Equilibria

Question Paper 9

Level	International A Level
Subject	Chemistry
Exam Board	CIE
Topic	Equilibria
Sub-Topic	
Paper Type	Theory
Booklet	Question Paper 9

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 Each of the Group VII elements chlorine, bromine and iodine forms a hydride.

(a) Outline how the relative thermal stabilities of these hydrides change from HC*l* to HI.

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(ii) Explain the variation you have outlined in **(i)**.

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[3]

Hydrogen iodide can be made by heating together hydrogen gas and iodine vapour. The reaction is incomplete.

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$$

(b) Write an expression for K_c and state the units.

K_c = ... units ..... [2]

(c) For this equilibrium, the numerical value of the equilibrium constant K_c is 140 at 500 K and 59 at 650 K.

Use this information to state and explain the effect of the following changes on the equilibrium position.

(i) increasing the pressure applied to the equilibrium

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(ii) decreasing the temperature of the equilibrium

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[4]

(d) A mixture of 0.02 mol of hydrogen and 0.02 mol of iodine was placed in a 1 dm^3 flask and allowed to come to equilibrium at 650 K.

Calculate the amount, in moles, of each substance present in the equilibrium mixture at 650 K.

	$H_2(g)$	$I_2(g)$	$\rightleftharpoons$	$2HI(g)$
initial moles	0.02	0.02		0

[4]

[Total: 13]

2 Hydrogen is the most abundant element in the Universe, although on Earth only very small quantities of molecular hydrogen have been found to occur naturally.

Hydrogen is manufactured on a large scale for use in the chemical industry and is also regarded as a possible fuel to replace fossil fuels in internal combustion engines.

(a) State **one** large scale use of hydrogen in the chemical industry.

..... [1]

One common way of producing hydrogen on a large scale for use in the chemical industry is by the steam 'reforming' of methane (natural gas), in which steam and methane are passed over a catalyst at 1000–1400 K to produce carbon monoxide and hydrogen.

$$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g) \qquad \Delta H = +206\,kJ\,mol^{-1}$$

(b) Use the information above to state and explain the effect on the equilibrium position of the following changes.

(i) increasing the pressure applied to the equilibrium

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(ii) decreasing the temperature of the equilibrium

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[4]

(c) What will be the effect on the rate of the reaction of increasing the pressure at which it is carried out? Explain your answer.

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..... [2]

(d) Further hydrogen can be obtained by the 'water-gas shift' reaction in which the carbon monoxide produced is reacted with steam.

$$CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g) \qquad K_c = 6.40 \times 10^{-1} \text{ at } 1100\,K$$

A mixture containing 0.40 mol of CO, 0.40 mol of H_2O, 0.20 mol of CO_2 and 0.20 mol of H_2 was placed in a 1 dm^3 flask and allowed to come to equilibrium at 1100 K

(i) Give an expression for K_c for this reaction.

(ii) Calculate the amount, in moles, of each substance present in the equilibrium mixture at 1100 K.

	$CO(g)$	+	$H_2O(g)$	$\rightleftharpoons$	$CO_2(g)$	+	$H_2(g)$
initial moles	0.40		0.40				

[5]

[Total: 12]

3 Crude oil contains a mixture of hydrocarbons together with other organic compounds which may contain nitrogen, oxygen or sulfur in their molecules.

At an oil refinery, after the fractional distillation of crude oil, a number of other processes may be used including 'cracking', 'isomerisation', and 'reforming'.

(a) (i) What is meant by the term '*cracking*' and why is it carried out?

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(ii) Outline briefly how the cracking of hydrocarbons would be carried out.

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(iii) Construct a balanced equation for the formation of heptane, C_7H_{16}, by cracking tetradecane, $C_{14}H_{30}$.

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[4]

One of the sulfur-containing compounds present in crude oil is ethanethiol, C_2H_5SH, the sulfur-containing equivalent of ethanol. Ethanethiol is toxic and is regarded as one of the smelliest compounds in existence.

(b) The boiling point of ethanol, C_2H_5OH, is higher than that of C_2H_5SH.
Suggest a reason for this difference.

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..... [1]

When ethanethiol is burned in an excess of air, three oxides of different elements are formed.

(c) (i) Construct a balanced equation for this reaction.

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(ii) **Two** of the oxides formed cause serious environmental damage.

For **each** of these oxides, identify the type of pollution caused and describe one consequence of this pollution.

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[6]

(d) A small amount of ethanethiol is added to liquefied gases such as butane that are widely used in portable cooking stoves.

Suggest a reason for this.

.....[1]

Sulfur-containing compounds are removed from oil products at the refinery. The sulfur is recovered and converted into SO_2, which is then used in the Contact process.

(e) State the main operating details of the formation of SO_3 in the Contact process.

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.....[3]

[Total: 15]

4 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]