OCR
Oxford Cambridge and RSA

A Level Chemistry B (Salters)

H433/01 Fundamentals of chemistry

Question Set 21

1 **(a)** Plants need nitrogen to synthesise proteins, but most plants cannot use atmospheric nitrogen. Ammonium nitrate is often used as a fertiliser as it contains nitrogen in a form that plants can absorb.

The first step in the process of making ammonium nitrate is the synthesis of ammonia fromatmospheric nitrogen.
This synthesis reaction has a very high activation enthalpy.
Explain this in terms of the bonding in nitrogen. **[1]**

(b) **(i)** The hydrogen needed to manufacture ammonia can be produced from steam and methaneas shown in **equation 36.1** below.

$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g) \quad \Delta H = +206\,kJ\,mol^{-1}$ **Equation 36.1**

Use the entropy values in the table below to calculate $\Delta_{sys}S$ for the forward reaction in **equation 36.1**

Substance	Entropy S / J K^{-1} mol^{-1}
$CH_4(g)$	186.2
$H_2O(g)$	189.0
$CO(g)$	197.6
$H_2(g)$	130.6

$\Delta_{sys}S =$ J K^{-1} mol^{-1} **[1]**

(b) **(ii)** Explain how the sign of your answer to **(i)** is predicted by **equation 36.1**. **[1]**

(c) Calculate the minimum temperature required for the forward reaction in **equation 36.1** to befeasible.

Give your answer to an **appropriate** number of significant figures.

Temperature = K **[2]**

(d) $CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g) \quad \Delta H = +206\,kJ\,mol^{-1}$ **Equation 36.1**

Another source of hydrogen is from the reaction shown in **equation 36.2**.

$CH_4(g) + CO_2(g) \rightleftharpoons 2CO(g) + 2H_2(g) \quad \Delta H = +247\,kJ\,mol^{-1}$ **Equation 36.2**

This is claimed to be a much greener process than that in **equation 36.1**.

Comment on the validity of this statement, considering:

- the raw materials used
- the operating conditions
- the mole ratios. **[3]**

(e) The Haber process for the manufacture of ammonia is shown in **equation 36.3**.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \quad \Delta H = -92\,kJ\,mol^{-1} \qquad \textbf{Equation 36.3}$$

At a certain temperature, a mixture of nitrogen and hydrogen was allowed to reach equilibrium in a container of fixed volume. Chemists found the concentrations shown in the table.

Substance	Concentration at the start / mol dm^{-3}	Concentration at equilibrium / mol dm^{-3}
N_2	1.00	0.90
H_2	1.00	
NH_3	0.00	

Calculate the equilibrium concentrations of H_2 and NH_3.
Use these values to calculate a value for K_c at the temperature of the experiment and give the units.

K_c = ... units …….. **[3]**

(f) **(i)** In order to make the ammonium nitrate fertiliser, some of the ammonia is oxidised to nitric acid in several stages shown by **equations 36.4–36.6**.

$$\text{.....}NH_3 + \text{.....}O_2 \rightarrow \text{.....}NO + \text{.....}H_2O \qquad \textbf{Equation 36.4}$$

$$2NO + O_2 \rightarrow 2NO_2 \qquad \textbf{Equation 36.5}$$

$$4NO_2 + O_2 + 2H_2O \rightarrow 4HNO_3 \qquad \textbf{Equation 36.6}$$

The nitric acid formed is reacted with more ammonia.

$$NH_3 + HNO_3 \rightarrow NH_4NO_3 \qquad \textbf{Equation 36.7}$$

Use oxidation states or some other method to balance **equation 36.4**. **[1]**

(f) **(ii)** The overall yield of the reactions **in equations 36.4 – 36.6** is 77%.
The yield of ammonium nitrate in **equation 36.7** can be taken as 100%.

What mass (in tonnes) of ammonia is needed to make 25 tonnes of ammonium nitrate?

mass of ammonia needed = tonnes **[4]**

(f) **(iii)** Describe a test that would identify nitrate ions. **[2]**

Total Marks for Question Set 21: 18