Please write clearly in block capitals.

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

Surname _____

Forename(s) _____

Candidate signature _____

AS CHEMISTRY

Unit 2 Chemistry in Action

Friday 10 June 2016 Afternoon Time allowed: 1 hour 45 minutes

Materials

For this paper you must have:
- the Periodic Table/Data Sheet, provided as an insert (enclosed)
- a ruler with millimetre measurements
- a calculator.

Instructions
- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Do not write outside the box around each page or on blank pages.
- All working must be shown.
- Do all rough work in this book. Cross through any work you do not want to be marked.

Information
- The marks for questions are shown in brackets.
- The maximum mark for this paper is 100.
- You are expected to use a calculator, where appropriate.
- The Periodic Table/Data Sheet is provided as an insert.
- Your answers to the questions in **Section B** should be written in continuous prose, where appropriate.
- You will be marked on your ability to:
  – use good English
  – organise information clearly
  – use scientific terminology accurately.

Advice
- You are advised to spend about 1 hour 15 minutes on **Section A** and about 30 minutes on **Section B**.

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Section A

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

1 This question is about the Group 2 metals and their compounds.

1 (a) Explain why the first ionisation energy of barium is less than the first ionisation energy of calcium.

[2 marks]

1 (b) Magnesium reacts readily with steam.

State **two** observations you would make when magnesium reacts with steam. Write an equation for the reaction.

[3 marks]

Observation 1 _____

Observation 2 _____

Equation _____

Do not write outside the box

1 (c) Explain why different observations are made when aqueous barium chloride is added separately to aqueous magnesium sulfate and to aqueous magnesium nitrate.

Write the simplest ionic equation, including state symbols, for any reaction that occurs.

[2 marks]

Explanation _____

_____

_____

_____

_____

Equation _____

7

Turn over for the next question

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2 Standard enthalpy of combustion data can be used to calculate enthalpies of formation.

2 (a) State the meaning of the term standard enthalpy of combustion.

[3 marks]

2 (b) The equation corresponding to the enthalpy of formation of propan-1-ol is shown.

$$3C(s) + 4H_2(g) + \frac{1}{2}O_2(g) \longrightarrow CH_3CH_2CH_2OH(l)$$

Table 1 contains some standard enthalpy of combustion data.

Table 1

	C(s)	**H_2(g)**	**$CH_3CH_2CH_2OH$(l)**
$\Delta H_c^{\ominus}$ / kJ mol^{-1}	–394	–286	–2010

Use data from **Table 1** to calculate a value for the standard enthalpy of formation of propan-1-ol. Show your working.

[3 marks]

Do not write outside the box

2 (c) An equation for the complete combustion of gaseous propan-1-ol is shown.

$$CH_3CH_2CH_2OH(g) + 4\tfrac{1}{2}O_2(g) \longrightarrow 3CO_2(g) + 4H_2O(g) \quad \Delta H = -1893 \text{ kJ mol}^{-1}$$

Table 2 shows some bond enthalpy data.

Table 2

	C–H	**C–O**	**O–H**	**C=O**	**O=O**
Bond enthalpy / kJ mol^{-1}	412	360	463	805	496

Use data from **Table 2** and the enthalpy change for this reaction to calculate a value for the bond enthalpy of a C–C bond in propan-1-ol.

[3 marks]

9

Turn over for the next question

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3 Haloalkanes are used as refrigerants, solvents and anaesthetics.

3 (a) Trichloromethane ($CHCl_3$) is a haloalkane that can be formed by heating a mixture of chloromethane (CH_3Cl) and chlorine.

3 (a) (i) Write an overall equation for the formation of trichloromethane by the reaction of chloromethane with chlorine.

[1 mark]

3 (a) (ii) Name the mechanism for this formation of trichloromethane.

[1 mark]

3 (a) (iii) Dichloromethane (CH_2Cl_2) is an intermediate in this formation of trichloromethane.

Write an equation for each of the following steps in the mechanism for the reaction of dichloromethane with chlorine.

[4 marks]

Initiation step

First propagation step

Second propagation step

A termination step leading to the formation of a compound with formula $C_2H_2Cl_4$

Do not write outside the box

3 (b) Chlorotrifluoromethane ($CClF_3$) is used as a refrigerant, but is being phased out due to concerns about ozone depletion in the upper atmosphere.
In the upper atmosphere, $CClF_3$ decomposes in the presence of UV light forming a reactive intermediate that catalyses the decomposition of ozone.

3 (b) (i) Write an equation to show how $CClF_3$ decomposes to form the reactive intermediate.

[1 mark]

_____

3 (b) (ii) Write two equations to show how this reactive intermediate is involved in catalysing the decomposition of ozone.

[2 marks]

1 _____

2 _____

9

Turn over for the next question

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4 Compounds **A**, **B**, **C** and **D** are isomers with the molecular formula $C_4H_{10}O$
They all have a broad absorption in their infrared spectra in the range 3230–3550 cm^{-1}.

4 (a) Use **Table A on the data sheet** to identify the bond and the functional group present responsible for this absorption.

[1 mark]

_____

4 (b) Compounds **A** and **B** are both straight-chain compounds.
A can be oxidised to form **P**.
B can be oxidised to form **Q**.
P and **Q** are isomers with molecular formula C_4H_8O

Tollens' reagent and Fehling's solution can be used to distinguish between isomers **P** and **Q**. The results shown in **Table 3** are obtained.

Table 3

Compound	Observation with Tollens' reagent	Observation with Fehling's solution
P	No visible change	No visible change
Q	Silver mirror formed	Brick-red precipitate formed

Use the information about compounds **P** and **Q** to identify compounds **A** and **B**.
Explain your answer with reference to the functional groups in **P** and **Q**.

[3 marks]

Identity of **A** _____

Identity of **B** _____

Explanation _____

_____

_____

_____

Do not write outside the box

4 (c) Isomer **C** is resistant to oxidation.
Isomer **C** reacts to form compound **R** that has an absorption in its infrared spectrum in the range 1620–1680 cm^{-1}.

State the bond that causes the absorption in the range 1620–1680 cm^{-1}.

Give the displayed formula of isomer **C**.

Identify the reagent and give **one** reaction condition needed to convert **C** into **R**.

[4 marks]

Bond _____

Displayed formula of **C**

Reagent _____

Condition _____

Question 4 continues on the next page

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4 (d) Compound **D** is a branched-chain isomer that can be oxidised to form compounds **S** and **T**.

4 (d) (i) Compound **S** is obtained by distilling it off as it forms during the oxidation.
Compound **T** is formed when the oxidation takes place under reflux.

Identify the functional groups in **S** and **T**.

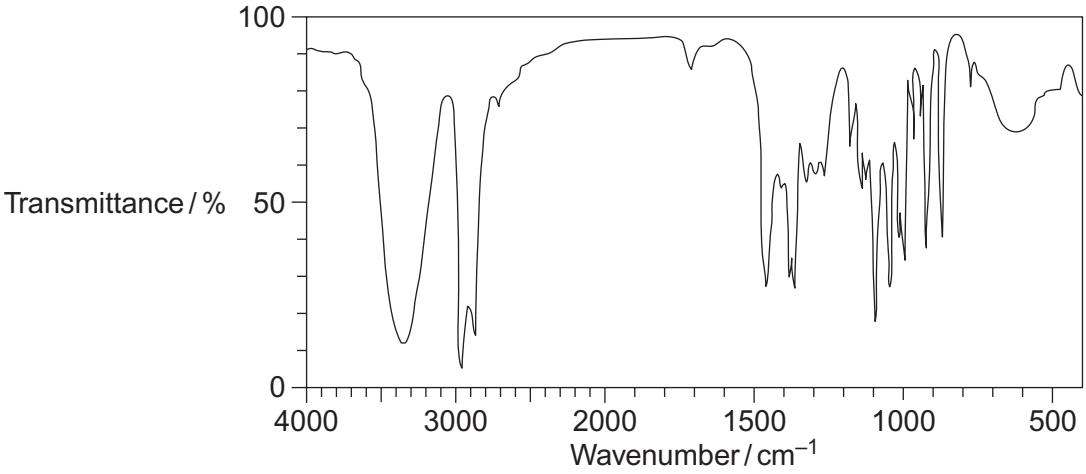
Explain, with reference to intermolecular forces, why it is possible to obtain compound **S** but not **T** from the reaction mixture by distilling off **S** as soon as it forms.

[3 marks]

Do not write outside the box

4 (d) (ii) A student claims to have oxidised compound **D**.
Figure 1 shows the infrared spectrum of the product obtained by the student.

Figure 1



Suggest two ways in which the spectrum shows that compound **D** has **not** been oxidised.

[2 marks]

13

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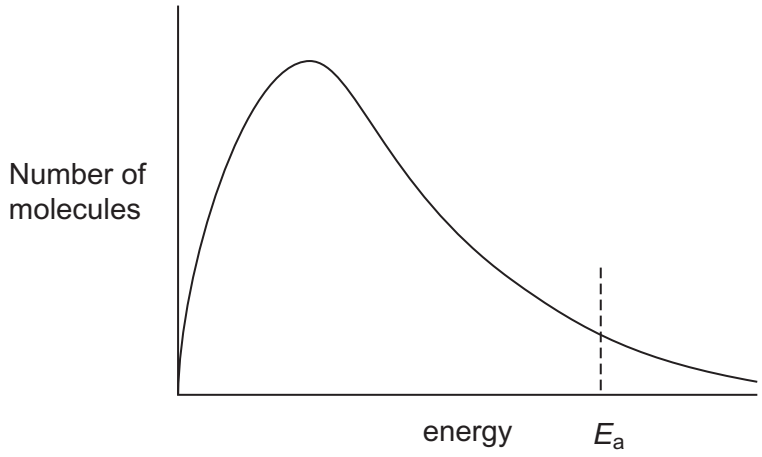
5 Methanol, for use as a fuel, can be produced by the reaction of carbon monoxide with hydrogen.

$$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g) \qquad \Delta H = -90 \text{ kJ mol}^{-1}$$

The reaction is typically carried out at 300 ºC and 3×10^7 Pa, in the presence of a catalyst.

5 (a) **Figure 2** shows the Maxwell–Boltzmann distribution for a mixture of carbon monoxide and hydrogen at 300 ºC.

Figure 2



5 (a) (i) Sketch a second curve on **Figure 2** to show the distribution of molecular energies in this mixture at a higher temperature.

[1 mark]

5 (a) (ii) Explain with reference to both curves in **Figure 2** how a small change in temperature leads to a large change in the rate of reaction.

[2 marks]

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5 (b) Both the rate of production and equilibrium yield of methanol are considered when choosing the most appropriate conditions for the operation of this process on an industrial scale.

5 (b) (i) State and explain the effect of a higher pressure on the equilibrium yield of methanol.

[3 marks]

5 (b) (ii) By considering both rate and yield, state why the reaction is carried out at a temperature of 300 ºC rather than at a higher temperature.

[2 marks]

8

Turn over for the next question

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6 The halogens are the elements in Group 7.

6 (a) The electronegativities of the halogens are shown in **Table 4**.

Table 4

Halogen	**Fluorine**	**Chlorine**	**Bromine**	**Iodine**
Electronegativity	4.0	3.0	2.8	2.5

Explain the trend in electronegativities shown by the halogens.

[2 marks]

6 (b) The halogens can all behave as oxidising agents in reactions.

6 (b) (i) Explain, in terms of electron transfer, the meaning of the term oxidising agent.

[1 mark]

6 (b) (ii) An equation for the reaction that takes place when chlorine gas is bubbled through aqueous potassium bromide is shown.

$$Cl_2(g) + 2KBr(aq) \longrightarrow Br_2(aq) + 2KCl(aq)$$

Explain, with reference to the oxidation states, why this is a redox reaction.

[1 mark]

Do not write outside the box

6 (c) Solid sodium halides react with concentrated sulfuric acid.

6 (c) (i) A sample of solid sodium iodide is reacted with concentrated sulfuric acid.
A black solid forms and hydrogen sulfide gas is produced.

Write a half-equation for the reaction of sulfuric acid to form hydrogen sulfide.

[1 mark]

---

6 (c) (ii) Write a half-equation for the formation of the black solid.

[1 mark]

---

6 (c) (iii) Use your answers to parts **(c) (i)** and **(c) (ii)** to write an overall equation for the reaction of sodium iodide with concentrated sulfuric acid.

[1 mark]

---

6 (c) (iv) Give the role of sulfuric acid in its reaction with sodium iodide.
Tick (✓) **one** box.

[1 mark]

Acid ☐

Oxidising agent ☐

Reducing agent ☐

Electrophile ☐

6 (c) (v) Write an equation for the reaction of concentrated sulfuric acid with solid sodium fluoride.

[1 mark]

---

6 (c) (vi) Suggest **one** reason why the reaction of sodium fluoride with concentrated sulfuric acid is different from the reaction with sodium iodide.

[1 mark]

Do not write outside the box

6 (d) Chlorine reacts with water to form an equilibrium mixture containing hydrochloric acid and chloric(I) acid.

6 (d) (i) Write an equation for the formation of this equilibrium mixture.

[1 mark]

6 (d) (ii) Household bleach contains sodium chlorate(I) and sodium chloride.
State and explain, with reference to your equation in part **(d)(i)**, why it is dangerous to acidify an aqueous mixture of sodium chlorate(I) and sodium chloride.

[2 marks]

13

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7 The ores used for the extraction of many metals contain metal sulfides or metal oxides. Various methods are used to extract metals from these ores.

7 (a) Sulfide ores such as zinc blende (ZnS) are crushed and then roasted in a stream of air to convert them into the metal oxide.

7 (a) (i) Write an equation for the reaction that takes place when ZnS is roasted in air.

[1 mark]

_____

7 (a) (ii) State a useful substance that can be manufactured from the gaseous product of this reaction.

[1 mark]

_____

7 (b) Zinc oxide is reduced by carbon monoxide in the extraction of zinc. The carbon monoxide is produced by the incomplete combustion of methane.

7 (b) (i) Write an equation for the production of carbon monoxide by the incomplete combustion of methane.

[1 mark]

_____

7 (b) (ii) Write an equation for the reaction between zinc oxide and carbon monoxide.

[1 mark]

_____

7 (c) Most copper is produced by reduction of copper(II) oxide with carbon. The copper(II) oxide is produced by roasting chalcopyrite ($CuFeS_2$) in air.

Copper can also be obtained from other low-grade ores. When these low-grade ores are processed, aqueous solutions containing low concentrations of Cu^{2+} ions are produced. Scrap iron is used to recover copper from these solutions.

7 (c) (i) Give the ionic equation for the reaction involved in the recovery of solid copper from an aqueous solution using scrap iron. Include state symbols.

[1 mark]

_____

Do not write outside the box

7 (c) (ii) Suggest two environmental reasons and one economic reason why the extraction of copper from solutions containing Cu^{2+} ions, using iron, is preferable to the reduction of copper(II) oxide made by roasting chalcopyrite.

[3 marks]

Environmental reason 1 _____

_____

_____

Environmental reason 2 _____

_____

_____

Economic reason _____

_____

_____

7 (d) Titanium can be extracted from its ore, rutile (TiO_2), in a two-step process using carbon, chlorine and magnesium. Extraction of titanium is not possible by direct reduction of TiO_2 with carbon.

7 (d) (i) Give equations for the two-step process using carbon, chlorine and magnesium.

[2 marks]

Step 1 _____

Step 2 _____

7 (d) (ii) State why direct reduction of TiO_2 with carbon cannot be used.

[1 mark]

_____

_____

11

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Section B

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

8 Two reactions of 2-bromopentane, ($CH_3CH_2CH_2CHBrCH_3$) are shown.

$$C_5H_{10} \xleftarrow{\text{reaction } \mathbf{1}} CH_3CH_2CH_2CHBrCH_3 \xrightarrow{\text{reaction } \mathbf{2}} C_5H_{11}OH$$

The C_5H_{10} formed in reaction **1** exists as a mixture of three isomers, one of which is pent-1-ene. Two of the isomers are a pair of stereoisomers. All three isomers decolourise bromine.

8 (a) The same reagent is used in both reactions. The product is determined by the choice of conditions.

State the reagent and the conditions for each of reaction **1** and reaction **2**.

State the role of the reagent in each reaction.

Name and outline the mechanism of reaction **1** for the formation of pent-1-ene.

[8 marks]

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8 (b) All three isomers of C_5H_{10} contain the same functional group.

Draw the displayed formula of pent-1-ene.

Draw the structures of the pair of stereoisomers and give their full IUPAC names.

Explain the origin of the stereoisomerism shown.

[5 marks]

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8 (c) The rates of hydrolysis of two chloroalkanes can be investigated by adding aqueous silver nitrate to the chloroalkanes. During the hydrolysis reactions, chloride ions are liberated slowly. Precipitates of silver chloride are formed.

Outline a method to compare the rate of hydrolysis of 1-chlorobutane with that of 2-chlorobutane. State how the method would ensure a fair test.

[4 marks]

17

Turn over for the next question

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9 Alcohols can be prepared from alkenes in various ways.

9 (a) On a laboratory scale, a mixture of propan-1-ol and propan-2-ol can be prepared from propene in two steps.

In step 1, propene reacts with cold, concentrated sulfuric acid to form intermediate compounds.

In step 2, the intermediate compounds react with water to form the mixture of alcohols.

Name and outline the mechanism for the reaction between propene and concentrated sulfuric acid to form the intermediate compound which gives propan-2-ol in step 2.

Explain why propan-2-ol is the major product of this preparation.

[7 marks]

Do not write outside the box

9 (b) On an industrial scale ethanol can be produced from ethene by direct hydration or from glucose by fermentation.

State the conditions for the direct hydration reaction.

State two advantages and two disadvantages of the fermentation method compared with the direct hydration method.

[6 marks]

13

END OF QUESTIONS

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