# Born-Haber Cycles

## Question Paper 4

| | |
|---|---|
| **Level** | International A Level |
| **Subject** | Chemistry |
| **Exam Board** | CIE |
| **Topic** | Chemical Energetics |
| **Sub-Topic** | Born-Haber Cycles |
| **Paper Type** | Theory |
| **Booklet** | Question Paper 4 |

**Time Allowed:** **66 minutes**

**Score:** **/55**

**Percentage:** **/100**

**Grade Boundaries:**

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

**1** Carbon disulfide,$CS_2$, is a volatile, flammableliquidwhichisproducedinsmall quantities in volcanoes.

**(a)** The sequence of atoms in the $CS_2$ molecule is sulfur to carbon to sulfur.

**(i)** Draw a 'dot-and-cross' diagram of the carbon disulfide molecule.
Show outer electrons only.

**(ii)** Suggest the shape of the molecule and state the bond angle.

shape .....

bond angle .....
[3]

**(b)** Carbon disulfide is readily combusted to give $CO_2$ and $SO_2$.

**(i)** Construct a balanced equation for the complete combustion of $CS_2$.

.....

**(ii)** Define the term *standard enthalpy change of combustion*, $\Delta H_c^{\ominus}$.

.....

.....

.....
[3]

**(c)** Calculate the standard enthalpy change of formation of $CS_2$ from the following data. Include a sign in your answer.

standard enthalpy change of combustion of $CS_2$ = $-1110\,kJ\,mol^{-1}$

standard enthalpy change of formation of $CO_2$ = $-395\,kJ\,mol^{-1}$

standard enthalpy change of formation of $SO_2$ = $-298\,kJ\,mol^{-1}$

[3]

**(d)** Carbon disulfide reacts with nitrogen monoxide, NO, in a 1:2 molar ratio.
A yellow solid and two colourless gases are produced.

**(i)** Construct a balanced equation for the reaction.

.....

**(ii)** What is the change in the oxidation number of sulfur in this reaction?

from ..... to .....

[3]

[Total: 12]

**2** A bromoalkane, R–Br, is hydrolysed by aqueous sodium hydroxide.

**(a)** **(i)** Write a balanced equation for this reaction.

.....

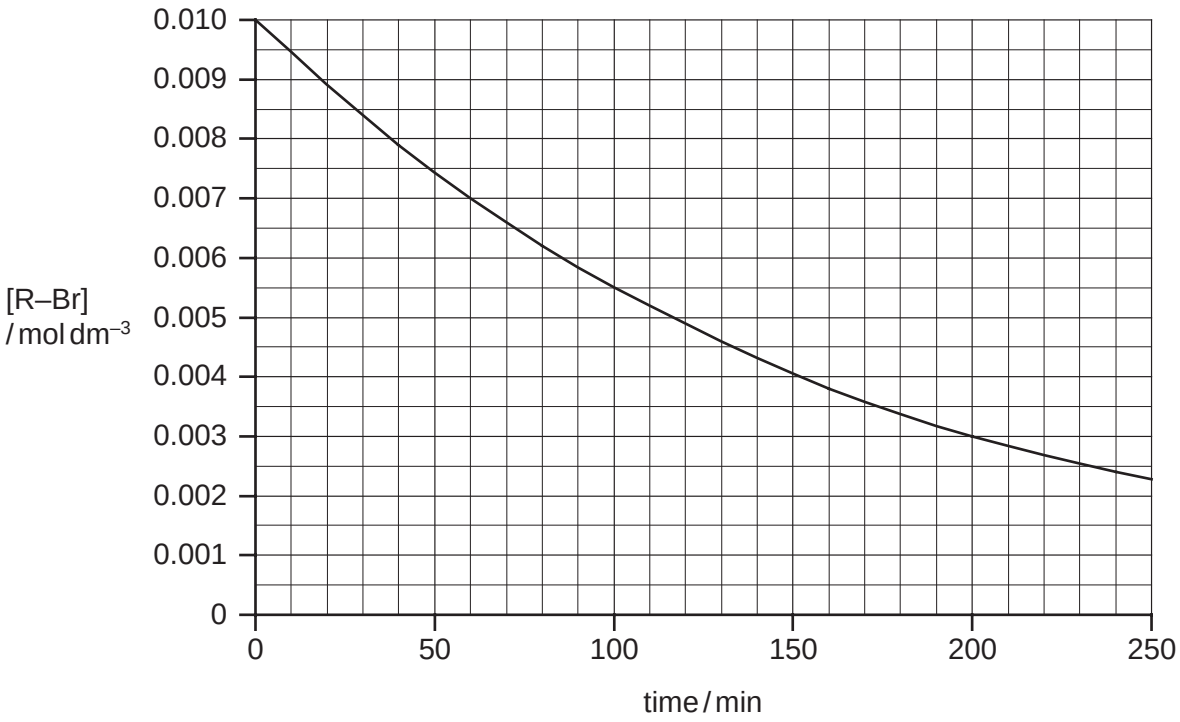
**(ii)** What *type of reaction* is this?

.....

[2]

**(b)** The concentration of bromoalkane was determined at regular time intervals as the reaction progressed.

Two separate experiments were carried out, with different NaOH concentrations.
The graph below shows the results of an experiment using [NaOH] = 0.10 mol dm$^{-3}$.




When the experiment was repeated using [NaOH] = 0.15 mol dm$^{-3}$, the following results were obtained.

| time / min | [R–Br] / mol dm$^{-3}$ |
|---|---|
| 0 | 0.0100 |
| 40 | 0.0070 |
| 80 | 0.0049 |
| 120 | 0.0034 |
| 160 | 0.0024 |
| 200 | 0.0017 |
| 240 | 0.0012 |

**(i)** Plot these data on the axes above, and draw a line of best fit.

**(ii)** Use one of the graphs to confirm that the reaction is first order with respect to R–Br. Show all your working, and show clearly any construction lines you draw.

**(iii)** Use the graphs to calculate the order of reaction with respect to NaOH. Show all your working, and show clearly any construction lines you draw on the graphs.

**(iv)** Write the rate equation for this reaction, and calculate the value of the rate constant.

rate =

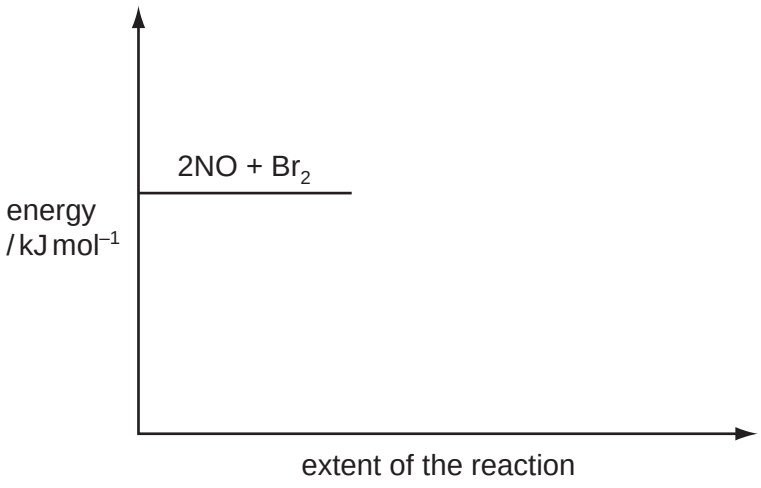
[7]

**(c)** Nitric oxide, NO, and bromine vapour react together according to the following equation.

$$2NO(g) + Br_2(g) \rightarrow 2NOBr(g) \qquad \Delta H = -23\,kJ\,mol^{-1}$$

The reaction has an activation energy of $+5.4\,kJ\,mol^{-1}$.

Use the following axes to sketch a fully-labelled reaction pathway diagram for this reaction.
Include all numerical data on your diagram.




[2]

[Total: 11]

**3** Petrol and diesel fuel are both used in internal combustion engines.
Petrol may be regarded as having the formula $C_9H_{20}$ and diesel fuel as having the formula $C_{14}H_{30}$.

**(a) (i)** To which class of compounds do these two hydrocarbons belong?

.....

**(ii)** Write a balanced equation for the complete combustion of petrol.

.....
[2]

**(b)** When petrol or diesel fuel are used in internal combustion engines, several different products of the incomplete combustion of the fuel may be formed.

**(i)** Name **two** of these products that do not contain hydrogen.

..... and .....

**(ii)** Choose one of these and state a hazard it causes.

product .....

hazard .....

**(iii)** Write a balanced equation for the formation of **one** of the products in **(i)** from diesel fuel.

.....
[4]

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

.....

.....

..... [2]

**(d)** A 1.00 $cm^3$ sample of $C_{14}H_{30}$ was completely burnt in air.
The heat produced raised the temperature of 250 g of water by 34.6 °C.
Assume no heat losses occurred during this experiment.
The density of $C_{14}H_{30}$ is 0.763 g $cm^{-3}$.

**(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 energy produced by the combustion of 1 mol of $C_{14}H_{30}$.

[5]

[Total: 13]

**4** **(a)** Explain what is meant by the term *bond energy*.

.....

.....

[2]

**(b)** Describe and explain the trend in bond energies of the C–X bond in halogenoalkanes, where X = F, C*l*, Br or I.

.....

.....

**(ii)** Describe the relationship between the reactivity of halogenoalkanes, RX, and the bond energies of the C–X bond.

.....

.....

[3]

**(c)** Use the *Data Booklet* to suggest an explanation as to why CFCs such as $CF_2Cl_2$ are much more harmful to the ozone layer than fluorocarbons such as $CF_4$ or hydrocarbons such as butane, $C_4H_{10}$.

.....

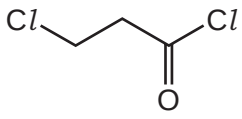
.....

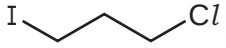
.....

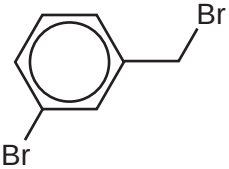
.....

[3]

**(d)** Predict the products of the following reactions and draw their structures in the boxes below. The molecular formula of each product is given, where X = C*l*, Br or I.

$H_2O$ +  → $C_3H_5O_2X$

$H_2O$ +  → $C_3H_7OX$

$H_2O$ +  → $C_7H_7OX$

[3]

**(e)** Ethane reacts with chlorine according to the following equation.

$$C_2H_6 + Cl_2 \rightarrow C_2H_5Cl + HCl$$

**(i)** State the conditions needed for this reaction.

.....

**(ii)** State the *type of reaction* occurring here.

.....

One of the steps during this reaction is the following process.

$$Cl^{\bullet} + CH_3CH_3 \rightarrow HCl + CH_3CH_2^{\bullet}$$

**(iii)** Use the *Data Booklet* to calculate the enthalpy change, $\Delta H$, of this step.

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

**(iv)** Use the *Data Booklet* to calculate the enthalpy change, $\Delta H$, of the similar reaction:

$$I^{\bullet} + CH_3CH_3 \rightarrow HI + CH_3CH_2^{\bullet}$$

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

**(v)** Hence suggest why it is **not** possible to make iodoethane by reacting together iodine and ethane.

.....

**(vi)** Complete the following equations of some possible steps in the formation of chloroethane.

$Cl_2 \rightarrow$ .....

$Cl^{\bullet} + CH_3CH_3 \rightarrow HCl + CH_3CH_2^{\bullet}$

$CH_3CH_2^{\bullet}$ + ..... → ..... + .....

..... + ..... → $CH_3CH_2Cl$

[8]

[Total: 19]