Born-Haber Cycles

Question Paper 1

Level	International A Level
Subject	Chemistry
Exam Board	CIE
Topic	Chemical Energetics
Sub-Topic	Born-Haber Cycles
Paper Type	Theory
Booklet	Question Paper 1

Time Allowed: **63 minutes**

Score: **/52**

Percentage: **/100**

Grade Boundaries:

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

1 Ammonium nitrate fertiliser is manufactured from ammonia. The first reaction in the manufacture of the fertiliser is the catalytic oxidation of ammonia to form nitrogen monoxide, NO. This is carried out at about 1×10^3 kPa (10 atmospheres) pressure and a temperature of 700 to 850 °C.

$$4NH_3(g) + 5O_2(g) \rightleftharpoons 4NO(g) + 6H_2O(g) \qquad \Delta H^{\ominus} = -906\ kJ\ mol^{-1}$$

(a) Write the expression for the equilibrium constant, K_p, stating the units.

K_p =

units ..... [2]

(b) What will be the effect on the yield of NO of **each** of the following?
In each case, explain your answer.

(i) increasing the temperature

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(ii) decreasing the applied pressure

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[4]

(c) The standard enthalpy changes of formation of $NH_3(g)$ and $H_2O(g)$ are as follows.

$NH_3(g)$, $\Delta H_f^\ominus = -46.0\,kJ\,mol^{-1}$ $H_2O(g)$, $\Delta H_f^\ominus = -242\,kJ\,mol^{-1}$

Use these data and the value of $\Delta H^\ominus_{reaction}$ given below to calculate the standard enthalpy change of formation of NO(g).
Include a sign in your answer.

$4NH_3(g) + 5O_2(g) \rightleftharpoons 4NO(g) + 6H_2O(g)$ $\Delta H^\ominus = -906\,kJ\,mol^{-1}$

[4]

[Total: 10]

2 Methanol, CH_3OH, is considered to be a possible alternative to fossil fuels, particularly for use in vehicles.

Methanol can be produced from fossil fuels and from agricultural waste. It can also be synthesised from carbon dioxide and hydrogen.

(a) Define, with the aid of an equation which includes state symbols, the standard enthalpy change of formation of carbon dioxide.

equation .....

definition .....

.....

..... [3]

(b) Relevant $\Delta H_f^\ominus$ values for the reaction that synthesises methanol are given in th

compound	$\Delta H_f^\ominus$ / kJ mol^{-1}
$CO_2(g)$	–394
$CH_3OH(g)$	–201
$H_2O(g)$	–242

(i) Use these values to calculate $\Delta H_{reaction}^\ominus$ fo

Include a sign in your answer.

$$CO_2(g) + 3H_2(g) \rightleftharpoons CH_3OH(g) + H_2O(g)$$

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

(ii) Suggest **one** possible environmental advantage of this reaction. Explain your answer.

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.....

[5]

(c) The synthesis of methanol is carried out at about 500 K with a pressure of between 40 and 100 atmospheres (between 4×10^6 Pa and 10×10^7 Pa) and using a catalyst. The use of such conditions will affect both the rate of reaction and the equilibrium yield.

In the spaces below, explain the effects of higher temperature, higher pressure, and the use of a catalyst on the **equilibrium yield** of methanol.

higher temperature

effect .....

explanation .....

.....

higher pressure

effect .....

explanation .....

.....

use of catalyst

effect .....

explanation .....

.....

[6]

[Total: 14]

3 With the prospect that fossil fuels will become increasingly scarce in the future, many compounds are being considered for use in internal combustion engines. One of these is DME or dimethyl ether, CH_3OCH_3. DME is a gas which can be synthesised from methanol. Methanol can be obtained from biomass, such as plant waste from agriculture.

(a) Define, with the aid of an equation which includes state symbols, the standard enthalpy change of combustion, $\Delta H_c^{\ominus}$, for DME at 298 K.

equation .....

definition .....

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..... [3]

(b) DME may be synthesised from methanol. Relevant enthalpy changes of formation, $\Delta H_f^{\ominus}$ for this reaction are given in the table below.

compound	$\Delta H_f^{\ominus}$ / kJ mol^{-1}
$CH_3OH(l)$	–239
$CH_3OCH_3(g)$	–184
$H_2O(l)$	–286

Use these values to calculate $\Delta H_{reaction}^{\ominus}$ for the synthesis of DME, using the following equation. Include a sign in your answer.

$$2CH_3OH(l) \rightarrow CH_3OCH_3(g) + H_2O(l)$$

$\Delta H_{reaction}^{\ominus}$ = ... kJ mol^{-1}
[3]

(c) DME and ethanol are isomers with the molecular formula C_2H_6O.

(i) Draw the displayed formula of DME and of ethanol.

DME	ethanol

(ii) What type of isomerism do DME and ethanol show?

.....

[2]

(d) DME is a gas at room temperature while ethanol is a liquid.

(i) Which intermolecular force exists between ethanol molecules, which causes ethanol to be a liquid at room temperature?

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(ii) Draw a diagram that clearly shows this intermolecular force.
Your diagram should show any lone pairs or dipoles present that you consider to be important. You should represent at least two molecules in your diagram.

[4]

[Total: 12]

4 **(a)** **(i)** What is meant by the term *enthalpy change of hydration*, $\Delta H^{\ominus}_{hyd}$?

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(ii) Write an equation that represents the $\Delta H^{\ominus}_{hyd}$ of the Mg^{2+} ion.

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(iii) Suggest a reason why $\Delta H^{\ominus}_{hyd}$ of the Mg^{2+} ion is greater than $\Delta H^{\ominus}_{hyd}$ of the Ca^{2+} ion.

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(iv) Suggest why it is impossible to determine the enthalpy change of hydration of the oxide ion, O^{2-}.

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[5]

(b) The enthalpy change of solution for $MgCl_2$, $\Delta H^{\ominus}_{sol}(MgCl_2(s))$, is represented by the following equation.

$$MgCl_2(s) + aq \rightarrow Mg^{2+}(aq) + 2Cl^{-}(aq)$$

Describe the simple apparatus you could use, and the measurements you would make, in order to determine a value for $\Delta H^{\ominus}_{sol}(MgCl_2(s))$ in the laboratory.

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..... [4]

(c) The table below lists data relevant to the formation of $MgCl_2(aq)$.

enthalpy change	value / kJ mol^{-1}
$\Delta H_f^{\ominus}(MgCl_2(s))$	–641
$\Delta H_f^{\ominus}(MgCl_2(aq))$	–801
lattice energy of $MgCl_2(s)$	–2526
$\Delta H_{hyd}^{\ominus}(Mg^{2+}(g))$	–1890

By constructing relevant thermochemical cycles, use the above data to calculate a value for

(i) $\Delta H_{sol}^{\ominus}(MgCl_2(s))$,

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

(ii) $\Delta H_{hyd}^{\ominus}(Cl^-(g))$.

$\Delta H_{hyd}^{\ominus}$ = ... kJ mol^{-1}
[3]

(d) Describe and explain how the solubility of magnesium sulfate compares to that of barium sulfate.

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..... [4]

[Total: 16]