

# Born-Haber Cycles

## Question Paper 2

|                   |                       |
|-------------------|-----------------------|
| <b>Level</b>      | International A Level |
| <b>Subject</b>    | Chemistry             |
| <b>Exam Board</b> | CIE                   |
| <b>Topic</b>      | Chemical Energetics   |
| <b>Sub-Topic</b>  | Born-Haber Cycles     |
| <b>Paper Type</b> | Theory                |
| <b>Booklet</b>    | Question Paper 2      |

**Time Allowed:** 60 minutes

**Score:** /50

**Percentage:** /100

**Grade Boundaries:**

| A*   | A     | B   | C     | D     | E   | U    |
|------|-------|-----|-------|-------|-----|------|
| >85% | 77.5% | 70% | 62.5% | 57.5% | 45% | <45% |

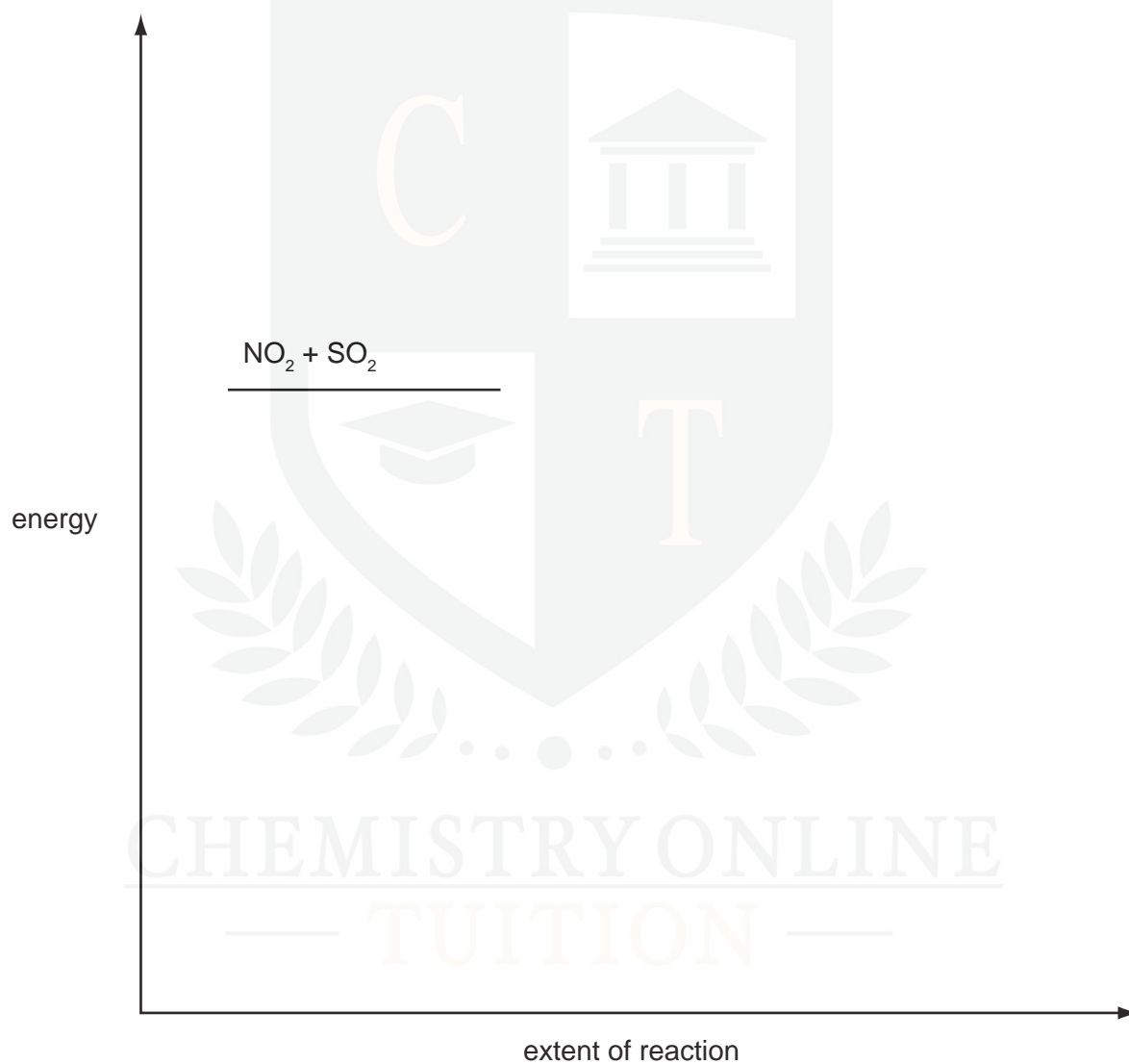


(b) The reaction between  $\text{SO}_2$ ,  $\text{NO}_2$  and  $\text{O}_2$  occurs in two steps.



The activation energy of the first reaction,  $E_{a1}$ , is higher than that of the second reaction,  $E_{a2}$ .

Use the axes below to construct a fully-labelled reaction pathway diagram for this reaction, labelling  $E_{a1}$ ,  $E_{a2}$ ,  $\Delta H_1^\circ$  and  $\Delta H_2^\circ$ .



[2]

[Total: 10]

- 2 The gas ethyne,  $C_2H_2$ , more commonly known as acetylene, is manufactured for use in the synthesis of organic compounds. It is also used, in combination with oxygen, in 'oxy-acetylene' torches for the cutting and welding of metals.

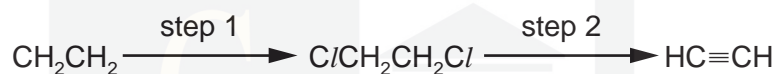
Industrially, ethyne is made from calcium carbide,  $CaC_2$ , or by cracking liquid hydrocarbons.

- (a) When calcium carbide is reacted with water, ethyne and calcium hydroxide are formed.

Construct a balanced equation for this reaction.

.....[1]

Ethyne can also be obtained from ethene by using the following sequence of reactions.



- (b) (i) What types of reaction are step 1 and step 2?

step 1 .....

step 2 .....

- (ii) Suggest what reagent and conditions would be used in a laboratory in step 2.

reagent .....

conditions .....

[5]

When ethyne is passed into water at  $60^\circ C$ , in the presence of a little  $H_2SO_4$  and  $Hg^{2+}$  ions, a pungent, colourless organic liquid, **Q**, with  $M_r$  of 44 is obtained. This is step 3.

When **Q** is warmed with Tollens' reagent in a test-tube, a silver mirror is formed.

On acidification, the solution remaining in the test-tube is found to contain the organic compound **R** which has  $M_r$  of 60. This is step 4.

- (c) (i) Give the structural formulae of **Q** and **R**.



- (ii) What type of reaction is step 3 and step 4?

step 3 .....

step 4 .....

[4]

(d) The standard enthalpy change of combustion of  $C_2H_2$ ,  $\Delta H_c^\ominus$ , is  $-1300 \text{ kJ mol}^{-1}$  at 298 K.

Values of relevant standard enthalpy changes of formation,  $\Delta H_f^\ominus$ , measured at 298 K, are given in the table.

| substance | $\Delta H_f^\ominus / \text{kJ mol}^{-1}$ |
|-----------|---|
| $CO_2(g)$ | -394                                      |
| $H_2O(l)$ | -286                                      |

(i) Write balanced equations, with state symbols, that represent the standard enthalpy change of combustion,  $\Delta H_c^\ominus$ , of  $C_2H_2$ , and

.....

the standard enthalpy change of formation,  $\Delta H_f^\ominus$ , of  $C_2H_2$ .

.....

(ii) Use the data above and your answer to (i) to calculate the standard enthalpy change of formation,  $\Delta H_f^\ominus$ , of  $C_2H_2$ . Show clearly whether the standard enthalpy change of formation of  $C_2H_2$  has a positive or negative value.

CHEMISTRY ONLINE  
— TUITION —

[6]

[Total: 16]

- 3 Taken together, nitrogen and oxygen make up 99% of the air. Oxygen is by far the more reactive of the two gases, and most of the substances that react with air combine with the oxygen rather than with the nitrogen.

(a) State **one** reason why the molecule of nitrogen,  $N_2$ , is so unreactive.

..... [1]

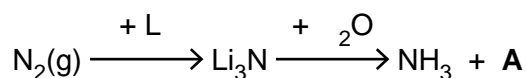
Despite the apparent lack of reactivity of  $N_2$ , nitrogen atoms have been found to form bonds with almost all of the elements in the Periodic Table. Lithium metal reacts with nitrogen gas at room temperature to give lithium nitride,  $Li_3N$ . Magnesium produces magnesium nitride,  $Mg_3N_2$ , as well as magnesium oxide, when heated in air.

(b) Calculate the lattice energy of magnesium nitride using the following data, in addition to relevant data from the *Data Booklet*.

| enthalpy change  | value/ $\text{kJ mol}^{-1}$ |
|--|-----------------------------|
| atomisation of $Mg(s)$   | +148                        |
| total of electron affinities for the change $N(g) \rightarrow N^{3-}(g)$ | +2148                       |
| enthalpy of formation of $Mg_3N_2(s)$                                    | -461                        |

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

- (c) Lithium reacts readily with nitrogen, and because of this  $\text{Li}_3\text{N}$  has been considered as a possible intermediate in the 'fixing' of nitrogen to make ammonia-based fertilisers.



- (i) Construct an equation for the reaction between  $\text{Li}_3\text{N}$  and  $\text{H}_2\text{O}$ , and hence identify compound **A**.

.....

- (ii) Using your knowledge of the Haber process, consider **one** advantage and **one** disadvantage of using lithium as a means of fixing nitrogen, rather than the Haber process.

advantage of the lithium method

.....

disadvantage of the lithium method

.....

[3]

- (d) Another possible advantage of  $\text{Li}_3\text{N}$  is that it contains a large percentage by mass of nitrogen. Another fertiliser that contains a large percentage by mass of nitrogen is urea,  $\text{NH}_2\text{CONH}_2$ .

- (i) Calculate and compare the percentages by mass of nitrogen in  $\text{Li}_3\text{N}$  and  $\text{NH}_2\text{CONH}_2$ .

.....

.....

- (ii) What *class* of organic compound is urea?

.....

- (iii) Write an equation for the production of ammonia by the reaction between urea and water.

.....

- (iv) Urea can be applied directly to the soil either before or during the growing of crops.

What would be a major **disadvantage** of using lithium nitride in this way?

.....

.....

[5]

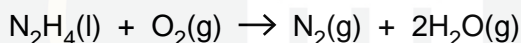
- 4 Hydrazine,  $\text{N}_2\text{H}_4$ , can be used as a rocket fuel and is stored as a liquid. It reacts exothermically with oxygen to give only gaseous products.

The enthalpy change of a reaction such as that between hydrazine and oxygen may be calculated by using standard enthalpy changes of formation.

- (a) Define the term *standard enthalpy change of formation*,  $\Delta H_f^\ominus$ .

.....  
.....  
..... [3]

- (b) Hydrazine reacts with oxygen according to the following equation.



- (i) Use the data in the table to calculate the standard enthalpy change of this reaction.

| compound                         | $\Delta H_f^\ominus/\text{kJ mol}^{-1}$ |
|----------------------------------|---|
| $\text{N}_2\text{H}_4(\text{l})$ | 50.6                                    |
| $\text{H}_2\text{O}(\text{g})$   | -241.8                                  |

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

- (ii) Although the above reaction is highly exothermic, hydrazine does not burn spontaneously in oxygen. Suggest a reason for this.

.....  
.....



- (iii) Suggest why using hydrazine as a rocket fuel could be regarded as being 'environmentally friendly'.

.....  
.....

[4]

- (c) The bonding in hydrazine is similar to that in ammonia.

- (i) Showing outer-shell electrons only, draw a 'dot-and-cross' diagram of an ammonia molecule.

- (ii) Draw a diagram to show the three-dimensional shape of an ammonia molecule.

- (iii) Draw a diagram to show the shape of a hydrazine molecule. Show clearly which atom is joined to which and show clearly the value of **one** bond angle.

CHEMISTRY ONLINE  
— TUITION —

[4]

- (d) Deduce the oxidation state of nitrogen in hydrazine.

.....

[1]

[Total: 12]