Born-Haber Cycles

Question Paper 6

Level	International A Level
Subject	Chemistry
Exam Board	CIE
Topic	Chemical Energetics
Sub-Topic	Born-Haber Cycles
Paper Type	Theory
Booklet	Question Paper 6

Time Allowed: **77 minutes**

Score: **/64**

Percentage: **/100**

Grade Boundaries:

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

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.

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(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.

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

(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*.

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

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[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]

2 Crude oil is a naturally occurring flammable liquid which consists of a complex mixture of hydrocarbons. In order to separate the hydrocarbons the crude oil is subjected to fractional distillation.

(a) Explain what is meant by the following terms.

(i) *hydrocarbon* .....

.....

(ii) *fractional distillation* .....

.....[2]

(b) Undecane, $C_{11}H_{24}$, is a long chain hydrocarbon which is present in crude oil.
Such long chain hydrocarbons are 'cracked' to produce alkanes and alkenes which have smaller molecules.

(i) Give the conditions for **two different** processes by which long chain molecules may be cracked.

process 1 .....

.....

process 2 .....

.....

(ii) Undecane, $C_{11}H_{24}$, can be cracked to form pentane, C_5H_{12}, and an alkene.
Construct a balanced equation for this reaction.

.....[3]

Pentane, C_5H_{12}, exhibits structural isomerism.

(c) **(i)** Draw the three structural isomers of pentane.

isomer **B**	isomer **C**	isomer **D**

(ii) The three isomers of pentane have different boiling points.

Which of your isomers has the highest boiling point?

isomer .....

Suggest an explanation for your answer.

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.....

.....[6]

The unsaturated hydrocarbon, **E**, is obtained by cracking hexane and is important in the chemical industry.

The standard enthalpy change of combustion of **E** is –2059 kJ mol^{-1}.

(d) Define the term *standard enthalpy change of combustion*.

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.....[2]

When 0.47 g of **E** was completely burnt in air, the heat produced raised the temperature of 200 g of water by 27.5 °C. Assume no heat losses occurred during this experiment.

(e) **(i)** Use relevant data from the *Data Booklet* to calculate the amount of heat released in this experiment.

(ii) Use the data above and your answer to **(i)** to calculate the relative molecular mass, M_r, of **E**.

[4]

(f) Deduce the molecular formula of **E**.

[1]

[Total: 18]

3 **(a)** **(i)** Write equations to illustrate the reactions of the following oxides with water.

phosphorus(V) oxide .....

sulfur(IV) oxide .....

(ii) When NO_2 reacts with water, nitrogen undergoes a disproportionation reaction in which one nitrogen atom decreases its oxidation number by 1 and another nitrogen atom increases its oxidation number by 1. A mixture of two acids results.
Suggest an equation for the reaction between NO_2 and water.

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(iii) In a similar disproportionation reaction, ClO_2 reacts with aqueous NaOH to produce a solution containing two chlorine-containing sodium salts.
Suggest an equation for the reaction between ClO_2 and aqueous NaOH.

.....

[4]

(b) The major source of sulfur for the manufacture of sulfuric acid by the Contact process is the de-sulfurisation of 'sour' natural gas. Many natural gas wells produce a mixture of volatile hydrocarbons (mainly CH_4 and C_2H_6) together with up to 25% hydrogen sulfide, H_2S.

(i) Complete and balance the following equation showing the complete combustion of a gaseous mixture consisting of 2 mol of CH_4, 1 mol of C_2H_6 and 1 mol of H_2S.

$$2CH_4 + C_2H_6 + H_2S + \_\_\_\_\_ \rightarrow SO_2 + \_\_\_\_\_ + \_\_\_\_\_$$

(ii) Explain why it is important to remove the H_2S before burning the natural gas industrially.

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The H_2S is removed by passing the 'sour' natural gas through a solvent containing ethanolamine. The following reaction takes place.

$$HOCH_2CH_2NH_2 + H_2S(g) \rightarrow HOCH_2CH_2NH_3^+ + SH^-$$

(iii) If a sample of natural gas contains 5% by volume of H_2S, calculate the mass of ethanolamine required to remove all the H_2S from a 1000 dm^3 sample of gas, measured under room conditions.

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The H_2S can be recovered by warming the solution to 120 °C, when the above reaction is reversed. The ethanolamine can then be recycled.

(iv) What *type* of reaction is occurring here?

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The recovered H_2S is converted to sulfur by the following two reactions.

I Part of the H_2S is burned in air.

$$H_2S + 1.5O_2 \rightarrow SO_2 + H_2O$$

II The gas stream resulting from reaction **I** is then blended with the remaining H_2S and fed into an iron oxide catalyst bed, where sulfur and water are produced according to the following equation.

$$2H_2S(g) + SO_2(g) \rightarrow 3S(g) + 2H_2O(g)$$

(v) Use the following data to calculate $\Delta H^{\ominus}$ for the reaction between H_2S and SO_2.

compound	$\Delta H_f^{\ominus}$ / kJ mol^{-1}
$H_2S(g)$	–21
$SO_2(g)$	–297
$H_2O(g)$	–242
S(g)	+11

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

[8]

[Total: 12]

4 Alkanes such as methane, CH_4, undergo few chemical reactions. Methane will, however, react with chlorine but not with iodine.

Relevant standard enthalpy changes of formation for the reaction of methane with chlorine to form chloromethane, CH_3Cl, are given below.

	$\Delta H_f^{\ominus}$/kJ mol^{-1}
CH_4	–75
CH_3Cl	–82
HCl	–92

(a) (i) Use the data to calculate $\Delta H_{reaction}^{\ominus}$ for the formation of CH_3Cl.

$$CH_4 + Cl_2 \rightarrow CH_3Cl + HCl$$

(ii) The corresponding reaction with iodine does **not** take place.

Use bond energy data from the *Data Booklet* to calculate a 'theoretical value' for $\Delta H_{reaction}$ for the following equation.

$$CH_4 + I_2 \rightarrow CH_3I + HI$$

(iii) Suggest why this reaction does **not** in fact occur.

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[5]

(b) **(i)** By using equations, describe the mechanism of the reaction between chlorine and methane to form chloromethane, CH_3Cl.

Identify, by name, the separate steps of the overall reaction.

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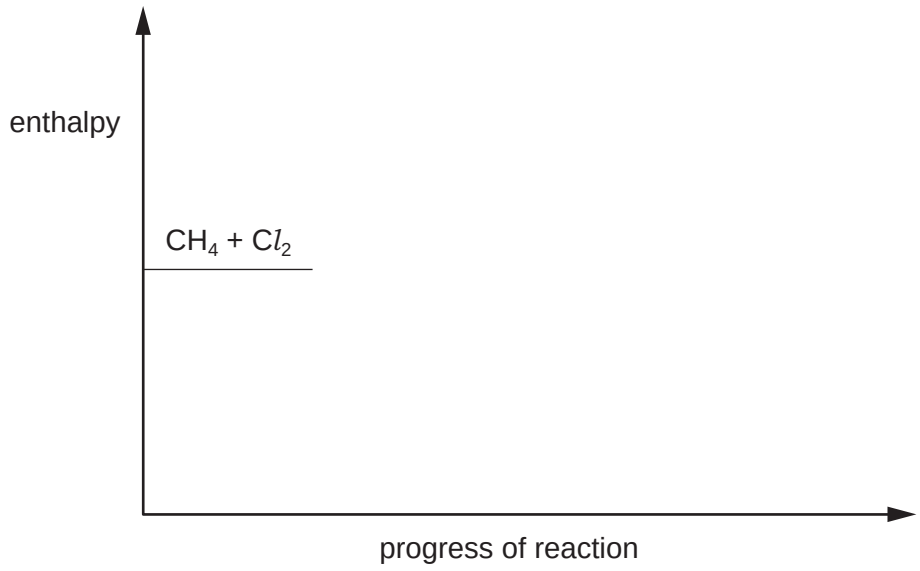
(ii) What is the intermediate organic species in this reaction?

..... [7]

(c) The energy of activation for the formation of CH_3Cl is 16 kJ mol^{-1}.
Use this figure and your answer to **(a)(i)** to complete the reaction pathway diagram below showing the formation of CH_3Cl from CH_4 and Cl_2.
Show clearly the intermediate organic species and the final products.
Indicate on your sketch the relevant enthalpy changes and their values.



[4]

[Total: 16]