Enthalpy Change & Hess's Law

Question Paper 3

Level	International A Level
Subject	Chemistry
Exam Board	CIE
Topic	Chemical Energetics
Sub-Topic	Enthalpy Change & Hess's Law
Paper Type	Theory
Booklet	Question Paper 3

Time Allowed:	**81 minutes**
Score:	**/67**
Percentage:	**/100**

Grade Boundaries:

A*	A	B	C	D	E	U
>85%	777.5%	70%	62.5%	57.5%	45%	<45%

1 Halogenoalkanes have been widely used as aerosol propellants, refrigerants and solvents for many years.

Fluoroethane, CH_3CH_2F, has been used as a refrigerant. It may be made by reacting ethene with hydrogen fluoride.

You are to calculate a value for the C–F bond energy in fluoroethane.

(a) Use relevant bond energies from the *Data Booklet*, and the equation below to calculate a value for the bond energy of the C–F bond.

$CH_2 = CH_2(g) \quad + \quad \rightarrow \quad CH_3CH_2F(g) \quad \Delta H^{\ominus} = -73\,kJ\,mol^{-1}$

C–F bond energy = ... $kJ\,mol^{-1}$ [4]

(b) Another halogenoalkane which was used as a refrigerant, and also as an aerosol propellant, is dichlorodifluoromethane, CCl_2F_2.

State **two** reasons why compounds such as CH_3CH_2F and CCl_2F_2 have been used as aerosol propellants and refrigerants.

.....

..... [2]

CCl_2F_2 is one of many chlorofluorocarbon compounds responsible for damage to the ozone layer in the stratosphere.

(c) By using relevant data from the *Data Booklet*, and your answer to **(a)** suggest why CCl_2F_2 is responsible for damage to the ozone layer in the stratosphere whereas CH_3CH_2F is not.

.....

.....

..... [2]

Both CH_3CH_2F and CCl_2F_2 are greenhouse gases.

The 'enhanced greenhouse effect' is of great concern to the international community.

(d) **(i)** What is meant by the term *enhanced greenhouse effect*?

.....

.....

.....

(ii) Water vapour is the most abundant greenhouse gas.

What is the second most abundant greenhouse gas?

..... [3]

A greenhouse gas which is present in very small amounts in the atmosphere is sulfur hexafluoride, SF_6, which is used in high voltage electrical switchgear.

(e) What shape is the SF_6 molecule?

..... [1]

[Total: 12]

2 Elements and compounds which have small molecules usually exist as gases or liquids.

(a) Chlorine, Cl_2, is a gas at room temperature whereas bromine, Br_2, is a liquid under the same conditions.

Explain these observations.

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..... [2]

(b) The gases nitrogen, N_2, and carbon monoxide, CO, are isoelectronic, that is they have the same number of electrons in their molecules.

Suggest why N_2 has a lower boiling point than CO.

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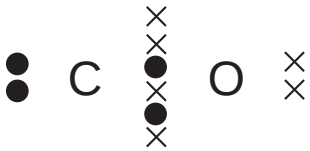
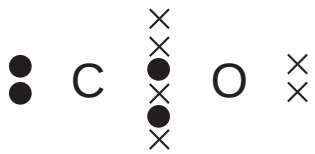
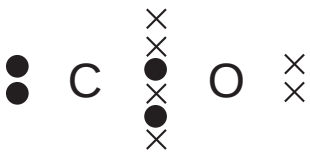
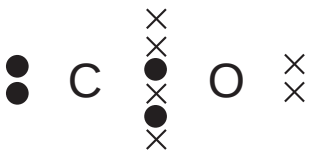
..... [2]

(c) A 'dot-and-cross' diagram of a CO molecule is shown below. Only electrons from outer shells are represented.



In the table below, there are three copies of this structure.
On the structures, draw a circle round a pair of electrons that is associated with **each** of the following.

(i) a co-ordinate bond	**(ii)** a covalent bond	**(iii)** a lone pair
		

[3]

(d) Hydrogen cyanide, HCN, is a gas which is also isoelectronic with N_2 and with CO. Each molecule contains a strong triple bond with the following bond energies.

bond	bond energy / kJ mol^{-1}
–C≡N in HCN	890
N≡N	994
C≡O	1078

Although each compound contains the same number of electrons and a strong triple bond in its molecule, CO and HCN are both very reactive whereas N_2 is not.

Suggest a reason for this.

.....

..... [1]

(e) HCN reacts with ethanal, CH_3CHO.

(i) Give the **displayed formula** of the organic product formed.

(ii) What type of reaction is this?

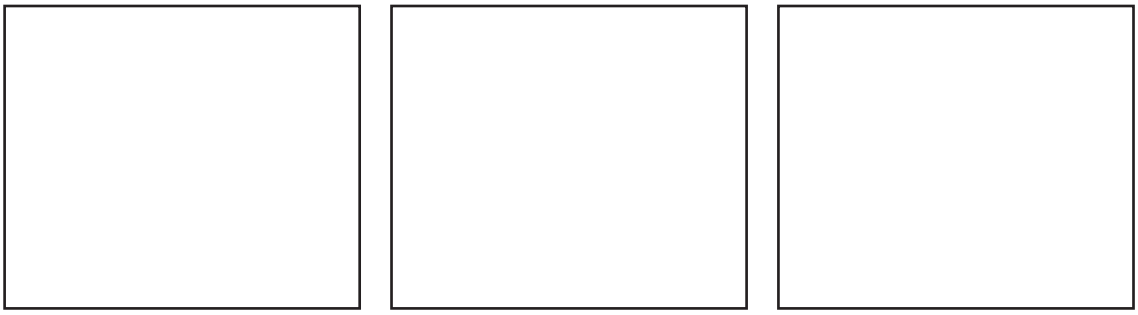
.....

(iii) Draw the mechanism of this reaction. You should show all full and partial charges and represent the movement of electron pairs by curly arrows.

[5]

[Total: 13]

3 **(a)** In the following boxes draw the structural formulae of **three** alcohols having straight (i.e. unbranched) chains, with the molecular formula $C_5H_{12}O$.



A **B** **C**

[2]

Use the letters **A**, **B** or **C** as appropriate when answering the following questions. Each letter may be used once, more than once or not at all.

(b) Which of the alcohols are chiral? ..... [1]

(c) **(i)** Which of these alcohols react with alkaline aqueous iodine? .....

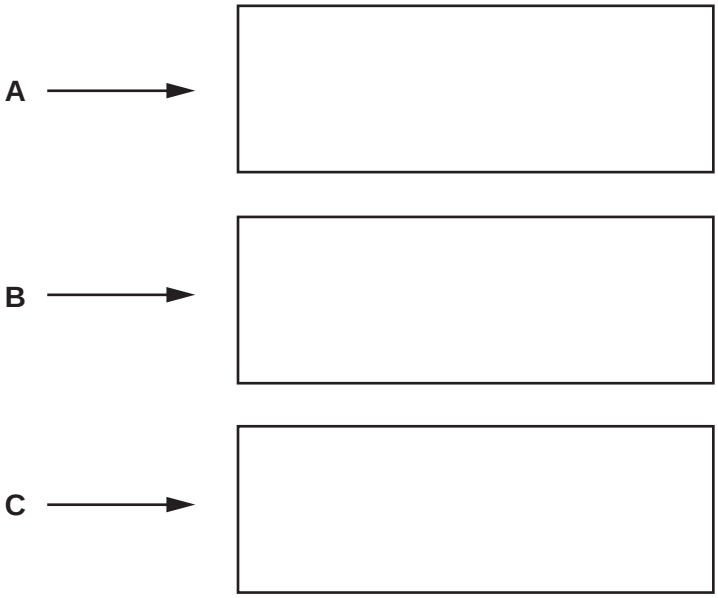
(ii) Describe the observation you would make during this reaction.

.....

(iii) Draw the structural formulae of the products of this reaction.

[4]

(d) Draw the structural formula of the product obtained when **each** of the alcohols **A**, **B** and **C** is heated with an excess of acidified $K_2Cr_2O_7$(aq).



[3]

(e) One of the many suggestions for converting biomass into liquid fuel for motor transport is the pyrolysis (i.e. heating in the absence of air) of cellulose waste, followed by the synthesis of alkanes.

(i) In the first reaction, cellulose, $(C_6H_{10}O_5)_n$, is converted into a mixture of carbon monoxide and hydrogen. Some carbon is also produced.

Complete and balance the equation for this reaction.

$(C_6H_{10}O_5)_n \longrightarrow$ _____ + _____ + _____

(ii) The second reaction involves the combination of CO and H_2 to produce alkanes such as heptane.

$$7CO + 15H_2 \longrightarrow \underset{\text{heptane}}{C_7H_{16}} + 7H_2O$$

Using the value of 1080 kJ mol^{-1} as the value for the C≡O bond energy in CO, and other relevant bond energies from the *Data Booklet*, calculate the ΔH for this reaction.

ΔH = ... kJ mol^{-1}
[5]

[Total: 15]

4 Monuments made of marble or limestone, such as the Taj Mahal in India and the Mayan temples in Mexico, are suffering erosion by acid rain. The carbonate stone is converted by the acid rain into the relatively more soluble sulphate.

$$CaCO_3(s) + \underset{\text{acid rain}}{H_2SO_4(aq)} \rightarrow CaSO_4(s) + H_2O(l) + CO_2(g)$$

(a) (i) Write an expression for the solubility product, K_{sp}, of $CaSO_4$, stating its units.

.....

(ii) The K_{sp} of $CaSO_4$ has a numerical value of 3×10^{-5}. Use your expression in **(i)** to calculate $[CaSO_4]$ in a saturated solution.

.....

(iii) Hence calculate the maximum loss in mass of a small statue if 100 dm^3 of acid rain falls on it. Assume the statue is made of pure calcium carbonate, and that the acid rain becomes saturated with $CaSO_4$.

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.....

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[5]

(b) The life of such monuments is now being extended by treating them with a mixture of urea and barium hydroxide solutions. After soaking into the pores of the carbonate rock, the urea gradually decomposes to ammonia and carbon dioxide. The carbon dioxide then reacts with the barium hydroxide to form barium carbonate.

$$(NH_2)_2CO(aq) + H_2O(l) \longrightarrow 2NH_3(g) + CO_2(g)$$

$$Ba(OH)_2(aq) + CO_2(g) \longrightarrow BaCO_3(s) + H_2O(l)$$

Acid rain then converts the barium carbonate to its sulphate.

$$BaCO_3(s) + H_2SO_4(aq) \longrightarrow BaSO_4(s) + H_2O(l) + CO_2(g)$$

Barium sulphate is much less soluble than calcium sulphate. A saturated solution contains $[Ba^{2+}] = 9.0 \times 10^{-6}$ mol dm^{-3}.

(i) Explain why barium sulphate is less soluble than calcium sulphate.

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.....

(ii) Write an expression for the K_{sp} of barium sulphate and use the data to calculate its value.

.....

.....

[4]

(c) **(i)** Explain what is meant by the term *lattice energy.*

.....

.....

(ii) Predict, with a reason, how the lattice energy of $BaSO_4$ might compare with that of $MgSO_4$.

.....

.....

.....

[3]

[Total: 12]

5 Magnesium is used extensively in the form of alloys as a constructional material due to its low density ($1.7\,g\,cm^{-3}$, compared to $7.8\,g\,cm^{-3}$ for iron). It is usually prepared by the electrolysis of magnesium chloride, $MgCl_2$, at a temperature a little above its melting point of 715 °C.

(a) Suggest the half-equation that represents the production of magnesium at the cathode during the electrolysis.

.....[1]

(b) What will be the product at the other electrode?

.....[1]

(c) Suggest **two** properties of its atoms that could explain why magnesium is less dense than iron.

.....

.....[2]

One of the reasons the melting point of magnesium chloride is quite high is because it has a fairly high lattice energy.

(d) **(i)** Explain the term *lattice energy*.

.....

.....

(ii) Write a balanced equation including state symbols to represent the lattice energy of magnesium chloride.

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.....[4]

(e) Suggest, with an explanation in each case, how the lattice energy of magnesium chloride might compare with that of

(i) sodium chloride, NaCl,

.....

.....

(ii) calcium chloride, $CaCl_2$.

.....

.....[4]

(f) Use the following data to calculate a value for the lattice energy of sodium chloride.

ΔH_f (NaCl)	=	$-411\ kJ\ mol^{-1}$
ΔH_{at} (Na)	=	$107\ kJ\ mol^{-1}$
ΔH_{at} (Cl)	=	$122\ kJ\ mol^{-1}$
first ionisation energy of Na	=	$494\ kJ\ mol^{-1}$
electron affinity of Cl	=	$-349\ kJ\ mol^{-1}$

lattice energy of NaCl = ... $kJ\ mol^{-1}$ [3]

[Total: 15]