank page.

1 You are to determine the enthalpy change of neutralisation of sodium hydroxide by an acid and also the concentration of hydrogen ions in the acid. These can be found by measuring the temperature change when solutions of the acid and alkali are mixed.

For Examiner's Use

FB 1 is 1.50 mol dm^{-3} sodium hydroxide, NaOH.
FB 2 is an aqueous solution of an acid.

(a) Method

- Fill a burette with **FB 1**. **[Care: FA1 is corrosive]**
- Support the plastic cup in a 250 cm^3 beaker.
- Run 10.0 cm^3 of **FB 1** from the burette into the plastic cup.
- Measure and record, in the table below, the temperature of the **FB 1** in the cup. You may need to tilt the beaker to ensure that the bulb of the thermometer is covered.
- Measure 40 cm^3 of **FB 2** using the measuring cylinder.
- Pour this volume of **FB 2** into the plastic cup containing **FB 1**. Stir carefully and measure the highest temperature obtained.
- Record this temperature in the table.
- Rinse the plastic cup with water.
- Repeat the experiment using 15.0 cm^3 of **FB 1** and 35 cm^3 of **FB 2** as shown for experiment **2** in the table.
- Carry out experiments **3** to **7** in the same way.
- Complete the table for each experiment.

Results

experiment number	**1**	**2**	**3**	**4**	**5**	**6**	**7**		
volume of **FB 1** / cm^3	10.0	15.0	20.0	25.0	30.0	35.0	40.0	50.0	0.0
volume of **FB 2** / cm^3	40	35	30	25	20	15	10	0	50
initial temperature **FB 1** / °C									
highest temperature / °C									
temperature change / °C								0.0	0.0

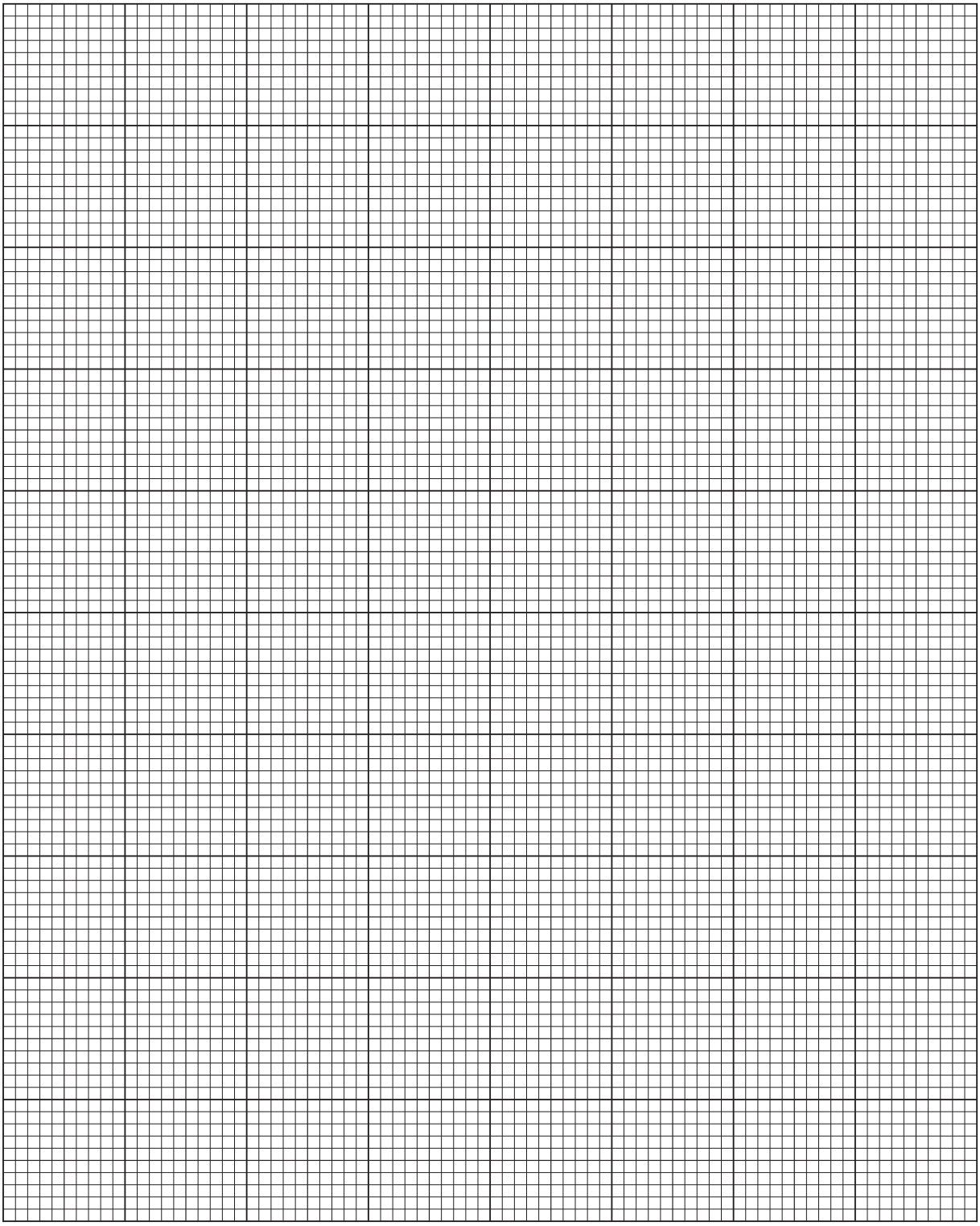
[8]

I	
II	
III	
IV	
V	
VI	
VII	
VIII	

(b) On the grid below plot the temperature **change** (*y*-axis) against the volume of **FB 1** (*x*-axis). Use **all** the results in the table including those provided in the final two columns.

Using these points, draw two straight lines that intersect.

For Examiner's Use



[4]

I	
II	
III	
IV	

[Turn over

(c) **(i)** Use your graph and the intersection of the two lines to determine the largest temperature change which could occur in the reaction between **FB 1** and **FB 2**.

For Examiner's Use

largest temperature change = ... °C

(ii) From your graph, read the volume of **FB 1** required to produce the temperature change in **(i)**.

volume of **FB 1** required is = ... cm^3

(iii) Calculate how many moles of sodium hydroxide are present in the volume of **FB 1** recorded in **(ii)**.

moles of sodium hydroxide present = ... mol

(iv) Use the temperature change from **(i)** to calculate the amount of heat energy produced in the reaction.

[Assume that 4.3 J are required to raise the temperature of 1 cm^3 of any solution by 1°C]

heat energy produced = ... J

(v) Use your answers from **(iii)** and **(iv)** to calculate the enthalpy change of neutralisation of sodium hydroxide by the acid.

Give your answer in $kJ\,mol^{-1}$ and include the relevant sign.

enthalpy change of neutralisation = ... $kJ\,mol^{-1}$
sign *value*

[7]

I	
II	
III	
IV	
V	
VI	
VII	

(d) Identify a source of error, other than heat loss, in the experimental method. Suggest an improvement which would reduce this source of error.

For Examiner's Use

.....

.....

.....

..... [2]

(e) **(i)** Calculate the concentration of hydrogen ions, H^+, in mol dm^{-3}, present in **FB 2**.

concentration of hydrogen ions in **FB 2** = ... mol dm^{-3}

(ii) If the acid present in **FB 2** is sulfuric acid, calculate its concentration.

concentration of sulfuric acid = ... mol dm^{-3}

(iii) Describe a chemical test by which you could prove that the acid in **FB 2** is sulfuric acid.

Do not carry out the test.

.....

.....

.....

.....

[4]

[Total: 25]

I	
II	
III	
IV	

2 Qualitative Analysis

For Examiner's Use

At each stage of any test you are to record the details of the following

- colour changes seen
- the formation of any precipitate
- the solubility of such precipitates in an excess of the reagent added

Where gases are released they should be identified by a test, **described in the appropriate place in your observations**.

You should indicate clearly at what stage in a test a change occurs.
Marks are **not** given for chemical equations.
No additional tests for ions present should be attempted.

If any solution is warmed, a boiling tube MUST be used.

Rinse and reuse test-tubes and boiling tubes where possible.

Where reagents are selected for use in a test, the full name or correct formula of the reagents must be given.

(a) (i) **FB 3**, **FB 4** and **FB 5** are aqueous solutions of sodium compounds. None of these compounds contains sulfur.

To about 1 cm depth of each of the solutions in separate test-tubes add the same depth of dilute sulfuric acid.

To another 1 cm depth of each of the solutions in separate test-tubes add a few drops of aqueous lead(II) nitrate.

Record your observations for these tests in an appropriate form in the space below.

I	
II	
III	
IV	
V	
VI	

Using the Qualitative Analysis Notes printed on pages 10 and 11 and your observations identify the anions in **FB 3** and **FB 4**.

For Examiner's Use

FB 3 contains .....

FB 4 contains .....

[6]

(ii) Select a reagent or pair of reagents that would enable you to determine the identity of the anion in **FB 5**.

reagent(s) .....

Carry out a test on **FB 5** using the reagent(s) given above. Record your observations below.

.....

.....

.....

I	
II	
III	

The anion present in **FB5** is ..... [3]

(b) You are provided with solid **FB 6.** Complete the following table.

For Examiner's Use

	test	*observations*
(i)	To 1 cm depth of aqueous hydrogen peroxide in a test-tube, add a very small spatula measure of **FB 6**.	
(ii)	To 1 cm depth of aqueous iron(II) sulfate in a boiling tube, add the same depth of dilute sulfuric acid. Add a very small spatula measure of **FB 6** to the tube. Warm the mixture gently using a Bunsen burner for about 20 seconds, then filter the warm mixture and collect the filtrate.	
	To the filtrate, add aqueous sodium hydroxide.	
(iii)	To 2 cm depth of aqueous potassium manganate(VII) in a test-tube, add the same depth of aqueous sodium hydroxide and then a small spatula measure of **FB 6**. Stir the contents of the test-tube for about 20 seconds. Filter the mixture and collect the filtrate.	
	To the filtrate, add dilute sulfuric acid.	

Suggest a conclusion that could be made about the chemical behaviour of **FB 6** from the observations in **(i)**. Explain the reasons for your answer.

.....

.....

What conclusion can be made about the chemical behaviour of **FB 6** from the observations in **(ii)**?

.....

.....

[6]

[Total: 15]

For Examiner's Use

I	
II	
III	
IV	
V	
VI	

[Turn over

Qualitative Analysis Notes

Key: [ppt. = precipitate]

1 Reactions of aqueous cations

ion	*reaction with*	
	NaOH(aq)	NH_3(aq)
aluminium, Al^{3+}(aq)	white ppt. soluble in excess	white ppt. insoluble in excess
ammonium, NH_4^+(aq)	no ppt. ammonia produced on heating	
barium, Ba^{2+}(aq)	no ppt. (if reagents are pure)	no ppt.
calcium, Ca^{2+}(aq)	white ppt. with high [Ca^{2+}(aq)]	no ppt.
chromium(III), Cr^{3+}(aq)	grey-green ppt. soluble in excess giving dark green solution	grey-green ppt. insoluble in excess
copper(II), Cu^{2+}(aq)	pale blue ppt. insoluble in excess	blue ppt. soluble in excess giving dark blue solution
iron(II), Fe^{2+}(aq)	green ppt. turning brown on contact with air insoluble in excess	green ppt. turning brown on contact with air insoluble in excess
iron(III), Fe^{3+}(aq)	red-brown ppt. insoluble in excess	red-brown ppt. insoluble in excess
lead(II), Pb^{2+}(aq)	white ppt. soluble in excess	white ppt. insoluble in excess
magnesium, Mg^{2+}(aq)	white ppt. insoluble in excess	white ppt. insoluble in excess
manganese(II), Mn^{2+}(aq)	off-white ppt. rapidly turning brown on contact with air insoluble in excess	off-white ppt. rapidly turning brown on contact with air insoluble in excess
zinc, Zn^{2+}(aq)	white ppt. soluble in excess	white ppt. soluble in excess

[Lead(II) ions can be distinguished from aluminium ions by the insolubility of lead(II) chloride.]

2 Reactions of anions

ion	*reaction*
carbonate, CO_3^{2-}	CO_2 liberated by dilute acids
chromate(VI), CrO_4^{2-} (aq)	yellow solution turns orange with H^+(aq); gives yellow ppt. with Ba^{2+}(aq); gives bright yellow ppt. with Pb^{2+}(aq)
chloride, Cl^- (aq)	gives white ppt. with Ag^+(aq) (soluble in NH_3(aq)); gives white ppt. with Pb^{2+}(aq)
bromide, Br^- (aq)	gives cream ppt. with Ag^+(aq) (partially soluble in NH_3(aq)); gives white ppt. with Pb^{2+}(aq)
iodide, I^- (aq)	gives yellow ppt. with Ag^+(aq) (insoluble in NH_3(aq)); gives yellow ppt. with Pb^{2+}(aq)
nitrate, NO_3^- (aq)	NH_3 liberated on heating with OH^-(aq) and Al foil
nitrite, NO_2^- (aq)	NH_3 liberated on heating with OH^-(aq) and Al foil; NO liberated by dilute acids (colourless NO → (pale) brown NO_2 in air)
sulfate, SO_4^{2-} (aq)	gives white ppt. with Ba^{2+}(aq) or with Pb^{2+}(aq) (insoluble in excess dilute strong acids)
sulfite, SO_3^{2-} (aq)	SO_2 liberated with dilute acids; gives white ppt. with Ba^{2+}(aq) (soluble in excess dilute strong acids)

3 Tests for gases

gas	*test and test result*
ammonia, NH_3	turns damp red litmus paper blue
carbon dioxide, CO_2	gives a white ppt. with limewater (ppt. dissolves with excess CO_2)
chlorine, Cl_2	bleaches damp litmus paper
hydrogen, H_2	“pops” with a lighted splint
oxygen, O_2	relights a glowing splint
sulfur dioxide, SO_2	turns acidified aqueous potassium dichromate(VI) from orange to green

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UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS
General Certificate of Education
Advanced Subsidiary Level and Advanced Level

CANDIDATE NAME

CENTRE NUMBER

CANDIDATE NUMBER

CHEMISTRY **9701/35**

Advanced Practical Skills 1 **October/November 2011**

2 hours

Candidates answer on the Question Paper.

Additional Materials: As listed in the Confidential Instructions

READ THESE INSTRUCTIONS FIRST

Write your Centre number, candidate number and name on all the work you hand in.
Give details of the practical session and laboratory where appropriate, in the boxes provided.
Write in dark blue or black pen.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.
DO **NOT** WRITE IN ANY BARCODES.

Answer **all** questions.
You may lose marks if you do not show your working or if you do not use appropriate units.
Use of a Data Booklet is unnecessary.

Qualitative Analysis Notes are printed on pages 11 and 12.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

Session
Laboratory

For Examiner's Use	
1	
2	
Total	

This document consists of **10** printed pages and **2** blank pages.

1 You are required to investigate the effect of temperature on the rate of reaction of peroxydisulfate ions with iodide ions. Iodide ions are oxidised to iodine by peroxydisulfate ions.

For Examiner's Use

$$S_2O_8^{2-}(aq) + 2I^-(aq) \longrightarrow 2SO_4^{2-}(aq) + I_2(aq)$$

FA 1 is aqueous potassium peroxydisulfate, $K_2S_2O_8$.
FA 2 is an aqueous solution containing a mixture of potassium iodide, KI, sodium thiosulfate, $Na_2S_2O_3$, and starch.

When **FA 1** and **FA 2** are mixed together the potassium peroxydisulfate reacts with the potassium iodide to make iodine. As soon as this iodine is formed, it reacts with the sodium thiosulfate and is turned back into iodide ions. Only when all the sodium thiosulfate has reacted does iodine remain in the solution. The solution then turns blue-black because of the presence of the starch indicator. The rate of reaction can be determined by the time it takes for a blue-black colour to first appear in the colourless mixture.

(a) Method

Read through the method and prepare a table on page 3 to record the initial and final temperatures and the reaction time for each experiment, before starting any practical work.

- Half-fill a 250 cm^3 beaker with water to act as a water bath.
- Place it on a tripod and gauze and heat it with a Bunsen burner to about 65 °C then remove the Bunsen. While your water is being heated continue with the following steps of the method.
- Fill the burette, labelled **FA 1**, with the aqueous potassium peroxydisulfate, **FA 1**.
- Fill the burette, labelled **FA 2**, with the mixture of solutions, **FA 2**.
- Measure 10.0 cm^3 of **FA 1** into a boiling tube.
- Measure 10.0 cm^3 of **FA 2** into a second boiling tube.
- Place both boiling tubes in the water bath.
- Clamp one of the tubes and place a thermometer in this tube.
- When the temperature of this solution has reached about 60 °C, pour the contents of the second tube into the clamped tube. Start timing immediately, note the temperature and stir the mixture.
- Record this initial temperature.
- Stop timing as soon as the blue-black colour appears. Record this reaction time to the **nearest second** and record the final temperature.
- Repeat the experiment at decreasing temperatures as many times as necessary to generate data for plotting a graph. The experiment should not be performed at a temperature below about 30 °C. The temperature of the water bath may be adjusted by adding cold water or by reheating. (Boiling tubes may be rinsed and reused.)

For Examiner's Use

I	
II	
III	
IV	
V	

[5]

(b) The rate of reaction for each experiment can be represented by the following.

$$\text{'rate'} = \frac{\textbf{1000}}{\textbf{reaction time in seconds}}$$

Complete the following table for each of your experiments. The mean temperature is the average of the initial and final temperature for the experiment.

mean temperature / °C	'rate'

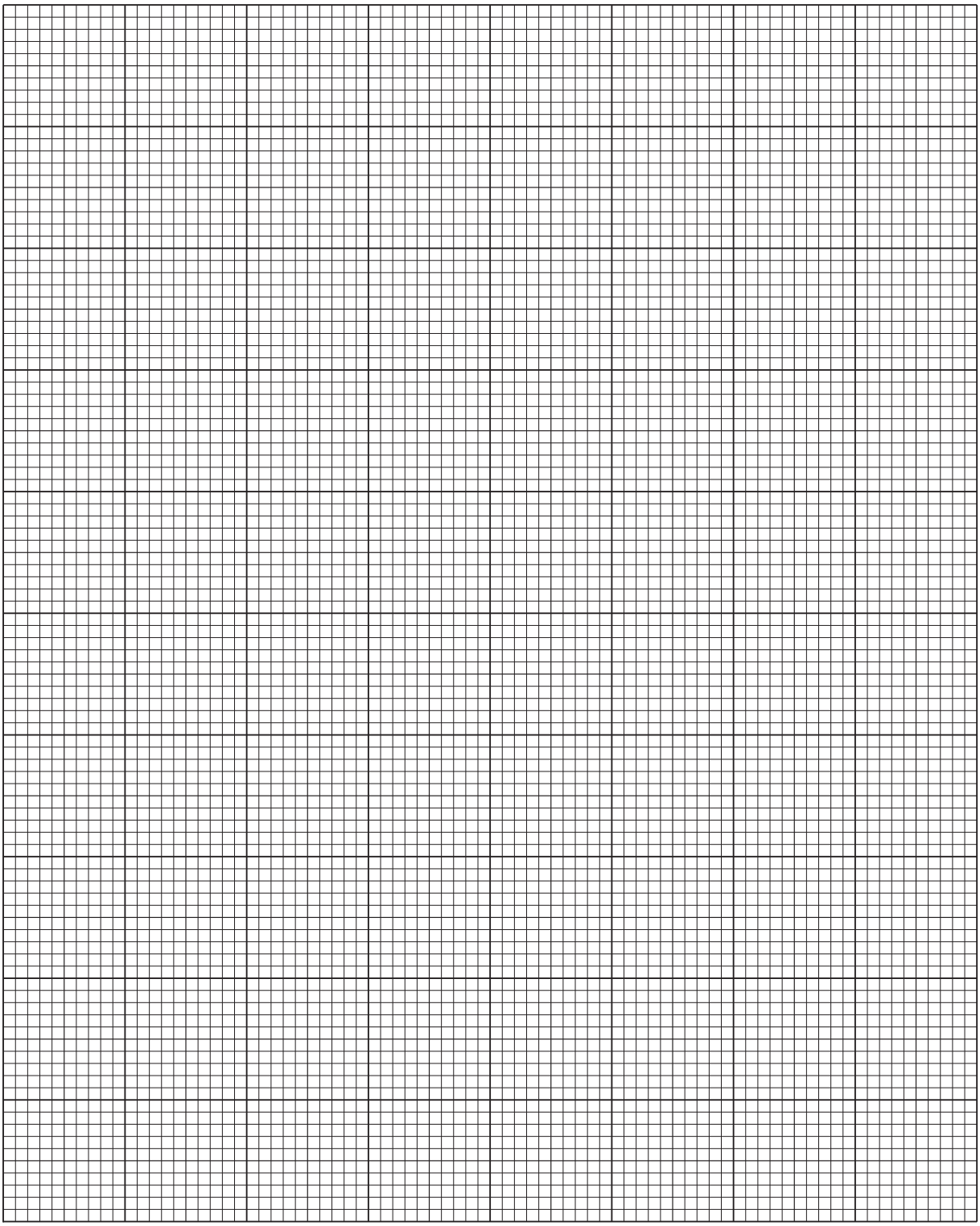
I	
II	
III	
IV	
V	
VI	

[6]

[Turn over

(c) **(i)** Using your values in **(b)**, plot a graph of 'rate' (*y*-axis) against mean temperature (*x*-axis). Choose suitable scales to allow you to extrapolate the graph to include the 'rate' at 20 °C.

For Examiner's Use



I	
II	
III	
IV	

(ii) Use your graph to obtain a value for the 'rate' at 20 °C.

'rate' at 20 °C is ..... [4]

(d) It has been suggested that an increase in temperature of 10 °C will double the rate of reaction. Use two pairs of temperatures from your graph to confirm or deny this statement.

.....

.....

.....

.....[2]

(e) **(i)** Which of your experiments has the greatest percentage error in timing?

.....

(ii) Calculate the percentage error in **(i)**.
You may assume that the error in measuring the time for a reaction is ±0.5 seconds.

error in **(i)** = ... % [2]

(f) A student had difficulty in drawing a line of best fit. Identify a source of error in the experimental **procedure**. Do not include any errors involving the precision of apparatus.

.....

.....[1]

(g) Suggest a modification that could be used to reduce this error.

.....

.....[1]

(h) Using **FA 1**, **FA 2** and distilled water, describe how you could investigate the effect of **concentration** of potassium peroxydisulfate on the rate of reaction.

.....

.....

.....

.....

.....[3]

[Total: 24]

[Turn over

2 Qualitative analysis

For Examiner's Use

At each stage of any test you are to record details of the following.

- colour changes seen
- the formation of any precipitate
- the solubility of such precipitates in an excess of the reagent added

Where gases are released they should be identified by a test, **described in the appropriate place in your observations**.

You should indicate clearly at what stage in a test a change occurs.
Marks are **not** given for chemical equations.
No additional tests for ions present should be attempted.

If any solution is warmed, a boiling tube MUST be used.

Rinse and reuse test-tubes and boiling tubes where possible.

Where reagents are selected for use in a test the full name or correct formula of the reagents must be given.

FA 3, **FA 4** and **FA 5** are aqueous solutions containing one cation and one anion. One of these solutions is a dilute acid and this is the only acid present.

(a) (i) Select a single chemical reagent from those supplied which would allow you to identify the dilute acid. You may not use indicator paper.

reagent .....

(ii) Use this reagent to test all three solutions and record your results in an appropriate form in the space below.

I	
II	
III	
IV	
V	

(iii) From your observations in **(ii)**, identify which solution is the dilute acid.

FA ..... is the dilute acid.

[5]

(b) The acid you have identified in **(a)(iii)** is dilute sulfuric acid.
Complete the following table.

For Examiner's Use

test	*observations*
To 1 cm depth of **FA 3** in a test-tube, add 1 cm depth of **FA 4**, then	
add excess hydrochloric acid.	
To 1 cm depth of **FA 4** in a test-tube, add 1 cm depth of **FA 5**, then	
add excess hydrochloric acid.	
To 1 cm depth of **FA 5** in a test-tube, add 1 cm depth of **FA 3**, then	
add excess hydrochloric acid.	

[4]

I	
II	
III	
IV	

(c) For the two unidentified solutions, complete the following table.

test	*observations*	
	FA	**FA .....**
To 1 cm depth of unknown in a boiling tube, add NaOH(aq)		
warm the tube carefully		

[2]

[Turn over

(d) From your observations in **(a)**, **(b)** and **(c)**, identify the ions present in the two solutions tested in **(c)**, giving the relevant evidence for each. If you have not been able to identify one or more of the ions, explain why the evidence obtained was insufficient.

For Examiner's Use

I	
II	
III	
IV	

FA ..... cation ..... evidence .....

.....

.....

anion ..... evidence .....

.....

.....

FA ..... cation ..... evidence .....

.....

.....

anion ..... evidence .....

.....

.....

[4]

(e) If one of the aqueous anions was a bromide, what would be the minimum evidence needed for its identification?

.....

.....

.....[1]

[Total: 16]

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Qualitative Analysis Notes

Key: [ppt. = precipitate]

1 Reactions of aqueous cations

ion	*reaction with*	
	NaOH(aq)	NH_3(aq)
aluminium, Al^{3+}(aq)	white ppt. soluble in excess	white ppt. insoluble in excess
ammonium, NH_4^+(aq)	no ppt. ammonia produced on heating	–
barium, Ba^{2+}(aq)	no ppt. (if reagents are pure)	no ppt.
calcium, Ca^{2+}(aq)	white ppt. with high [Ca^{2+}(aq)]	no ppt.
chromium(III), Cr^{3+}(aq)	grey-green ppt. soluble in excess giving dark green solution	grey-green ppt. insoluble in excess
copper(II), Cu^{2+}(aq)	pale blue ppt. insoluble in excess	blue ppt. soluble in excess giving dark blue solution
iron(II), Fe^{2+}(aq)	green ppt. turning brown on contact with air insoluble in excess	green ppt. turning brown on contact with air insoluble in excess
iron(III), Fe^{3+}(aq)	red-brown ppt. insoluble in excess	red-brown ppt. insoluble in excess
lead(II), Pb^{2+}(aq)	white ppt. soluble in excess	white ppt. insoluble in excess
magnesium, Mg^{2+}(aq)	white ppt. insoluble in excess	white ppt. insoluble in excess
manganese(II), Mn^{2+}(aq)	off-white ppt. rapidly turning brown on contact with air insoluble in excess	off-white ppt. rapidly turning brown on contact with air insoluble in excess
zinc, Zn^{2+}(aq)	white ppt. soluble in excess	white ppt. soluble in excess

[Lead(II) ions can be distinguished from aluminium ions by the insolubility of lead(II) chloride.]

2 Reactions of anions

ion	*reaction*
carbonate, CO_3^{2-}	CO_2 liberated by dilute acids
chromate(VI), CrO_4^{2-}(aq)	yellow solution turns orange with H^+(aq); gives yellow ppt. with Ba^{2+}(aq); gives bright yellow ppt. with Pb^{2+}(aq)
chloride, Cl^-(aq)	gives white ppt. with Ag^+(aq) (soluble in NH_3(aq)); gives white ppt. with Pb^{2+}(aq)
bromide, Br^-(aq)	gives cream ppt. with Ag^+(aq) (partially soluble in NH_3(aq)); gives white ppt. with Pb^{2+}(aq)
iodide, I^-(aq)	gives yellow ppt. with Ag^+(aq) (insoluble in NH_3(aq)); gives yellow ppt. with Pb^{2+}(aq)
nitrate, NO_3^-(aq)	NH_3 liberated on heating with OH^-(aq) and Al foil
nitrite, NO_2^-(aq)	NH_3 liberated on heating with OH^-(aq) and Al foil, NO liberated by dilute acids (colourless NO → (pale) brown NO_2 in air)
sulfate, SO_4^{2-}(aq)	gives white ppt. with Ba^{2+}(aq) or with Pb^{2+}(aq) (insoluble in excess dilute strong acids)
sulfite, SO_3^{2-}(aq)	SO_2 liberated with dilute acids; gives white ppt. with Ba^{2+}(aq) (soluble in excess dilute strong acids)

3 Tests for gases

gas	*test and test result*
ammonia, NH_3	turns damp red litmus paper blue
carbon dioxide, CO_2	gives a white ppt. with limewater (ppt. dissolves with excess CO_2)
chlorine, Cl_2	bleaches damp litmus paper
hydrogen, H_2	“pops” with a lighted splint
oxygen, O_2	relights a glowing splint
sulfur dioxide, SO_2	turns potassium dichromate(VI) (aq) from orange to green

UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS
General Certificate of Education
Advanced Subsidiary Level and Advanced Level

CANDIDATE NAME

CENTRE NUMBER

CANDIDATE NUMBER

CHEMISTRY **9701/36**

Advanced Practical Skills 2 **October/November 2011**

2 hours

Candidates answer on the Question Paper.

Additional Materials: As listed in the Confidential Instructions

READ THESE INSTRUCTIONS FIRST

Write your Centre number, candidate number and name on all the work you hand in.
Give details of the practical session and laboratory where appropriate, in the boxes provided.
Write in dark blue or black pen.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.
DO **NOT** WRITE IN ANY BARCODES.

Answer **all** questions.
You may lose marks if you do not show your working or if you do not use appropriate units.
Use of a Data Booklet is unnecessary.

Qualitative Analysis Notes are printed on pages 11 and 12.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

Session
Laboratory

For Examiner's Use	
1	
2	
Total	

This document consists of **11** printed pages and **1** blank page.

1 Iodine and propanone react together at room temperature in the presence of an acid catalyst.

For Examiner's Use

$$CH_3COCH_3(aq) + I_2(aq) \longrightarrow CH_3COCH_2I(aq) + HI(aq)$$

In the following experiment you will investigate how the rate of reaction alters when the concentration of a reagent is changed. When the reaction is complete, the solution turns colourless as all the iodine has been used up. It is possible to determine the rate of the reaction by measuring how long it takes for the mixture to go colourless.

The product of the reaction, CH_3COCH_2I, is a strong irritant to the eyes. Make sure that at the end of each experiment you wash out the reaction flask with plenty of water.

FB 1 is 2.0 mol dm^{-3} aqueous propanone, CH_3COCH_3.
FB 2 is 3.0 mol dm^{-3} hydrochloric acid, HC*l*.
FB 3 is 0.0050 mol dm^{-3} aqueous iodine, I_2.

(a) Method

Read through the method and prepare a table for your results before starting any practical work.

Experiment 1

- Fill the burette labelled **FB 1** with the propanone solution, **FB 1**.
- Fill the second burette with distilled water.
- Run 20.0 cm^3 of **FB 1** into a 100 cm^3 beaker.
- Using a 25 cm^3 measuring cylinder, add 20 cm^3 of **FB 2** to the beaker.
- Using a second 25 cm^3 measuring cylinder, measure 10 cm^3 of **FB 3**.
- Add the measured **FB 3** to the solution in the 100 cm^3 beaker and start timing immediately.
- Stir the mixture once and place the beaker on a white tile.
- Stop timing as soon as the solution goes colourless. Record this reaction time to the **nearest second**.
- Wash out the beaker thoroughly.

Experiment 2

- Run 14.0 cm^3 of **FB 1** into the 100 cm^3 beaker.
- Run 6.0 cm^3 of distilled water into the 100 cm^3 beaker.
- Using the measuring cylinder, add 20 cm^3 of **FB 2** to the beaker.
- Using the second measuring cylinder, measure 10 cm^3 of **FB 3**.
- Add the measured **FB 3** to the solution in the 100 cm^3 beaker and start timing immediately.
- Stir the mixture once and place the beaker on a white tile.
- Stop timing as soon as the solution goes colourless and record the reaction time as before.
- Wash out the beaker thoroughly.

Experiment 3

For Examiner's Use

Repeat the experiment as before using the volumes below.

- 8.0 cm^3 of **FB 1**
- 12.0 cm^3 of distilled water
- 20 cm^3 of **FB 2**
- 10 cm^3 of **FB 3**

Record all your results for experiments **1**, **2** and **3** in the space below showing the volume of propanone solution, **FB1**, the volume of distilled water and the reaction time.

[3]

(b) Carry out two experiments to investigate further how the reaction time changes with different concentrations of propanone. Remember that the combined volume of propanone solution and distilled water must always be 20.0 cm^3. Record these results in the space below.

[2]

(c) **(i)** Calculate the number of moles of iodine that were added in each experiment.

For Examiner's Use

…… mol

(ii) Calculate the initial concentration of the iodine in 50 cm^3 of the reaction mixture.

initial concentration of iodine = …… mol dm^{-3}
[2]

(d) The rate of the reaction can be represented by the following formula.

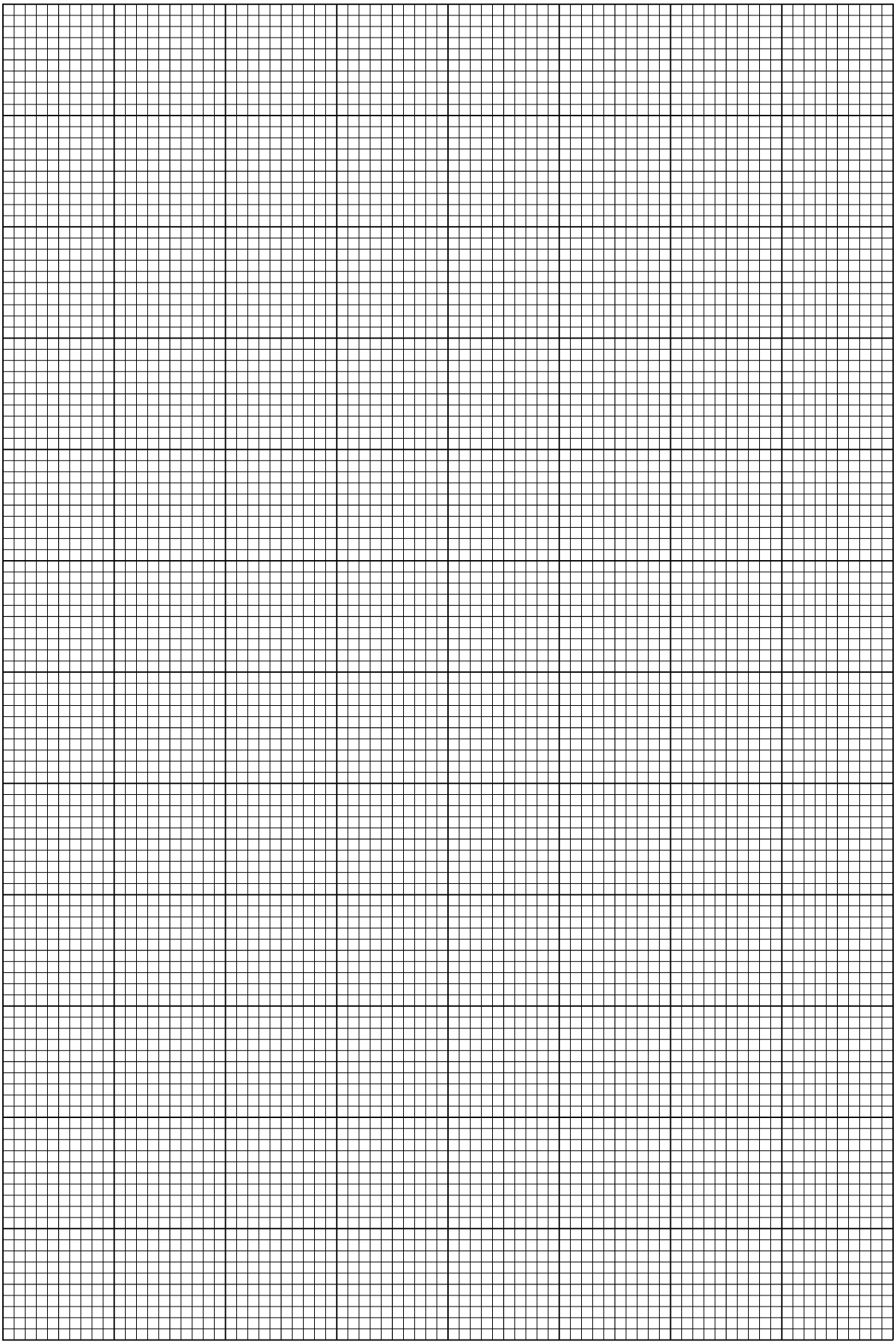
$$\text{'rate'} = \frac{\text{concentration of iodine from } \mathbf{(c)(ii)}}{\text{reaction time}} \times 10^5$$

Use your experimental results to complete the following table to include the reaction time and the 'rate'.

volume of propanone solution, **FB1** / cm^3		

[2]

(e) On the grid opposite, plot the 'rate' against the volume of propanone solution, **FB1**. Draw a line of best fit through the points you have plotted.



For Examiner's Use

I	
II	
III	
IV	
V	
VI	
VII	
VIII	

[8]

[Turn over

(f) **(i)** From your results what conclusion can you draw about the relationship between the rate of this reaction and the concentration of propanone?

.....

.....

(ii) Suggest an improvement to the experiment that would allow you to be more confident about this conclusion.

.....

.....

[3]

(g) Carry out **one** additional experiment to investigate how the 'rate' is altered when the concentration of **iodine** is halved. Record the volume of each solution used and the reaction time in the space below. Calculate the 'rate' using the equation in **(d)**.

'rate' = ... [2]

(h) From your results in **(d)** and **(g)**, what conclusion can you draw about the relationship between the rate of reaction and the concentration of iodine?

.....

..... [1]

(i) In these experiments you used a burette to measure 20.0 cm^3 of **FB 1**. Calculate the percentage error in measuring this volume.

percentage error = ... [2]

[Total: 25]

2 Qualitative Analysis

For Examiner's Use

At each stage in any test you are to record details of the following.

- colour changes seen
- the formation of any precipitate
- the solubility of such precipitates in an excess of the reagent added

Where gases are released they should be identified by a test, **described in the appropriate place in your observations**.

You should indicate clearly at what stage in a test a change occurs.
Marks are **not** given for chemical equations.
No additional tests for ions present should be attempted.

If any solution is warmed a boiling tube MUST be used.

Rinse and reuse test-tubes and boiling tubes where possible.

Where reagents are selected for use in a test, the full name or correct formula of the reagents must be given.

FB 4, **FB 5** and **FB 6** are aqueous solutions each of which contains a single cation and a single anion. One of these solutions is a dilute acid and this is the only acid present.
By carrying out specific tests you will identify all three compounds.

(a) (i) Select a single chemical reagent which would allow you to identify the dilute acid. You may not use indicator paper.

reagent ……

(ii) Use this reagent to test all three solutions and record your observations in an appropriate form in the space below.

(iii) From your observations in **(ii)**, identify which solution is the dilute acid.

FB …… is the dilute acid. [4]

(b) The acid you have identified in **(a)(iii)** is dilute sulfuric acid.

Complete the following table.

For Examiner's Use

test	*observations*
To 1 cm depth of **FB 4** in a test-tube, add 1 cm depth of **FB 5.**	
To 1 cm depth of **FB 5** in a test-tube, add 1 cm depth of **FB 6.**	
To 1 cm depth of **FB 6** in a test-tube, add 1 cm depth of **FB 4.**	

[3]

(c) Test the two remaining unidentified solutions separately with aqueous sodium hydroxide and aqueous ammonia. Record your observations in a suitable form below. You are reminded that if any solution is warmed a boiling tube **MUST** be used.

[4]

(d) From your observations in **(a)**, **(b)** and **(c)**, identify the ions present in the two solutions tested in **(c)**, giving the relevant evidence for each. If you have not been able to identify one or more of the ions, explain why the evidence obtained was insufficient.

For Examiner's Use

FB ..... cation ..... evidence .....

.....

.....

..... anion ..... evidence .....

.....

.....

FB ..... cation ..... evidence .....

.....

.....

..... anion ..... evidence .....

.....

.....

[4]

[Total: 15]

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Qualitative Analysis Notes

Key: [ppt. = precipitate]

1 Reactions of aqueous cations

ion	*reaction with*	
	NaOH(aq)	NH_3(aq)
aluminium, Al^{3+}(aq)	white ppt. soluble in excess	white ppt. insoluble in excess
ammonium, NH_4^+(aq)	no ppt. ammonia produced on heating	
barium, Ba^{2+}(aq)	no ppt. (if reagents are pure)	no ppt.
calcium, Ca^{2+}(aq)	white ppt. with high [Ca^{2+}(aq)]	no ppt.
chromium(III), Cr^{3+}(aq)	grey-green ppt. soluble in excess giving dark green solution	grey-green ppt. insoluble in excess
copper(II), Cu^{2+}(aq)	pale blue ppt. insoluble in excess	blue ppt. soluble in excess giving dark blue solution
iron(II), Fe^{2+}(aq)	green ppt. turning brown on contact with air insoluble in excess	green ppt. turning brown on contact with air insoluble in excess
iron(III), Fe^{3+}(aq)	red-brown ppt. insoluble in excess	red-brown ppt. insoluble in excess
lead(II), Pb^{2+}(aq)	white ppt. soluble in excess	white ppt. insoluble in excess
magnesium, Mg^{2+}(aq)	white ppt. insoluble in excess	white ppt. insoluble in excess
manganese(II), Mn^{2+}(aq)	off-white ppt. rapidly turning brown on contact with air insoluble in excess	off-white ppt. rapidly turning brown on contact with air insoluble in excess
zinc, Zn^{2+}(aq)	white ppt. soluble in excess	white ppt. soluble in excess

[Lead(II) ions can be distinguished from aluminium ions by the insolubility of lead(II) chloride.]

[Turn over

2 Reactions of anions

ion	*reaction*
carbonate, CO_3^{2-}	CO_2 liberated by dilute acids
chromate(VI), CrO_4^{2-} (aq)	yellow solution turns orange with H^+(aq); gives yellow ppt. with Ba^{2+}(aq); gives bright yellow ppt. with Pb^{2+}(aq)
chloride, Cl^- (aq)	gives white ppt. with Ag^+(aq) (soluble in NH_3(aq)); gives white ppt. with Pb^{2+}(aq)
bromide, Br^- (aq)	gives cream ppt. with Ag^+(aq) (partially soluble in NH_3(aq)); gives white ppt. with Pb^{2+}(aq)
iodide, I^- (aq)	gives yellow ppt. with Ag^+(aq) (insoluble In NH_3(aq)); gives yellow ppt. with Pb^{2+}(aq)
nitrate, NO_3^- (aq)	NH_3 liberated on heating with OH^-(aq) and Al foil
nitrite, NO_2^- (aq)	NH_3 liberated on heating with OH^-(aq) and Al foil, NO liberated by dilute acids (colourless NO → (pale) brown NO_2 in air)
sulfate, SO_4^{2-} (aq)	gives white ppt. with Ba^{2+}(aq) or with Pb^{2+}(aq) (insoluble in excess dilute strong acids)
sulfite, SO_3^{2-} (aq)	SO_2 liberated with dilute acids; gives white ppt. with Ba^{2+}(aq) (soluble in excess dilute strong acids)

3 Tests for gases

gas	*test and test result*
ammonia, NH_3	turns damp red litmus paper blue
carbon dioxide, CO_2	gives a white ppt. with limewater (ppt. dissolves with excess CO_2)
chlorine, Cl_2	bleaches damp litmus paper
hydrogen, H_2	“pops” with a lighted splint
oxygen, O_2	relights a glowing splint
sulfur dioxide, SO_2	turns acidified aqueous potassium dichromate(VI) from orange to green

UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS
General Certificate of Education Advanced Level

CANDIDATE NAME

CENTRE NUMBER

CANDIDATE NUMBER

CHEMISTRY **9701/41**

Paper 4 Structured Questions **October/November 2011**

2 hours

Candidates answer on the Question Paper.

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your name, Centre number and candidate number on all the work you hand in.
Write in dark blue or black pen.
You may use a pencil for any diagrams, graphs, or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.
DO **NOT** WRITE ON ANY BARCODES.

Section A
Answer **all** questions.

Section B
Answer **all** questions.

You may lose marks if you do not show your working or if you do not use appropriate units.
A Data Booklet is provided.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
1	
2	
3	
4	
5	
6	
7	
8	
Total	

This document consists of **17** printed pages and **3** blank pages.

Section A

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

For Examiner's Use

1 **(a)** The halogens chlorine and bromine react readily with hydrogen.

$$X_2(g) + H_2(g) \longrightarrow 2HX(g) \qquad [X = Cl \text{ or } Br]$$

(i) Describe how you could carry out this reaction using chlorine.

.....

(ii) Describe **two** observations you would make if this reaction was carried out with bromine.

.....

.....

(iii) Use bond energy data from the *Data Booklet* to calculate the $\Delta H^{\ominus}$ for this reaction when

X = C*l*,

$\Delta H^{\ominus}$ = ... kJ mol^{-1}

X = Br.

$\Delta H^{\ominus}$ = ... kJ mol^{-1}

(iv) What is the major reason for the difference in these two $\Delta H^{\ominus}$ values?

.....

[8]

(b) Some halogens also react readily with methane.

$$CH_4(g) + X_2(g) \longrightarrow CH_3X(g) + HX(g)$$

For Examiner's Use

(i) What conditions are needed to carry out this reaction when X is bromine, Br?

.....

(ii) Use bond energy data from the *Data Booklet* to calculate the $\Delta H^{\ominus}$ of this reaction for the situation where X is iodine, I.

$\Delta H^{\ominus}$ = ... kJ mol^{-1}

(iii) Hence suggest why it is not possible to make iodomethane, CH_3I, by this reaction.

.....

[4]

(c) Halogenoalkanes can undergo *homolytic fission* in the upper atmosphere.

(i) Explain the term *homolytic fission*.

.....

.....

(ii) Suggest the most likely organic radical that would be formed by the homolytic fission of bromochloromethane, CH_2BrCl. Explain your answer.

.....

.....

.....

[3]

(d) The reaction between propane and chlorine produces a mixture of many compounds, four of which are structural isomers with the molecular formula $C_3H_6Cl_2$.
Draw the structural or skeletal formulae of these isomers, and indicate any chiral atoms with an asterisk (*).

[3]

[Total: 18]

[Turn over

2 Acetals are compounds formed when aldehydes are reacted with an alcohol and an acid catalyst. The reaction between ethanal and methanol was studied in the inert solvent dioxan.

For Examiner's Use

$$\underset{\text{ethanal}}{CH_3CHO} + \underset{\text{methanol}}{2CH_3OH} \overset{H^+}{\rightleftharpoons} \underset{\text{acetal } \mathbf{A}}{CH_3CH(OCH_3)_2} + H_2O$$

(a) When the initial rate of this reaction was measured at various starting concentrations of the three reactants, the following results were obtained.

experiment number	$[CH_3CHO]$ / mol dm^{-3}	$[CH_3OH]$ / mol dm^{-3}	$[H^+]$ / mol dm^{-3}	relative rate
1	0.20	0.10	0.05	1.00
2	0.25	0.10	0.05	1.25
3	0.25	0.16	0.05	2.00
4	0.20	0.16	0.10	3.20

(i) Use the data in the table to determine the order with respect to each reactant.

order with respect to $[CH_3CHO]$ .....

order with respect to $[CH_3OH]$ .....

order with respect to $[H^+]$ .....

(ii) Use your results from part **(i)** to write the rate equation for the reaction.

.....

(iii) State the units of the rate constant in the rate equation .....

(iv) Calculate the relative rate of reaction for a mixture in which the starting concentrations of all three reactants are 0.20 mol dm^{-3}.

relative rate = ...

[6]

(b) The concentration of the acetal product was measured when experiment number 1 was allowed to reach equilibrium. The result is included in the following table.

For Examiner's Use

	$[CH_3CHO]$ / mol dm^{-3}	$[CH_3OH]$ / mol dm^{-3}	$[H^+]$ / mol dm^{-3}	[acetal **A**] / mol dm^{-3}	$[H_2O]$ / mol dm^{-3}
at start	0.20	0.10	0.05	0.00	0.00
at equilibrium	(0.20–***x***)			***x***	
at equilibrium				0.025	

(i) Complete the second row of the table in terms of ***x***, the concentration of acetal **A** at equilibrium. You may wish to consult the chemical equation opposite.

(ii) Using the [acetal **A**] as given, 0.025 mol dm^{-3}, calculate the equilibrium concentrations of the other reactants and products and write them in the third row of the table.

(iii) Write the expression for the equilibrium constant for this reaction, K_c, stating its units.

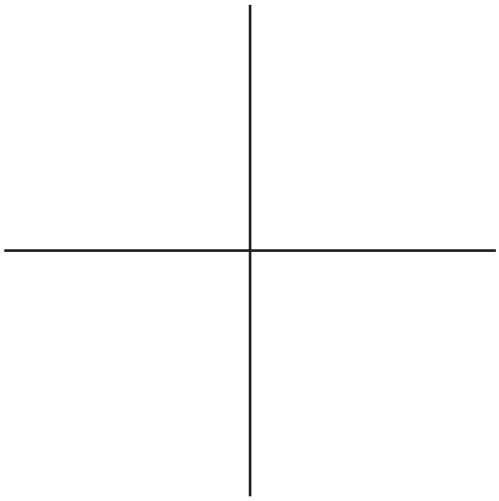
K_c = ... units = ...

(iv) Use your values in the third row of the table to calculate the value of K_c.

K_c = ...
[9]

[Total: 15]

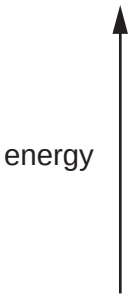
3 **(a)** On the following diagram draw a clear **labelled** sketch to describe the shape and symmetry of a typical d-orbital.



[2]

(b) Although the five d-orbitals are at the same energy in an isolated atom, when a transition element ion is in an octahedral complex the orbitals are split into two groups.

(i) Draw an orbital energy diagram to show this, indicating the number of orbitals in each group.



(ii) Use your diagram as an aid in explaining the following.

- Transition element complexes are often coloured.

.....

.....

.....

.....

- The colour of a complex of a given transition element often changes when the ligands around it are changed.

.....

.....

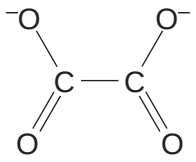
.....

[7]

(c) Heating a solution containing potassium ethanedioate, iron(II) ethanedioate and hydrogen peroxide produces the light green complex $K_3Fe(C_2O_4)_3$, which contains the ion $[Fe(C_2O_4)_3]^{3-}$.

For Examiner's Use

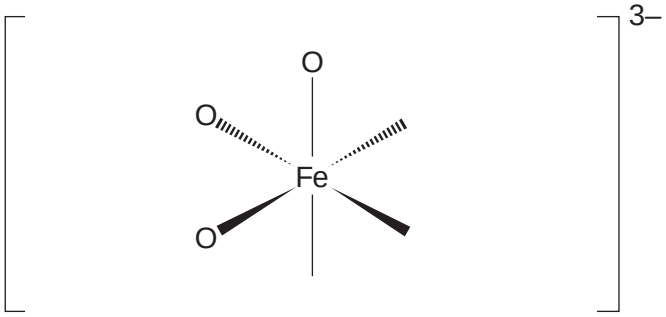
The structure of the ethanedioate ion is as follows.



(i) Calculate the oxidation number of carbon in this ion. .....

(ii) Calculate the oxidation number of iron in $[Fe(C_2O_4)_3]^{3-}$. .....

(iii) The iron atom in the $[Fe(C_2O_4)_3]^{3-}$ ion is surrounded octahedrally by six oxygen atoms. Complete the following **displayed** formula of this ion.



(iv) In sunlight the complex decomposes into potassium ethanedioate, iron(II) ethanedioate and carbon dioxide.

Use oxidation numbers to help you balance the following equation for this decomposition.

$$K_3Fe(C_2O_4)_3 \rightarrow \text{.....}K_2C_2O_4 + \text{.....}FeC_2O_4 + \text{.....}CO_2$$

[5]

[Total: 14]

[Turn over

4 **(a)** **(i)** Write the equation for a reaction in which ethylamine, $C_2H_5NH_2$, acts as a Brønsted-Lowry base.

.....

(ii) Ammonia, ethylamine and phenylamine, $C_6H_5NH_2$, are three nitrogen-containing bases.

Place these three compounds in order of basicity, with the most basic first.

most basic		least basic

(iii) Explain why you have placed the three compounds in this order.

.....

.....

.....

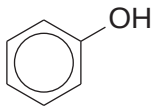
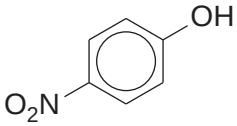
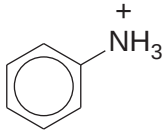
.....

[4]

(b) **(i)** Write an equation for a reaction in which phenol, C_6H_5OH, acts as a Brønsted-Lowry acid.

.....

The pK_a values for phenol, 4-nitrophenol and the phenylammonium ion are given in the table.

compound	pK_a
	10.0
	7.2
	4.6

(ii) Suggest an explanation for the difference in the pK_a values of phenol and nitrophenol.

.....

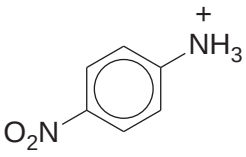
.....

.....

.....

(iii) Using the information in the table opposite, predict which of the following pK_a values is the most likely for the 4-nitrophenylammonium ion.

For Examiner's Use



Place a tick (✓) in the box beside the value you have chosen.

pK_a	
1.0	
4.5	
7.0	
10.0	

(iv) Explain your answer to part **(iii)**.

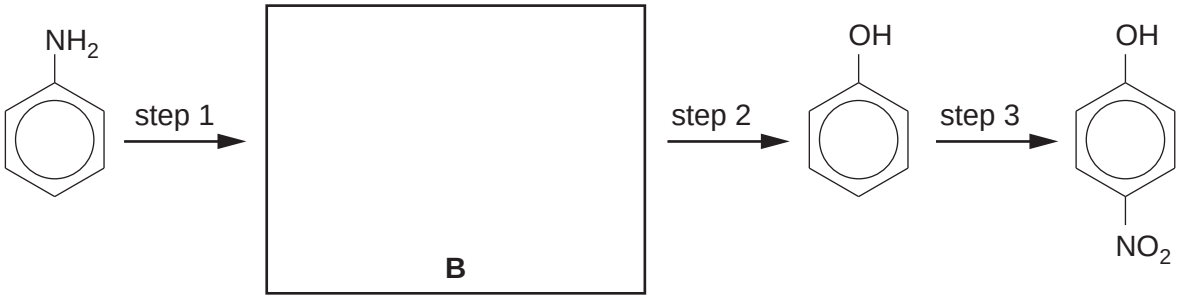
.....

.....

.....

[5]

(c) Phenylamine can be converted to 4-nitrophenol by the following steps.



(i) Suggest the identity of intermediate **B** by drawing its structure in the box above.

(ii) Suggest reagents and conditions for the three steps in the above scheme.

	reagent(s)	conditions
step 1		
step 2		
step 3		

[5]

[Total: 14]

5 Compound **C** has the molecular formula $C_7H_{14}O$. Treating **C** with hot concentrated acidified $KMnO_4(aq)$ produces two compounds, **D**, C_4H_8O, and **E**, $C_3H_4O_3$. The results of four tests carried out on these three compounds are shown in the following table.

For Examiner's Use

test reagent	result of test with		
	compound **C**	compound **D**	compound **E**
$Br_2(aq)$	decolourises	no reaction	no reaction
Na(s)	fizzes	no reaction	fizzes
$I_2(aq) + OH^-(aq)$	no reaction	yellow precipitate	yellow precipitate
2,4-dinitrophenylhydrazine	no reaction	orange precipitate	orange precipitate

(a) State the functional groups which the above four reagents test for.

(i) $Br_2(aq)$

.....

(ii) Na(s)

.....

(iii) $I_2(aq) + OH^-(aq)$

.....

(iv) 2,4-dinitrophenylhydrazine

.....

[4]

(b) Based upon the results of the above tests, suggest structures for compounds **D** and **E**.

D, C_4H_8O

E, $C_3H_4O_3$

[2]

(c) Compound **C** exists as two stereoisomers.

Draw the structural formula of **each** of the two isomers, and state the type of stereoisomerism involved.

For Examiner's Use

type of stereoisomerism .....

[3]

[Total: 9]

Section B

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

For Examiner's Use

6 Proteins exist in an enormous variety of sizes and structures in living organisms. They have a wide range of functions which are dependent upon their structures. The structure and properties of an individual protein are a result of the primary structure – the sequence of amino acids that form the protein.

(a) Proteins are described as condensation polymers.

(i) Write a balanced equation for the condensation reaction between two glycine molecules, $H_2NCH_2CO_2H$.

(ii) Draw the skeletal formula for the organic product.

[2]

(b) X-ray analysis has shown that in many proteins there are regions with a regular arrangement within the polypeptide chain. This is called the secondary structure and exists in two main forms.

(i) State the two forms of secondary structure found in proteins.

.....

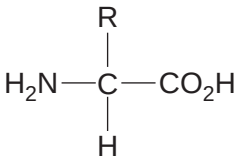
.....

(ii) Draw a diagram to illustrate **one** form of secondary structure.

[4]

(c) There are around 20 different common amino acids found in humans most of which have the same general structure.

For Examiner's Use



The nature of the group R affects which bonds are formed as the secondary structure of the protein is further folded to give the tertiary structure.

Complete the table indicating the type of **tertiary** bonding that each pair of the amino acid residues is likely to produce.

residue 1	residue 2	type of tertiary bonding
–HNCH($CH_2CH_2CH_2CH_2NH_2$)CO–	–HNCH($CH_2CH_2CO_2H$)CO–	
–HNCH(CH_3)CO–	–HNCH(CH_3)CO–	
–HNCH(CH_2SH)CO–	–HNCH(CH_2SH)CO–	
–HNCH(CH_2OH)CO–	–HNCH(CH_2CO_2H)CO–	

[4]

[Total: 10]

[Turn over

7 One of the key areas of investigation in understanding the structures of polypeptides and proteins is the sequence of amino acids that make up the polypeptide chains.

(a) One of the methods used to determine the amino acids present in a polypeptide chain is electrophoresis.

Sketch and label the apparatus used to carry out electrophoresis.

[4]

(b) In electrophoresis, different amino acids move in different directions and at different speeds.

(i) What factors determine the *direction of travel* of an amino acid?

.....

.....

.....

(ii) What factors determine the *speed of movement* of an amino acid?

.....

.....

[3]

(c) Another important technique used to examine the structure of proteins is X-ray crystallography. In this technique the position of individual atoms can be determined, and the distances between them measured.

For Examiner's Use

(i) Hydrogen atoms never produce images using X-ray crystallography. Explain why this is the case.

.....

.....

(ii) Suggest and explain which one of the atoms in a molecule of cysteine, $H_2NCH(CH_2SH)CO_2H$, would show up most clearly using X-ray crystallography.

.....

.....

[3]

[Total: 10]

8 In today's world we make use of a wide range of different polymers. These polymers are often substitutes for traditional materials, but may have more useful properties.

For Examiner's Use

(a) Complete the table identifying one traditional material that has been replaced by each polymer.

traditional material	modern polymer and its use
	PVC in packaging
	Terylene in fabrics
	polycarbonate bottle

[2]

(b) Throwing away articles made from polymers after use is a major environmental concern for **two** main reasons. Identify **each** of these reasons and suggest a strategy that has been adopted to try to overcome each of these.

reasons : .....

.....

.....

strategy 1 : .....

.....

strategy 2 : .....

.....

[3]

(c) One suggestion for the disposal of polymers is to use them as a fuel to provide energy for small-scale power stations or district heating schemes.
Identify one polymer which would be **unsuitable** for this use, explaining the reason behind this.

polymer .....

reason .....

.....

.....
[2]

(d) Polymers can be either thermoplastic or thermosetting.

Name a thermoplastic polymer. .....

State which type of polymerisation produces thermoplastic polymers, explaining your answer in terms of the structure of the polymer.

.....

.....

.....

.....
[3]

[Total: 10]

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UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS
General Certificate of Education Advanced Level

CANDIDATE NAME

CENTRE NUMBER

CANDIDATE NUMBER

CHEMISTRY **9701/42**

Paper 4 Structured Questions **October/November 2011**

2 hours

Candidates answer on the Question Paper.

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your name, Centre number and candidate number on all the work you hand in.
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You may use a pencil for any diagrams, graphs, or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.
DO **NOT** WRITE ON ANY BARCODES.

Section A
Answer **all** questions.

Section B
Answer **all** questions.

You may lose marks if you do not show your working or if you do not use appropriate units.
A Data Booklet is provided.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
1	
2	
3	
4	
5	
6	
7	
8	
Total	

This document consists of **17** printed pages and **3** blank pages.

Section A

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

For Examiner's Use

1 **(a)** The halogens chlorine and bromine react readily with hydrogen.

$$X_2(g) + H_2(g) \longrightarrow 2HX(g) \qquad [X = Cl \text{ or } Br]$$

(i) Describe how you could carry out this reaction using chlorine.

.....

(ii) Describe **two** observations you would make if this reaction was carried out with bromine.

.....

.....

(iii) Use bond energy data from the *Data Booklet* to calculate the $\Delta H^{\ominus}$ for this reaction when

X = C*l*,

$\Delta H^{\ominus}$ = ... kJ mol^{-1}

X = Br.

$\Delta H^{\ominus}$ = ... kJ mol^{-1}

(iv) What is the major reason for the difference in these two $\Delta H^{\ominus}$ values?

.....

[8]

(b) Some halogens also react readily with methane.

$$CH_4(g) + X_2(g) \longrightarrow CH_3X(g) + HX(g)$$

For Examiner's Use

(i) What conditions are needed to carry out this reaction when X is bromine, Br?

.....

(ii) Use bond energy data from the *Data Booklet* to calculate the $\Delta H^{\ominus}$ of this reaction for the situation where X is iodine, I.

$\Delta H^{\ominus}$ = ... kJ mol^{-1}

(iii) Hence suggest why it is not possible to make iodomethane, CH_3I, by this reaction.

.....

[4]

(c) Halogenoalkanes can undergo *homolytic fission* in the upper atmosphere.

(i) Explain the term *homolytic fission*.

.....

.....

(ii) Suggest the most likely organic radical that would be formed by the homolytic fission of bromochloromethane, CH_2BrCl. Explain your answer.

.....

.....

.....

[3]

(d) The reaction between propane and chlorine produces a mixture of many compounds, four of which are structural isomers with the molecular formula $C_3H_6Cl_2$.
Draw the structural or skeletal formulae of these isomers, and indicate any chiral atoms with an asterisk (*).

[3]

[Total: 18]

[Turn over

2 Acetals are compounds formed when aldehydes are reacted with an alcohol and an acid catalyst. The reaction between ethanal and methanol was studied in the inert solvent dioxan.

For Examiner's Use

$$\underset{\text{ethanal}}{CH_3CHO} + \underset{\text{methanol}}{2CH_3OH} \overset{H^+}{\rightleftharpoons} \underset{\text{acetal } \mathbf{A}}{CH_3CH(OCH_3)_2} + H_2O$$

(a) When the initial rate of this reaction was measured at various starting concentrations of the three reactants, the following results were obtained.

experiment number	$[CH_3CHO]$ / mol dm^{-3}	$[CH_3OH]$ / mol dm^{-3}	$[H^+]$ / mol dm^{-3}	relative rate
1	0.20	0.10	0.05	1.00
2	0.25	0.10	0.05	1.25
3	0.25	0.16	0.05	2.00
4	0.20	0.16	0.10	3.20

(i) Use the data in the table to determine the order with respect to each reactant.

order with respect to $[CH_3CHO]$ .....

order with respect to $[CH_3OH]$ .....

order with respect to $[H^+]$ .....

(ii) Use your results from part **(i)** to write the rate equation for the reaction.

.....

(iii) State the units of the rate constant in the rate equation .....

(iv) Calculate the relative rate of reaction for a mixture in which the starting concentrations of all three reactants are 0.20 mol dm^{-3}.

relative rate = ...

[6]

(b) The concentration of the acetal product was measured when experiment number 1 was allowed to reach equilibrium. The result is included in the following table.

For Examiner's Use

	$[CH_3CHO]$ / mol dm^{-3}	$[CH_3OH]$ / mol dm^{-3}	$[H^+]$ / mol dm^{-3}	[acetal **A**] / mol dm^{-3}	$[H_2O]$ / mol dm^{-3}
at start	0.20	0.10	0.05	0.00	0.00
at equilibrium	(0.20–***x***)			***x***	
at equilibrium				0.025	

(i) Complete the second row of the table in terms of ***x***, the concentration of acetal **A** at equilibrium. You may wish to consult the chemical equation opposite.

(ii) Using the [acetal **A**] as given, 0.025 mol dm^{-3}, calculate the equilibrium concentrations of the other reactants and products and write them in the third row of the table.

(iii) Write the expression for the equilibrium constant for this reaction, K_c, stating its units.

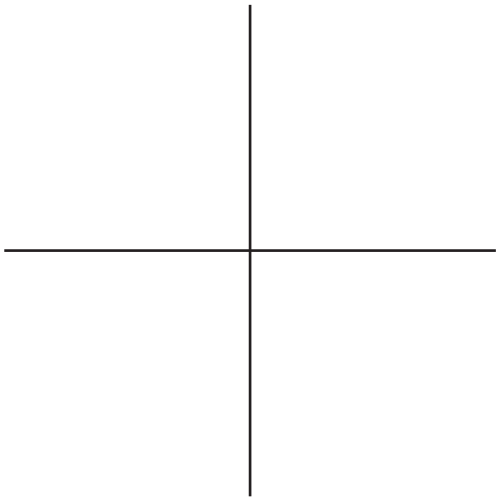
K_c = ... units = ...

(iv) Use your values in the third row of the table to calculate the value of K_c.

K_c = ...
[9]

[Total: 15]

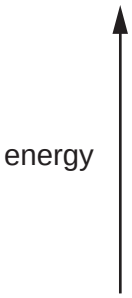
3 **(a)** On the following diagram draw a clear **labelled** sketch to describe the shape and symmetry of a typical d-orbital.



[2]

(b) Although the five d-orbitals are at the same energy in an isolated atom, when a transition element ion is in an octahedral complex the orbitals are split into two groups.

(i) Draw an orbital energy diagram to show this, indicating the number of orbitals in each group.



(ii) Use your diagram as an aid in explaining the following.

- Transition element complexes are often coloured.

.....

.....

.....

.....

- The colour of a complex of a given transition element often changes when the ligands around it are changed.

.....

.....

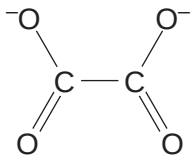
.....

[7]

(c) Heating a solution containing potassium ethanedioate, iron(II) ethanedioate and hydrogen peroxide produces the light green complex $K_3Fe(C_2O_4)_3$, which contains the ion $[Fe(C_2O_4)_3]^{3-}$.

For Examiner's Use

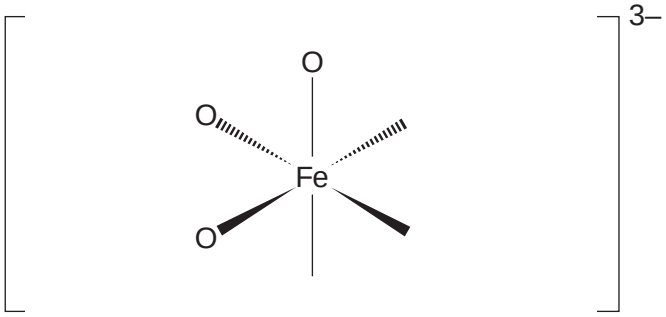
The structure of the ethanedioate ion is as follows.



(i) Calculate the oxidation number of carbon in this ion. .....

(ii) Calculate the oxidation number of iron in $[Fe(C_2O_4)_3]^{3-}$. .....

(iii) The iron atom in the $[Fe(C_2O_4)_3]^{3-}$ ion is surrounded octahedrally by six oxygen atoms. Complete the following **displayed** formula of this ion.



(iv) In sunlight the complex decomposes into potassium ethanedioate, iron(II) ethanedioate and carbon dioxide.

Use oxidation numbers to help you balance the following equation for this decomposition.

$$K_3Fe(C_2O_4)_3 \rightarrow \text{.....}K_2C_2O_4 + \text{.....}FeC_2O_4 + \text{.....}CO_2$$

[5]

[Total: 14]

For Examiner's Use

4 **(a)** **(i)** Write the equation for a reaction in which ethylamine, $C_2H_5NH_2$, acts as a Brønsted-Lowry base.

.....

(ii) Ammonia, ethylamine and phenylamine, $C_6H_5NH_2$, are three nitrogen-containing bases.

Place these three compounds in order of basicity, with the most basic first.

most basic		least basic

(iii) Explain why you have placed the three compounds in this order.

.....

.....

.....

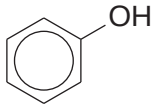
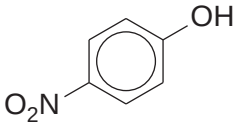
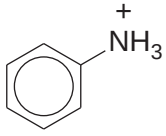
.....

[4]

(b) **(i)** Write an equation for a reaction in which phenol, C_6H_5OH, acts as a Brønsted-Lowry acid.

.....

The pK_a values for phenol, 4-nitrophenol and the phenylammonium ion are given in the table.

compound	pK_a
	10.0
	7.2
	4.6

(ii) Suggest an explanation for the difference in the pK_a values of phenol and nitrophenol.

.....

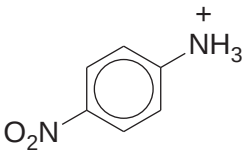
.....

.....

.....

For Examiner's Use

(iii) Using the information in the table opposite, predict which of the following pK_a values is the most likely for the 4-nitrophenylammonium ion.



Place a tick (✓) in the box beside the value you have chosen.

pK_a	
1.0	
4.5	
7.0	
10.0	

(iv) Explain your answer to part **(iii)**.

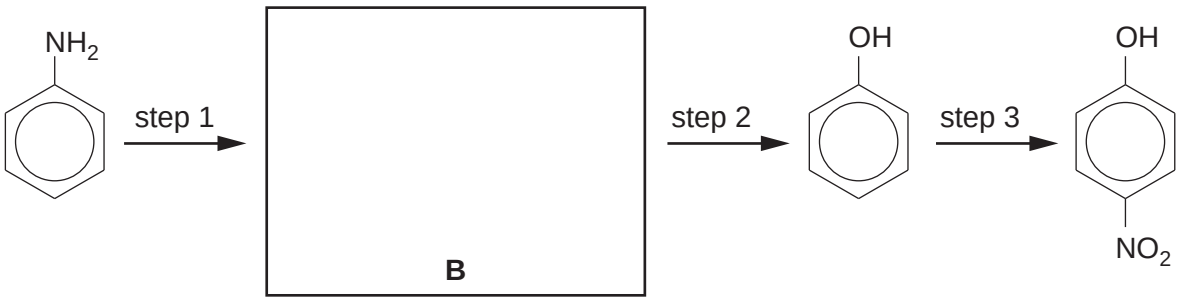
.....

.....

.....

[5]

(c) Phenylamine can be converted to 4-nitrophenol by the following steps.



(i) Suggest the identity of intermediate **B** by drawing its structure in the box above.

(ii) Suggest reagents and conditions for the three steps in the above scheme.

	reagent(s)	conditions
step 1		
step 2		
step 3		

[5]

[Total: 14]

5 Compound **C** has the molecular formula $C_7H_{14}O$. Treating **C** with hot concentrated acidified $KMnO_4(aq)$ produces two compounds, **D**, C_4H_8O, and **E**, $C_3H_4O_3$. The results of four tests carried out on these three compounds are shown in the following table.

For Examiner's Use

test reagent	result of test with		
	compound **C**	compound **D**	compound **E**
$Br_2(aq)$	decolourises	no reaction	no reaction
Na(s)	fizzes	no reaction	fizzes
$I_2(aq) + OH^-(aq)$	no reaction	yellow precipitate	yellow precipitate
2,4-dinitrophenylhydrazine	no reaction	orange precipitate	orange precipitate

(a) State the functional groups which the above four reagents test for.

(i) $Br_2(aq)$

.....

(ii) Na(s)

.....

(iii) $I_2(aq) + OH^-(aq)$

.....

(iv) 2,4-dinitrophenylhydrazine

.....

[4]

(b) Based upon the results of the above tests, suggest structures for compounds **D** and **E**.

D, C_4H_8O

E, $C_3H_4O_3$

[2]

(c) Compound **C** exists as two stereoisomers.

Draw the structural formula of **each** of the two isomers, and state the type of stereoisomerism involved.

For Examiner's Use

type of stereoisomerism .....

[3]

[Total: 9]

Section B

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

For Examiner's Use

6 Proteins exist in an enormous variety of sizes and structures in living organisms. They have a wide range of functions which are dependent upon their structures. The structure and properties of an individual protein are a result of the primary structure – the sequence of amino acids that form the protein.

(a) Proteins are described as condensation polymers.

(i) Write a balanced equation for the condensation reaction between two glycine molecules, $H_2NCH_2CO_2H$.

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[2]

(b) X-ray analysis has shown that in many proteins there are regions with a regular arrangement within the polypeptide chain. This is called the secondary structure and exists in two main forms.

(i) State the two forms of secondary structure found in proteins.

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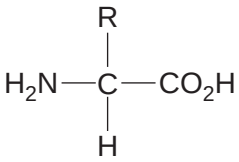

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–HNCH(CH_2SH)CO–	–HNCH(CH_2SH)CO–	
–HNCH(CH_2OH)CO–	–HNCH(CH_2CO_2H)CO–	

[4]

[Total: 10]

[Turn over

7 One of the key areas of investigation in understanding the structures of polypeptides and proteins is the sequence of amino acids that make up the polypeptide chains.

(a) One of the methods used to determine the amino acids present in a polypeptide chain is electrophoresis.

Sketch and label the apparatus used to carry out electrophoresis.

[4]

(b) In electrophoresis, different amino acids move in different directions and at different speeds.

(i) What factors determine the *direction of travel* of an amino acid?

.....

.....

.....

(ii) What factors determine the *speed of movement* of an amino acid?

.....

.....

[3]

(c) Another important technique used to examine the structure of proteins is X-ray crystallography. In this technique the position of individual atoms can be determined, and the distances between them measured.

For Examiner's Use

(i) Hydrogen atoms never produce images using X-ray crystallography. Explain why this is the case.

.....

.....

(ii) Suggest and explain which one of the atoms in a molecule of cysteine, $H_2NCH(CH_2SH)CO_2H$, would show up most clearly using X-ray crystallography.

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8 In today's world we make use of a wide range of different polymers. These polymers are often substitutes for traditional materials, but may have more useful properties.

(a) Complete the table identifying one traditional material that has been replaced by each polymer.

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	Terylene in fabrics
	polycarbonate bottle

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(b) Throwing away articles made from polymers after use is a major environmental concern for **two** main reasons. Identify **each** of these reasons and suggest a strategy that has been adopted to try to overcome each of these.

reasons : .....

.....

.....

strategy 1 : .....

.....

strategy 2 : .....

.....

[3]

(c) One suggestion for the disposal of polymers is to use them as a fuel to provide energy for small-scale power stations or district heating schemes.
Identify one polymer which would be **unsuitable** for this use, explaining the reason behind this.

polymer .....

reason .....

.....

.....
[2]

(d) Polymers can be either thermoplastic or thermosetting.

Name a thermoplastic polymer. .....

State which type of polymerisation produces thermoplastic polymers, explaining your answer in terms of the structure of the polymer.

.....

.....

.....

.....
[3]

[Total: 10]

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UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS
General Certificate of Education Advanced Level

CANDIDATE NAME

CENTRE NUMBER

CANDIDATE NUMBER

3761334623

CHEMISTRY **9701/43**

Paper 4 Structured Questions **October/November 2011**

2 hours

Candidates answer on the Question Paper.

Additional Materials: Data Booklet

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For Examiner's Use	
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UNIVERSITY of CAMBRIDGE International Examinations

Section A

For Examiner's Use

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

1 **(a)** Complete the electronic configurations of the following ions.

Cr^{3+}: $1s^2 2s^2 2p^6$.....

Mn^{2+}: $1s^2 2s^2 2p^6$.....

[2]

(b) Both $KMnO_4$ and $K_2Cr_2O_7$ are used as oxidising agents, usually in acidic solution.

(i) Use information from the *Data Booklet* to explain why their oxidising power increases as the $[H^+(aq)]$ in the solution increases.

.....

.....

.....

(ii) What colour changes would you observe when each of these oxidising agents is completely reduced?

- $KMnO_4$
  from ..... to .....
- $K_2Cr_2O_7$
  from..... to .....

[4]

(c) Manganese(IV) oxide, MnO_2, is a dark brown solid, insoluble in water and dilute acids. Passing a stream of $SO_2(g)$ through a suspension of MnO_2 in water does, however, cause it to dissolve, to give a colourless solution.

(i) Use the *Data Booklet* to suggest an equation for this reaction, and explain what happens to the oxidation states of manganese and of sulfur during the reaction.

.....

.....

.....

(ii) The pH of the suspension of MnO_2 is reduced.
Explain what effect, if any, this would have on the extent of this reaction.

.....

.....

[4]

(d) The main ore of manganese, pyrolusite, is mainly MnO_2. A solution of $SnCl_2$ can be used to estimate the percentage of MnO_2 in a sample of pyrolusite, using the following method.

- A known mass of pyrolusite is warmed with an acidified solution containing a known amount of $SnCl_2$.
- The excess $Sn^{2+}(aq)$ ions are titrated with a standard solution of $KMnO_4$.

In one such experiment, 0.100 g of pyrolusite was warmed with an acidified solution containing 2.00×10^{-3} mol Sn^{2+}. After the reaction was complete, the mixture was titrated with 0.0200 mol dm^{-3} $KMnO_4$, and required 18.1 cm^3 of this solution to reach the end point.

The equation for the reaction between $Sn^{2+}(aq)$ and $MnO_4^-(aq)$ is as follows.

$$2MnO_4^- + 5Sn^{2+} + 16H^+ \longrightarrow 2Mn^{2+} + 5Sn^{4+} + 8H_2O$$

(i) Use the *Data Booklet* to construct an equation for the reaction between MnO_2 and Sn^{2+} ions in acidic solution.

.....

(ii) Calculate the percentage of MnO_2 in this sample of pyrolusite by the following steps.

- number of moles of MnO_4^- used in the titration

- number of moles of Sn^{2+} this MnO_4^- reacted with

- number of moles of Sn^{2+} that reacted with the 0.100 g sample of pyrolusite

- number of moles of MnO_2 in 0.100 g pyrolusite. Use your equation in **(i)**.

- mass of MnO_2 in 0.100 g pyrolusite

- percentage of MnO_2 in pyrolusite

percentage = ...%

[6]

[Total: 16]

For Examiner's Use

2 **(a)** **(i)** What is meant by the term *ligand* as applied to the chemistry of the transition elements?

.....

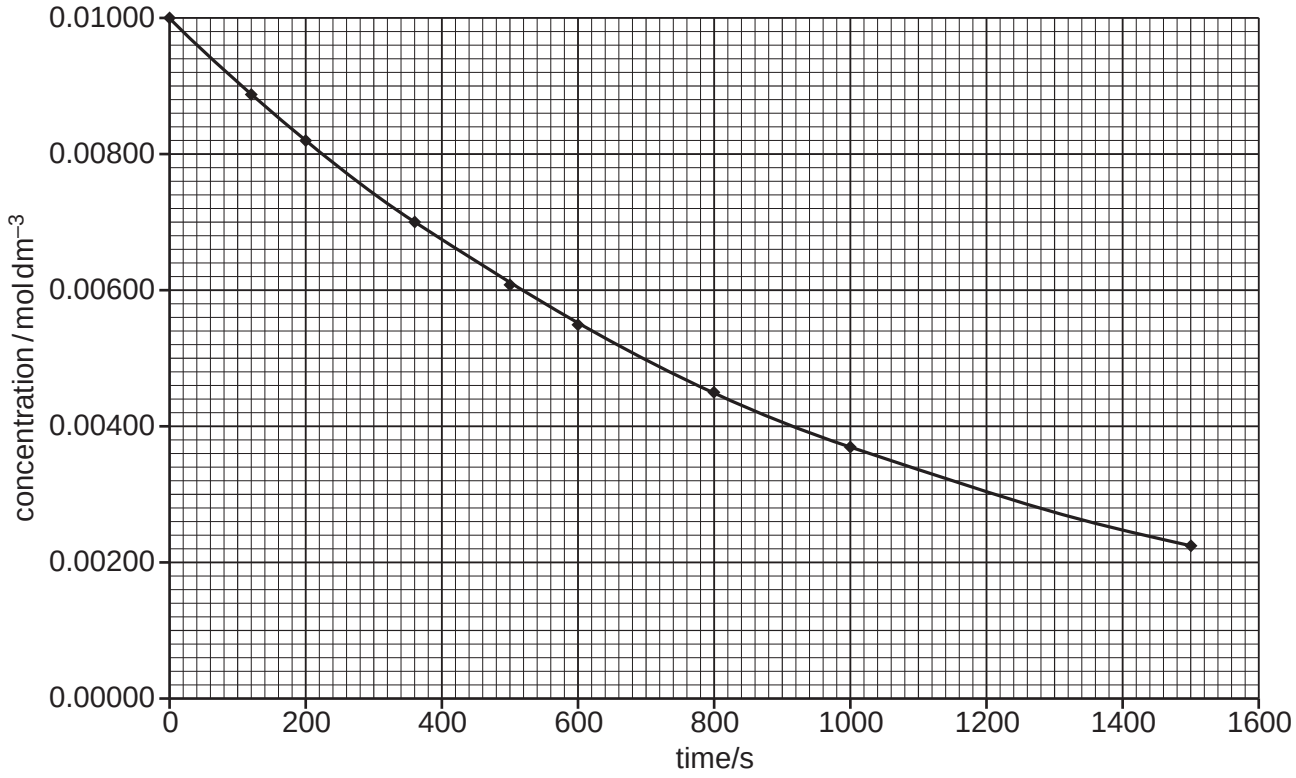
(ii) Describe the type of bonding that occurs between a ligand and a transition element.

.....
[2]

(b) Chromium hexacarbonyl undergoes the following ligand replacement reaction.

$$Cr(CO)_6 + PR_3 \longrightarrow Cr(CO)_5PR_3 + CO$$

Two separate experiments were carried out to study the rate of this reaction.
In the first experiment, the ligand PR_3 was in a large excess and $[Cr(CO)_6]$ was measured with time. The results are shown on the graph below.



In the second experiment, $Cr(CO)_6$ was in a large excess, and $[PR_3]$ was measured with time. The following results were obtained.

time / s	$[PR_3]$ / mol dm^{-3}
0	0.0100
120	0.0076
200	0.0060
360	0.0028

(i) Plot the data in the table on the graph above, using the same axis scales, and draw the best-fit line through your points.

(ii) Use the graphs to determine the order of reaction with respect to $Cr(CO)_6$ and PR_3. In each case explain how you arrived at your answer.

$Cr(CO)_6$

.....

.....

PR_3

.....

.....

(iii) Write the rate equation for the reaction, and calculate a value for the rate constant, using the method of initial rates, or any other method you prefer.

.....

.....

.....

.....

(iv) State the units of the rate constant.

.....

(v) Four possible mechanisms for this reaction are given below. Draw a **circle** around the letter next to the **one** mechanism which is consistent with the rate equation you have written in **(iii)**.

A
$Cr(CO)_6 \longrightarrow Cr(CO)_5 + CO$ fast
$Cr(CO)_5 + PR_3 \longrightarrow Cr(CO)_5PR_3$ slow

B
$Cr(CO)_6 \longrightarrow Cr(CO)_5 + CO$ slow
$Cr(CO)_5 + PR_3 \longrightarrow Cr(CO)_5PR_3$ fast

C
$Cr(CO)_6 + PR_3 \longrightarrow [OC\text{---}Cr(CO)_4\text{---}PR_3] \longrightarrow Cr(CO)_5PR_3 + CO$
(transition state)

D
$Cr(CO)_6 + PR_3 \longrightarrow Cr(CO)_6PR_3$ slow
$Cr(CO)_6PR_3 \longrightarrow Cr(CO)_5PR_3 + CO$ fast

Explain your answer.

.....

.....

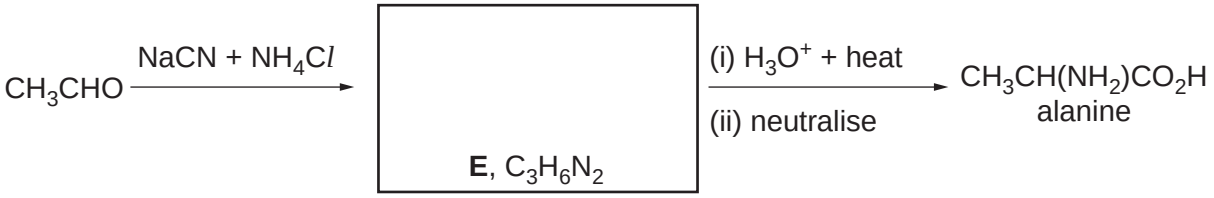
[9]

[Total: 11]

[Turn over

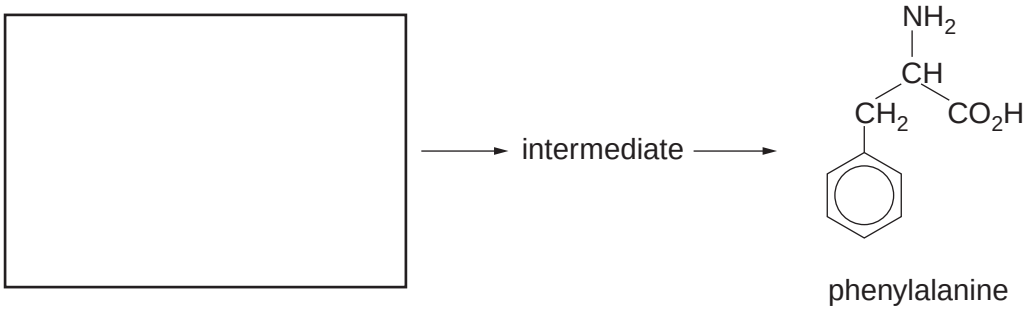
For Examiner's Use

3 **(a)** Amino acids such as alanine are essential building blocks for making proteins. They can be synthesised by a general reaction of which the following is an example.



(i) Suggest the structure of the intermediate compound **E** by drawing its structural formula in the box above.

(ii) Suggest, in the box below, the structural formula of the starting material needed to synthesise phenylalanine by the above general reaction.



[2]

(b) **(i)** What is a *protein*?

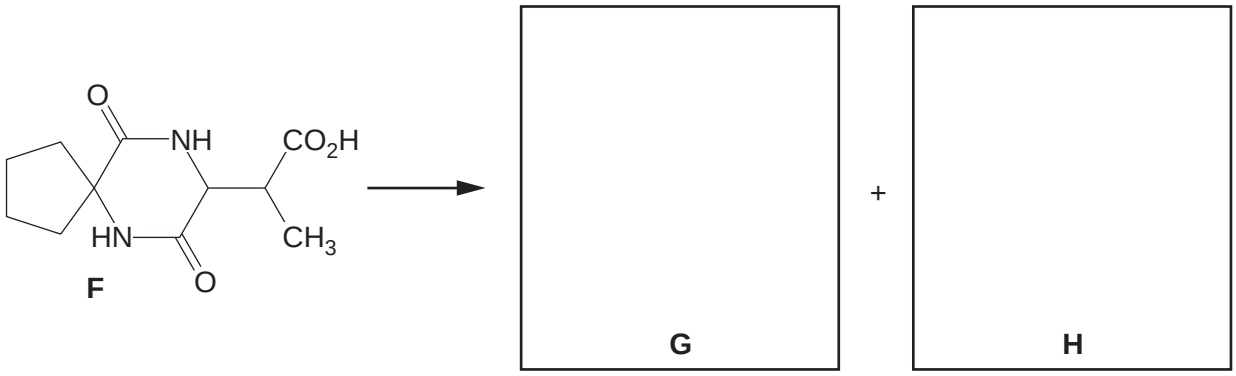
.....

(ii) Using alanine as an example, draw a diagram to show how proteins are formed from amino acids. Show two repeat units in your answer.

[3]

(c) The hydrolysis of compound **F** produces two compounds **G** and **H**.

For Examiner's Use



(i) State the reagents and conditions needed for this hydrolysis.

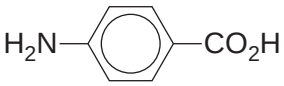
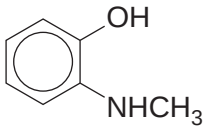
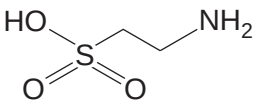
.....

(ii) Draw the structures of the two products **G** and **H** in the boxes above.

[3]

(d) **(i)** Draw the zwitterionic structure of alanine.

(ii) Suggest the structural formulae of the zwitterions that could be formed from the following compounds.

compound	zwitterion
	
	
	

[4]

(e) Solutions of amino acids are good buffers.

For Examiner's Use

(i) What is meant by the term *buffer*?

.....

(ii) Write an equation to show how a solution of alanine, $CH_3CH(NH_2)CO_2H$, behaves as a buffer in the presence of an acid such as HC*l*(aq).

.....

(iii) Briefly describe how the pH of blood is controlled.

.....

.....

.....

(iv) Calculate the pH of the buffer formed when 10.0 cm^3 of 0.100 mol dm^{-3} NaOH is added to 10.0 cm^3 of 0.250 mol dm^{-3} CH_3CO_2H, whose pK_a = 4.76.

pH = ...

[7]

[Total: 19]

4 **(a)** Write an equation representing the action of heat on calcium nitrate, $Ca(NO_3)_2$.

For Examiner's Use

.....

[1]

(b) Describe and explain the trend in the thermal stabilities of the nitrates of the Group II elements.

.....

.....

.....

.....

.....

[3]

(c) Sodium carbonate is stable to heat, but heating lithium carbonate readily produces $CO_2(g)$.

(i) Suggest an equation for the action of heat on lithium carbonate.

.....

(ii) Suggest a reason for the difference in reactivity of these two carbonates.

.....

.....

(iii) Predict what you would see if a sample of lithium nitrate was heated. Explain your answer.

.....

.....

.....

[4]

[Total: 8]

5 Alkanes are generally considered to be unreactive compounds, showing an inertness to common reagents such as NaOH, H_2SO_4, and $K_2Cr_2O_7$.

For Examiner's Use

(a) Suggest a reason why these reagents **do not** attack an alkane such as CH_4.

.....

[1]

(b) When a mixture of chlorine and ethane gas is exposed to strong sunlight, an explosion can occur due to the fast exothermic reaction.
Under more controlled conditions, however, the following reaction occurs.

$$C_2H_6 + Cl_2 \longrightarrow C_2H_5Cl + HCl$$

(i) What is the name of this type of reaction?

.....

(ii) Use equations to describe the mechanism of this reaction, naming the steps involved.

.....

.....

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(iii) This reaction can produce organic by-products, in addition to C_2H_5Cl.
Draw the structural formulae of three possible organic by-products. Two of your by-products should contain 4 carbon atoms per molecule.
Briefly describe how each by-product could be formed.

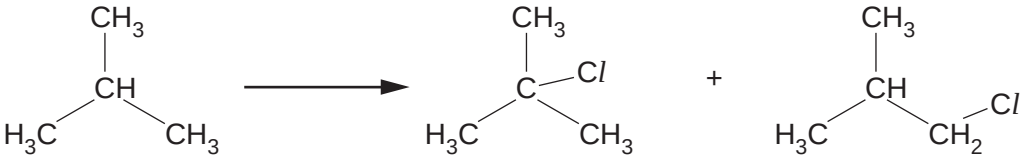
structural formula of by-product	formed by

(iv) It is found by experiment that, during this type of reaction, primary, secondary and tertiary hydrogen atoms are replaced by chlorine atoms at different rates, as shown in the following table.

For Examiner's Use

reaction	relative rate
$RCH_3 \longrightarrow RCH_2Cl$	1
$R_2CH_2 \longrightarrow R_2CHCl$	7
$R_3CH \longrightarrow R_3CCl$	21

Using this information, and considering the number of hydrogen atoms of each type (primary, secondary or tertiary) within the molecule, predict the relative ratio of the two possible products **J** and **K** from the chlorination of 2-methylpropane. Explain your answer.



2-methylpropane **J** **K**

ratio **J** / **K** = ...

explanation:

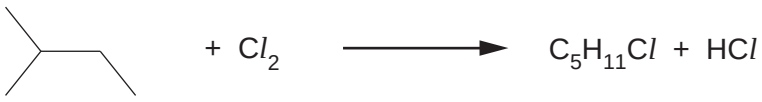
.....

.....

.....

[10]

(c) In the boxes below draw the **skeletal** formulae of **four** different structural isomers of $C_5H_{11}Cl$ that could be obtained from the chlorination of 2-methylbutane. Indicate any chiral centres in your structures by an asterisk (*).



2-methylbutane

[5]

[Total: 16]

[Turn over

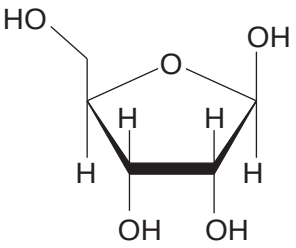
Section B

For Examiner's Use

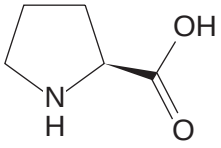
Answer **all** questions in the spaces provided.

6 The formation of proteins is a key process in the growth and repair of tissues in living organisms.

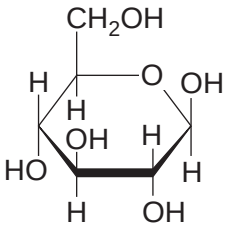
(a) (i) Study the structures of the three molecules below. One of the molecules could be a building block for a protein while the other two could be building blocks for other biological polymers.



J



K



L

Which of the three could be a building block for a protein? Explain your answer.

.....

.....

(ii) For which biological polymer could **one** of the other molecules form a building block?

molecule ..... **polymer** .....

[2]

(b) Protein molecules have four levels of structure as the long molecules fold and take shape.

(i) The primary structure is the sequence of amino acids in the protein chain. What type of bonding exists between the amino acids in this chain?

.....

(ii) What type of bonding can exist in **all** of the other types of structure?

.....

(iii) Name one type of bonding that does **not** occur in the primary or secondary structure of the protein.

.....

[3]

(c) Many proteins play an important role in catalysing chemical reactions in living organisms.

For Examiner's Use

(i) What name is given to these catalysts?

.....

(ii) Give **two** changes in conditions under which these catalysts may be inactivated, explaining the chemical reason for this in each case.

.....

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[4]

[Total: 9]

7 Different analytical techniques are used to build up a picture of complex molecules. Each technique on its own provides different information about complex molecules but together the techniques can give valuable structural information.

(a) Complete the table, identifying the technique which can provide the appropriate structural information.

structural information	analytical technique
three-dimensional arrangement of atoms and bonds in a molecule	
chemical environment of protons in a molecule	
identity of amino acids present in a polypeptide	

[3]

(b) One general method of separating organic molecules is chromatography. Briefly explain the chemical principles involved in each of the following techniques.

(i) paper chromatography

.....

.....

.....

(ii) thin-layer chromatography

.....

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[2]

For Examiner's Use

(c) A combination of mass spectrometry and NMR spectroscopy is often enough to determine the structure of a simple organic compound.
The organic compound **N** produced a mass spectrum in which the ratio of the M:M+1 peaks was 5.9:0.20, and which had an M+2 peak of similar height to the M peak.

(i) Calculate how many carbon atoms are present in one molecule of **N**.

(ii) Deduce which element, other than carbon and hydrogen, is present in **N**.

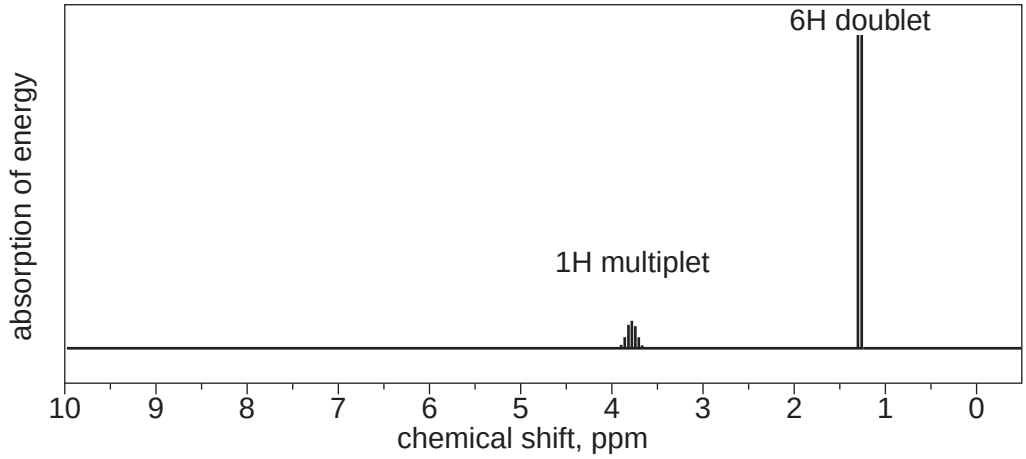
.....

(iii) Explain how many atoms of this element are present in one molecule of **N**.

.....

.....

The NMR spectrum of **N** is shown.



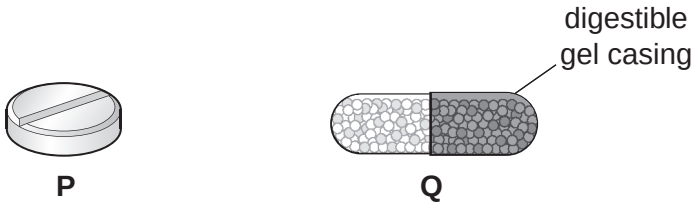
(iv) State the empirical formula of **N** and, using the NMR data, suggest the structural formula of **N**, explaining your reasons.

[6]

[Total: 11]

8 Drugs can be delivered in a number of ways. The method chosen depends both on the nature of the drug, and the problem it is being used to treat.

(a) Many common drugs are taken by mouth in forms similar to those shown.



(i) Some drugs are available in solution. How would the speed of action of this form compare with **P** and **Q**? Explain your answer.

.....

.....

(ii) Explain which of the two forms, **P** or **Q**, would act the most rapidly when taken by mouth.

.....

.....

(iii) Some drugs are broken down before they can be absorbed by the intestine. Suggest how the design of **Q** prevents this.

.....

.....

[3]

(b) After an abdominal operation drugs are often delivered by means of a 'drip' inserted into a blood vessel in the patient's arm. Explain why this is more effective than taking painkillers by mouth.

.....

.....

.....

[2]

(c) One of the molecules that has found a variety of uses in drug delivery is poly(ethylene glycol) or PEG. It is formed from dihydroxyethane, $HOCH_2CH_2OH$.

For Examiner's Use

$$2n\ HOCH_2CH_2OH \longrightarrow H–(OCH_2CH_2OCH_2CH_2)_n–OH + (2n–1)\ H_2O$$

(i) What type of reaction is this?

.....

Attaching a PEG molecule to a drug increases the time that it takes for the drug to be broken down and flushed from the body. There are thought to be two major reasons for this: firstly the PEG can form bonds to slow the passage of the drug around the body; secondly it may reduce the efficiency of breakdown of the drug by enzymes.

(ii) What type of bonds would the PEG part of the molecule form with molecules in the body?

.....

(iii) Suggest why attaching a PEG molecule to a drug molecule would reduce the rate of the drug's decomposition by enzymes.

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(iv) Drugs are often protein or polypeptide molecules. What type of reaction might occur in the breakdown of such a drug?

.....

[5]

[Total: 10]

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UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS
General Certificate of Education
Advanced Subsidiary Level and Advanced Level

CANDIDATE NAME

CENTRE NUMBER

CANDIDATE NUMBER

CHEMISTRY **9701/51**

Paper 5 Planning, Analysis and Evaluation **October/November 2011**

1 hour 15 minutes

Candidates answer on the Question Paper.

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your Centre number, candidate number and name on all the work you hand in.
Write in dark blue or black pen.
You may use a soft pencil for any diagrams, graphs, or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.
DO **NOT** WRITE IN ANY BARCODES.

Answer **all** questions.
You are advised to show all working in calculations.
Use of Data Booklet is unnecessary.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
1	
2	
Total	

This document consists of **8** printed pages and **4** blank pages.

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1 When potassium nitrate dissolves in water, the temperature of the solution goes down because the enthalpy of solution is endothermic.

For Examiner's Use

You are to plan an experiment to investigate how the solubility of potassium nitrate varies with temperature. The units of solubility are grams per one hundred grams of water (g / 100g water).

(a) (i) Predict how the solubility of potassium nitrate will change if the solution temperature is **increased**.

Explain your prediction using the fact that dissolving potassium nitrate is endothermic.

prediction .....

.....

explanation .....

.....

.....

.....

(ii) Display your prediction in the form of a sketch graph, labelling clearly the axes.

[3]

(b) In the experiment you are about to plan, identify the following.

(i) the independent variable .....

(ii) the dependent variable .....

[2]

(c) Design a laboratory experiment to test your prediction in **(a)**.

For Examiner's Use

In addition to the standard apparatus present in a laboratory you are provided with the following materials,

a boiling tube,
a looped wire stirrer,
a thermometer covering the temperature range 0 °C to 100 °C.

Describe how you would carry out the experiment. You should

- ensure a wide range of results suitable for analysis by graph,
- decide on the amounts of water and potassium nitrate to use,
- measure the amounts of the two reagents,
- heat the apparatus,
- decide at what point the temperature of the solution is to be taken.

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.....[7]

(d) State a hazard that must be considered when planning the experiment and describe precautions that should be taken to keep risks to a minimum.

For Examiner's Use

.....

..... [1]

(e) Draw a table with appropriate headings to show the data you would record when carrying out your experiments and the values you would calculate in order to construct a graph to support or reject your prediction in **(a)**. The headings **must** include the appropriate units.

[2]

[Total: 15]

[Turn over

2 Chemical reactions occur more rapidly as the temperature of the reaction mixture increases. The mathematical relationship that summarises this is

For Examiner's Use

$$\log_{10}(\text{rate of reaction}) = \frac{-E_A}{19T}$$

where $\mathbf{E_A}$ is the **activation energy** of the reaction and **T** is the **absolute temperature** in Kelvin and the **rate of reaction** can be taken as the reciprocal of the time taken in seconds **(1/time)**.

An experiment was carried out to investigate this relationship using dilute hydrochloric acid and aqueous sodium thiosulfate.

- 20 cm^3 of dilute hydrochloric acid was placed in a boiling tube contained in a water bath.
- 20 cm^3 of aqueous sodium thiosulfate was added to the dilute hydrochloric acid, while stirring and a stopwatch started.
- The temperature of the water bath was recorded.
- After a period of time the liquid became cloudy (opaque) due to the formation of a precipitate of sulfur.
- As soon as this cloudiness (opacity) appeared the time was recorded.
- The temperature of the water bath was raised and the whole experiment repeated.

(a) The results of several such experiments are recorded below.

Process the results in the table to calculate **$\log_{10}$ (rate of reaction)**, the reciprocal of the absolute temperature (**1/T**) and the 'rate of reaction' (**1/time**). You should expect the values of **$\log_{10}$ (rate of reaction)** to be negative.

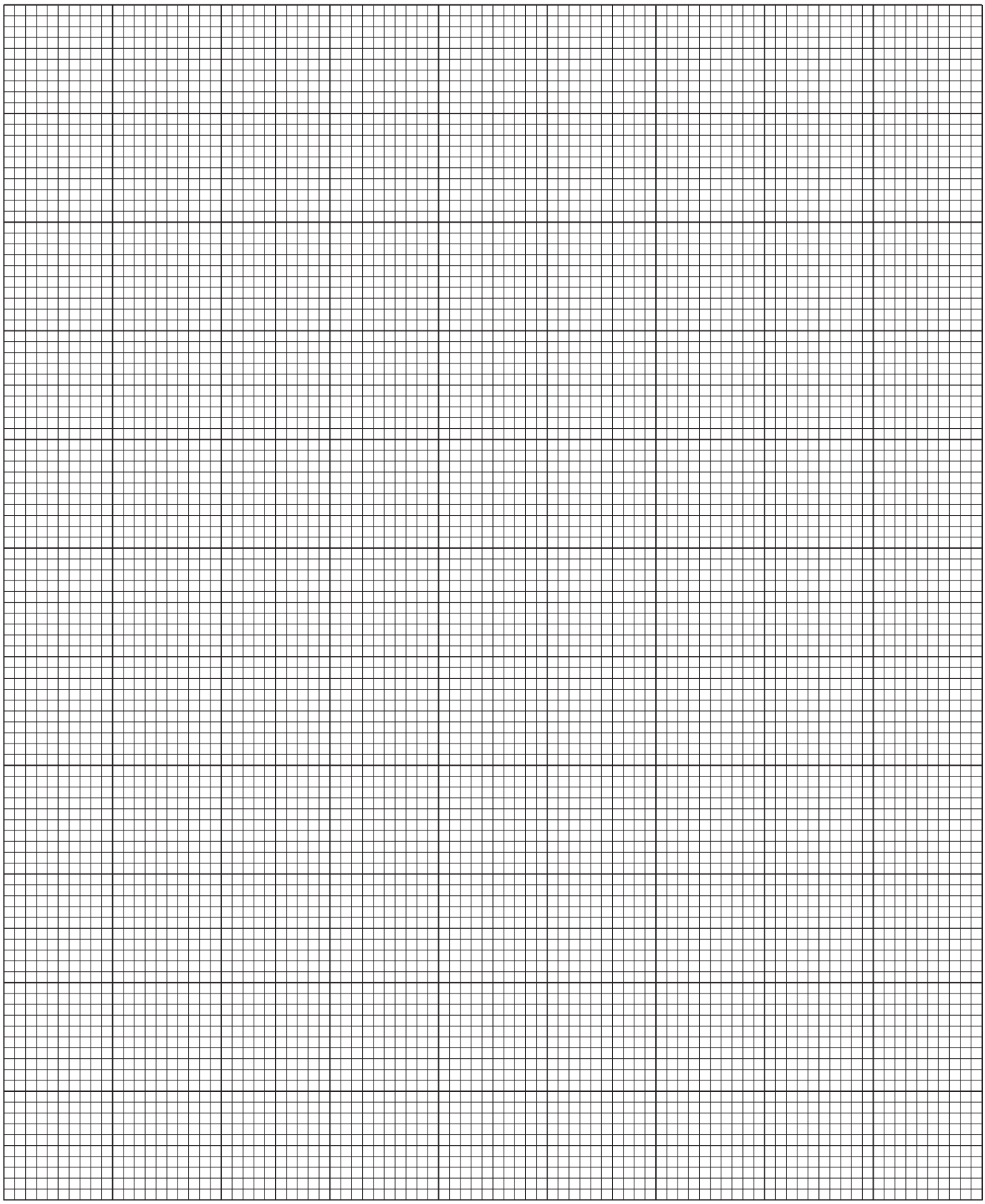
Record these values to **three significant figures** in the additional columns of the table.

Label the columns you use. For each column you use include units where appropriate and an expression to show how your values are calculated.

You may use the column headings A to F for these expressions (e.g. A–B). [3]

A	B	C	D	E	F
temperature / °C	absolute temperature / K	time / s			
20.0	293	60.3			
30.0	303	46.8			
40.0	313	41.6			
45.0	318	31.6			
50.0	323	28.8			
55.0	328	25.1			
60.0	333	21.0			
65.0	338	20.4			
70.0	343	18.1			
80.0	353	15.1			

(b) Plot a graph to show the relationship between **$\log_{10}$ (rate of reaction)** and the reciprocal of the absolute temperature. You are reminded that the values for **$\log_{10}$ (rate of reaction)** are negative.
Draw the line of best fit.



[3]

[Turn over

(c) Circle and label on the graph any point(s) you consider to be anomalous. For each anomalous point give a different reason why it is anomalous, clearly stating which point you are describing.

For Examiner's Use

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..... [3]

(d) Comment on whether the results obtained can be considered as reliable.

.....

..... [1]

(e) Determine the slope of the graph. Mark clearly on the graph any construction lines and show clearly in your calculation how the values from the intercepts were used in the calculation of the slope.

[2]

(f) Using the value of the slope of your graph calculated in **(f)** calculate a value for the **activation energy, E_A**. Correct use of the equation will produce an answer in $kJ\,mol^{-1}$.

[1]

(g) By considering the movement of particles in the reaction explain why the rate of reaction increases with increasing temperature.

For Examiner's Use

[2]

[Total: 15]

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UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS
General Certificate of Education
Advanced Subsidiary Level and Advanced Level

CANDIDATE NAME

CENTRE NUMBER

CANDIDATE NUMBER

CHEMISTRY **9701/52**

Paper 5 Planning, Analysis and Evaluation **October/November 2011**

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Total	

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prediction .....

.....

explanation .....

.....

.....

.....

(ii) Display your prediction in the form of a sketch graph, labelling clearly the axes.

[3]

(b) In the experiment you are about to plan, identify the following.

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(ii) the dependent variable .....

[2]

(c) Design a laboratory experiment to test your prediction in **(a)**.

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.....[7]

(d) State a hazard that must be considered when planning the experiment and describe precautions that should be taken to keep risks to a minimum.

For Examiner's Use

.....

..... [1]

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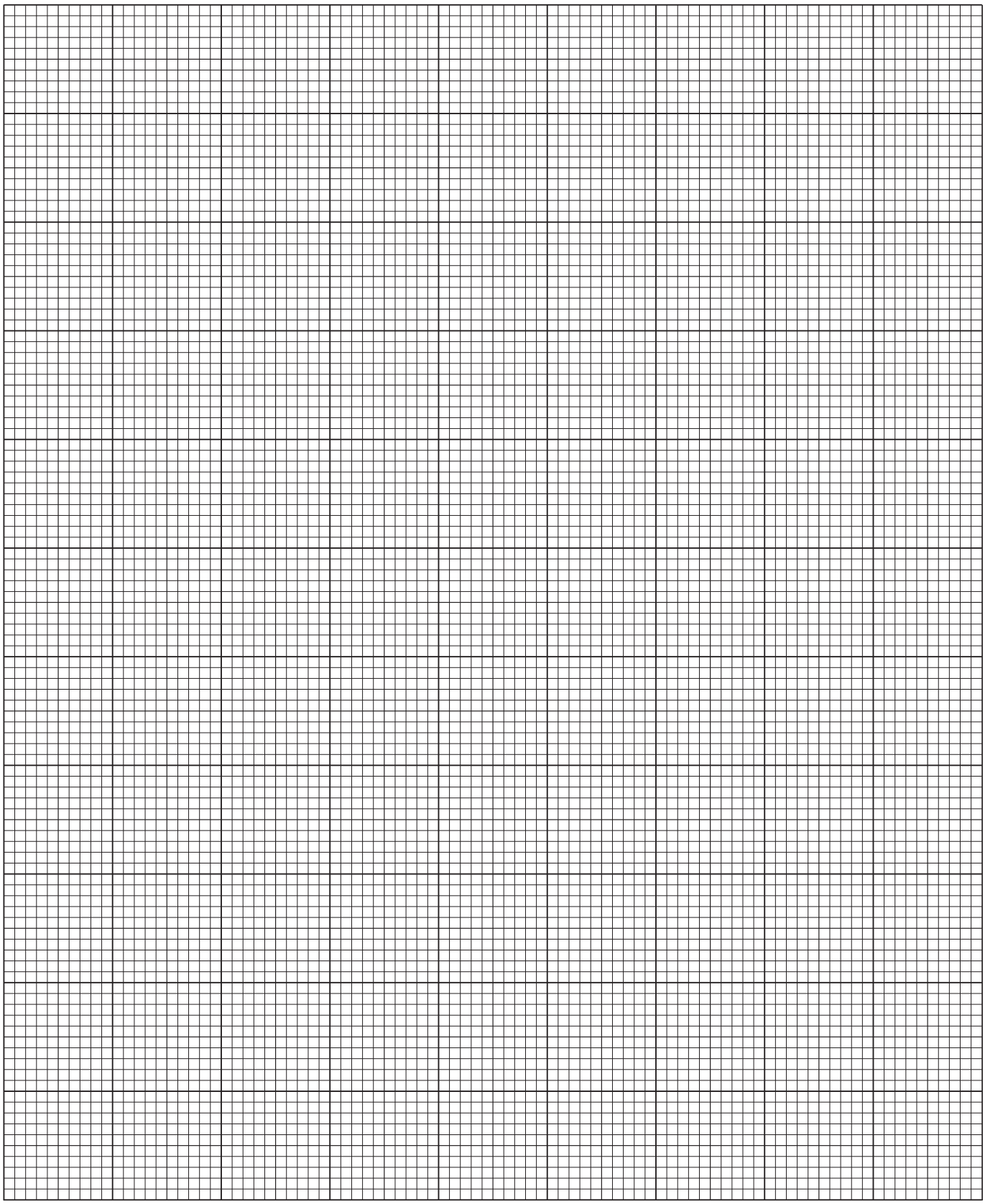
Label the columns you use. For each column you use include units where appropriate and an expression to show how your values are calculated.

You may use the column headings A to F for these expressions (e.g. A–B). [3]

A	B	C	D	E	F
temperature / °C	absolute temperature / K	time / s			
20.0	293	60.3			
30.0	303	46.8			
40.0	313	41.6			
45.0	318	31.6			
50.0	323	28.8			
55.0	328	25.1			
60.0	333	21.0			
65.0	338	20.4			
70.0	343	18.1			
80.0	353	15.1			

(b) Plot a graph to show the relationship between **$\log_{10}$ (rate of reaction)** and the reciprocal of the absolute temperature. You are reminded that the values for **$\log_{10}$ (rate of reaction)** are negative.
Draw the line of best fit.



[3]

[Turn over

(c) Circle and label on the graph any point(s) you consider to be anomalous. For each anomalous point give a different reason why it is anomalous, clearly stating which point you are describing.

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(d) Comment on whether the results obtained can be considered as reliable.

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(e) Determine the slope of the graph. Mark clearly on the graph any construction lines and show clearly in your calculation how the values from the intercepts were used in the calculation of the slope.

[2]

(f) Using the value of the slope of your graph calculated in **(f)** calculate a value for the **activation energy, E_A**. Correct use of the equation will produce an answer in $kJ\,mol^{-1}$.

[1]

(g) By considering the movement of particles in the reaction explain why the rate of reaction increases with increasing temperature.

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[2]

[Total: 15]

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UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS
General Certificate of Education
Advanced Subsidiary Level and Advanced Level

CANDIDATE NAME

CENTRE NUMBER

CANDIDATE NUMBER

CHEMISTRY **9701/53**

Paper 5 Planning, Analysis and Evaluation **October/November 2011**

1 hour 15 minutes

Candidates answer on the Question Paper.

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your Centre number, candidate number and name on all the work you hand in.
Write in dark blue or black pen.
You may use a soft pencil for any diagrams, graphs, or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.
DO **NOT** WRITE IN ANY BARCODES.

Answer **all** questions.
You are advised to show all working in calculations.
Use of Data Booklet is unnecessary.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
1	
2	
Total	

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1 If a container of gas has a tiny hole in it, the gas will gradually escape through the hole. This process is called **effusion** and the rate at which it occurs is called **the rate of effusion**.

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You are to plan an experiment to investigate how the **rate of effusion** depends on the **relative molecular mass**, M_r, of a gas.

(a) At a constant temperature, the rate of effusion of a gas depends on the kinetic energy of the molecules of the gas. So, for a series of gases all at the same temperature, as the M_r of a gas increases the speed of the molecules of the gas decreases.

(i) Predict how the rate of effusion will change as the M_r of the gas **increases**. Explain your prediction using the information in part **(a)** above.

prediction .....

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explanation .....

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(ii) Display your prediction in the form of a sketch graph below, clearly labelling the axes.

[3]

(b) In the experiment you are about to plan, identify the following.

(i) the independent variable .....

(ii) the dependent variable .....

[2]

(c) Using the apparatus shown below design a laboratory experiment to test your prediction in **(a)**.

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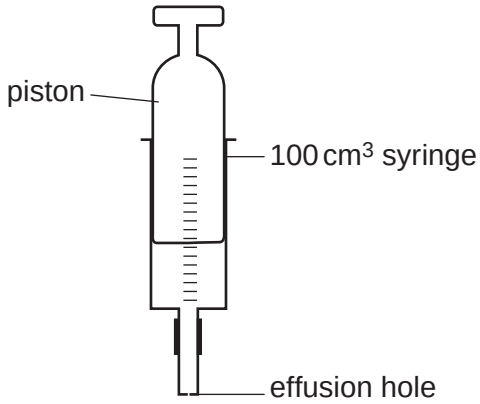

In addition to the standard apparatus present in a laboratory you are provided with the following materials,

- access to samples of the following gases; hydrogen, oxygen, carbon dioxide, butane and chlorine,
- a stop watch/clock.

Describe how you would carry out the experiment. You should

- ensure that the volume of gas measured is the same for each experiment,
- ensure that the syringe contains only the gas under investigation,
- ensure that the syringe is used under the same conditions throughout all of the experiments,
- measure the effusion time,
- produce reliable results.

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(d) State a hazard that must be considered when planning the experiment and describe precautions that should be taken to keep risks to a minimum.

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(e) Draw a table with appropriate headings to show the data you would record when carrying out your experiments and the values you would calculate in order to construct a graph to support or reject your prediction in **(a)**. The headings **must** include the appropriate units. Ensure that the table covers all the detail relating to the five gases listed in **(c)**.

[A_r: H, 1.0; C, 12.0; O, 16.0; C*l*, 35.5]

[2]

[Total: 15]

2 There are three oxides of lead, PbO, PbO_2 and Pb_3O_4 all of which can be reduced to metallic lead by hydrogen. A sample of one of these oxides is reduced to find out which of the three oxides it is.

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An experiment was carried out as follows.

- An empty reduction tube was weighed and the mass recorded.
- A sample of the lead oxide was added to the reduction tube and the new mass recorded.
- The reduction tube and lead oxide was heated strongly for five minutes in a stream of hydrogen and then allowed to cool back to room temperature.
- The reduction tube and contents were then reweighed and the mass recorded.

(a) The results of several such experiments are recorded below.

[A_r: O, 16.0; Pb, 207.0]

Process the results in the table to calculate the number of moles of lead **atoms** and the number of moles of oxygen **atoms**.

Record these values in the additional columns of the table. You may use some or all of the columns. Label the columns you use.

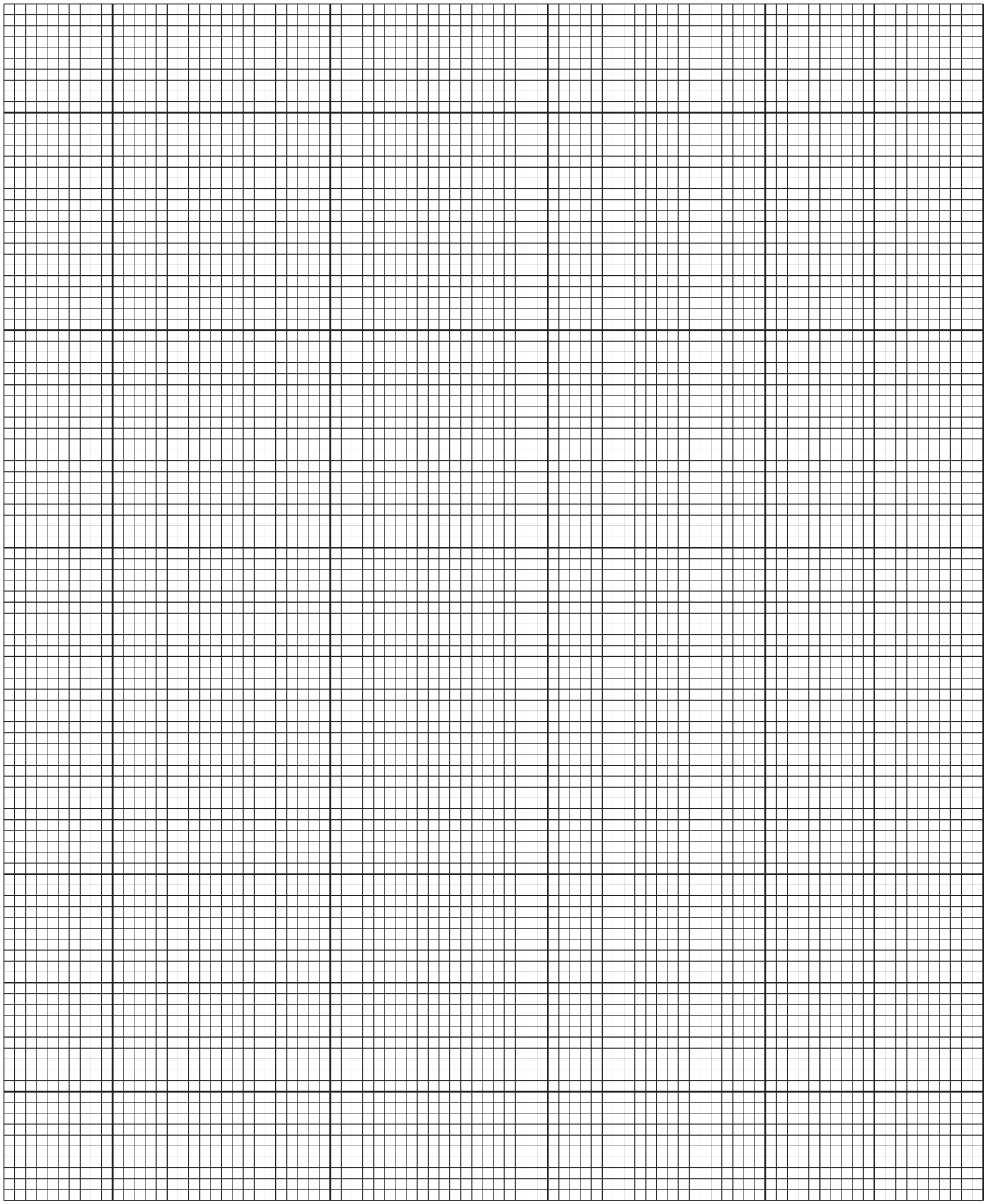
Masses should be recorded to **two decimal places** while the number of moles should be recorded to **two significant figures**.

For each column you use include units where appropriate and an expression to show how your values are calculated.

You may use the column headings A to G for these expressions (e.g. A–B). [3]

A	B	C	D	E	F	G
mass of reduction tube / g	mass of reduction tube + lead oxide / g	mass of reduction tube + lead / g				
9.90	14.95	14.48				
10.05	16.17	15.60				
10.25	17.92	17.21				
9.80	18.12	17.43				
9.60	18.43	17.61				
10.30	20.27	19.34				
11.05	22.05	21.03				
10.00	21.46	20.26				
9.75	24.07	22.74				
10.15	26.15	24.66				

(b) Plot a graph to show the relationship between the number of moles of oxygen **atoms** and the number of moles of lead **atoms**.
Draw the line of best fit.



[3]

[Turn over

(c) Circle and label on the graph any point(s) you consider to be anomalous. For each anomalous point give a different reason why it is anomalous, clearly stating which point you are describing.

For Examiner's Use

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.....[3]

(d) Comment on whether the results obtained can be considered as reliable.

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.....[1]

(e) Determine the slope of the graph. Mark clearly on the graph any construction lines and show clearly in your calculation how the values from the intercepts were used in the calculation of the slope.

[2]

(f) Comment on the value of the slope of the graph.
Deduce and explain the formula of the oxide investigated in this experiment.

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comment .....

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deduction and explanation .....

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[Total: 15]

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