Born-Haber Cycles

Question Paper 2

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

Time Allowed: **60 minutes**

Score: **/50**

Percentage: **/100**

Grade Boundaries:

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

1 **(a)** Catalysts can be described as homogeneous or heterogeneous.

(i) What is meant by the terms *homogeneous* and *heterogeneous*?

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(ii) By using iron and its compounds as examples, outline the different modes of action of homogeneous and heterogeneous catalysis.
Choose **one** example of each type, and for **each** example you should

- state what the catalyst is, and whether it is acting as a homogeneous or a heterogeneous catalyst,
- write a balanced equation for the reaction,
- outline how the catalyst you have chosen works to decrease the activation energy.

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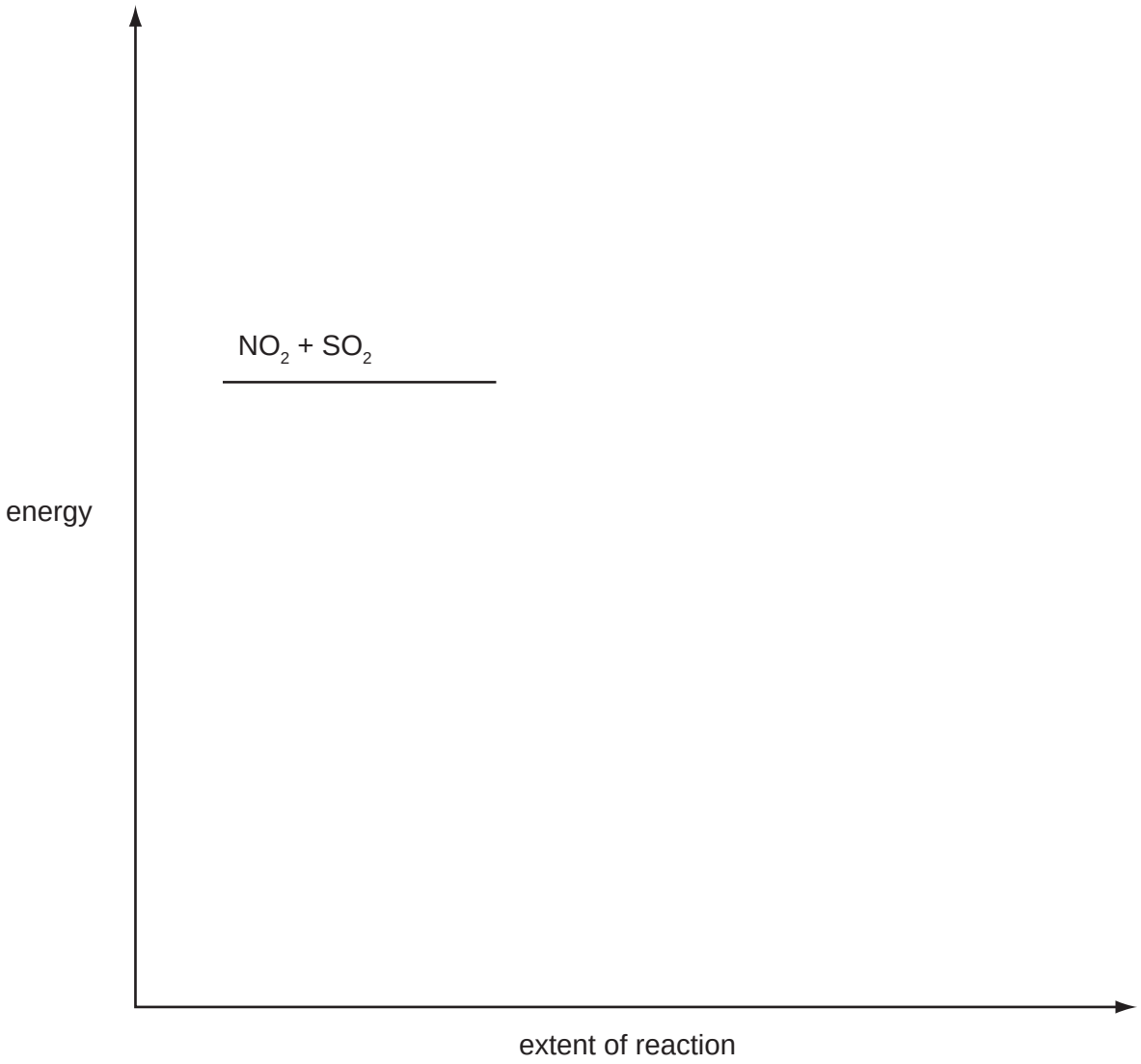
[8]

(b) The reaction between SO_2, NO_2 and O_2 occurs in two steps.

$$NO_2 + SO_2 \rightarrow NO + SO_3 \qquad \Delta H_1^{\ominus} = -88\,kJ\,mol^{-1}$$
$$NO + \tfrac{1}{2}O_2 \rightarrow NO_2 \qquad \Delta H_2^{\ominus} = -57\,kJ\,mol^{-1}$$

The activation energy of the first reaction, E_{a_1}, is higher than that of the second reaction, E_{a_2}.

Use the axes below to construct a fully-labelled reaction pathway diagram for this reaction, labelling E_{a_1}, E_{a_2}, $\Delta H_1^{\ominus}$ and $\Delta H_2^{\ominus}$.



[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.

$$CH_2CH_2 \xrightarrow{\text{step 1}} ClCH_2CH_2Cl \xrightarrow{\text{step 2}} HC{\equiv}CH$$

(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.

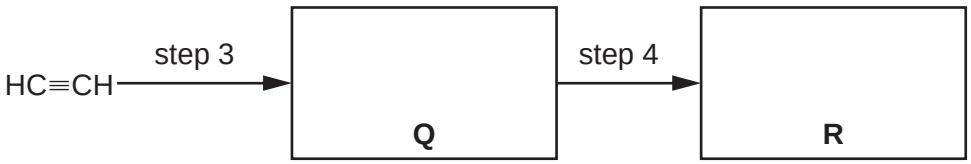
reagent .....

conditions ..... [5]

When ethyne is passed into water at 60 °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 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	$\Delta H_f^{\ominus}$ / 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

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

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(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.

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

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

(c) Lithium reacts readily with nitrogen, and because of this Li_3N has been considered as a possible intermediate in the 'fixing' of nitrogen to make ammonia-based fertilisers.

$$N_2(g) \xrightarrow{+\ L} Li_3N \xrightarrow{+\ {}_2O} NH_3 + \mathbf{A}$$

(i) Construct an equation for the reaction between Li_3N and H_2O, and hence identify compound **A**.

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(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

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[3]

(d) Another possible advantage of Li_3N is that it contains a large percentage by mass of nitrogen. Another fertiliser that contains a large percentage by mass of nitrogen is urea, NH_2CONH_2.

(i) Calculate and compare the percentages by mass of nitrogen in Li_3N and NH_2CONH_2.

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

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

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(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?

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[5]

[Total: 12]

4 Hydrazine, N_2H_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*, $\Delta H_f^{\ominus}$.

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..... [3]

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

$$N_2H_4(l) + O_2(g) \rightarrow N_2(g) + 2H_2O(g)$$

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

compound	$\Delta H_f^{\ominus}$/kJ mol^{-1}
$N_2H_4(l)$	50.6
$H_2O(g)$	–241.8

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

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

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

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[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.

[4]

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

..... [1]

[Total: 12]