Pages 284–285 Exam practice questions

1 a) $CO_2(g) + aq \rightleftharpoons CO_2(aq)$ [1]

b) At equilibrium, CO_2 molecules are constantly leaving the solution and entering the gas phase. They are also leaving the gas phase and passing into solution. [1]

The two processes happen at the same rate and so overall cancel each other out. [1]

c) Reducing the pressure on the gas slows the rate of dissolution but does not affect the rate that gas molecules leave the solution and enter the gas phase. [1]

The net effect is that overall gas bubbles out of solution. [1]

d) Adding an alkali neutralises the hydrogen ions and removes them from the equilibrium. [1]

As a result the equilibrium shifts to the right and more carbon dioxide dissolves. [1]

2 a) In the lungs the oxygen concentration is relatively high. [1] This pushes this equilibrium over to the oxygenated Hb side. [1]

b) Around muscle cells the oxygen concentration is relatively low. [1]

This means that the equilibrium shifts over to the deoxygenated Hb side. [1]

c) The carbon dioxide concentration is higher where cells are respiring and releasing carbon dioxide into the blood. [1]

This helps the Hb to release oxygen to the respiring cells that need it. [1]

3 a) i) The reaction makes no difference the amount of gas in moles [1], so this change is not affected by raising the pressure. [1]

ii) The reaction is slightly exothermic. Raising the temperature tends to reduce the formation of HI. [1]

b) i) There is a slight decrease in volume when salt dissolves in water so raising the pressure tends to favour the solution side of the equilibrium. [1]

ii) It is an endothermic process. [1] Raising the temperature tends to increase the solubility of the salt. [1]

c) i) The change from graphite to diamond leads to a reduction of volume. [1] This is favoured by high pressure. [1]

ii) The formation of diamond from graphite is endothermic [1] so it is favoured by high temperatures. [1]

4 a) $I_2(s) + aq \rightleftharpoons I_2(aq)$

This equilibrium is well over to the left-hand side. [1] However in KI(aq) the iodide ions react with iodine to form I_3^- ions. [1] This removes free aqueous iodine molecules from the above equilibrium, which favours the forward reaction, and so more iodine dissolves. [1]

b) The dark yellow-brown colour is caused by the presence of the tri-iodide ions. [1]

$I_2(aq) + I^-(aq) \rightleftharpoons I_3^-(aq)$

Thiosulfate ions react with iodine molecules, removing them from the above equilibrium. [1]

$2S_2O_3^{2-}(aq) + I_2(aq) \rightleftharpoons S_4O_6^{2-}(aq) + 2I^-(aq)$

The equilibrium shifts to the left so the concentration of tri-iodide ions falls. [1] In dilute solution the tri-iodide ion is pale yellow. [1] If sufficient thiosulfate is added, the $I_3^-(aq)$ concentration is so low that the solution becomes colourless. [1]

5 a) $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$ [1]

b) Adding an excess of oxygen gas [1] to the reaction mixture tends to push the equilibrium to the right and favour the conversion of SO_3 to SO_2. [1]

The reaction from left to right reduces the amount of gas in moles, [1] so this change is favoured by raising the pressure. [1]

The reaction is highly exothermic. [1] Lowering the temperature tends to increase the proportion of SO_2 converted to SO_3 at equilibrium. [1]

c) There is a limited flow rate of gases through the reactor. [1] Adding more air to give an excess of oxygen means that less of the gas mixture flowing through the reactor in a given time is sulfur dioxide. [1] This increases the percentage of SO_2 converted to SO_3 but reduces the amount of SO_3 formed in a given time. [1]

d) This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully sustained line of reasoning. Assess the quality of the answer taking into account both the key points made (*up to 4 marks*) and the logic and coherence of the discussion (*up to 2 marks*).

Points to make in the answer:

- The chosen temperature is a compromise.
- It must be as low as possible …
- … but high enough for the catalyst to be active and…
- … for the product to form quickly enough.
- The percentage conversion of SO_2 to SO_3 in this process is sufficiently high at atmospheric pressure …
- … so that the cost of operating the plant at a higher pressure is not justified.

6 a) $H_2(g) + Cl_2(g) \rightleftharpoons 2HCl(g)$ [1]

$K_c = \frac{[HCl(g)]^2}{[H_2(g)][Cl_2(g)]}$ numerator [1], denominator [1]

b) $4NH_3(g) + 5O_2(g) \rightleftharpoons 4NO(g) + 6H_2O(g)$ [1]

$K_c = \frac{[NO(g)]^4[H_2O(g)]^6}{[NH_3(g)]^4[O_2(g)]^5}$ numerator [1], denominator [1]

c) $NH_4HS(s) \rightleftharpoons NH_3(g) + H_2S(g)$ [1]

$K_c = [NH_3(g)][H_2S(g)]$ numerator [1], no denominator [1]

7 **a)** $CH_4(g) + H_2O(g) \rightleftharpoons 3H_2(g) + CO(g)$ [1]

The reaction is endothermic. [1] The amount of gas in moles increases from left to right. [1] Formation of products is favoured by: high temperatures [1], low pressures [1] and an excess of steam. [1]

b) **i)** $CO(g) + H_2O(g) \rightleftharpoons H_2(g) + CO_2(g)$ [1]

$$K_c = \frac{[H_2(g)][CO_2(g)]}{[H_2(g)][CO(g)]}$$ numerator [1], denominator [1]

ii) At the higher temperature the value of K_c is smaller. This means that as the temperature rises the proportion of products at equilibrium decreases. [1] Le Chatelier predicts that raising the temperature shifts the equilibrium of an exothermic reaction to the left. [1] The reaction is exothermic. [1]

iii) The temperature has to be high enough for the catalyst to be active [1] and the reaction to proceed fast enough. [1]

c) Zeolites are crystalline materials with channels through which small molecules (hydrogen) and pass freely [1] while larger molecules (carbon dioxide) are trapped. [1]

d) Carbon dioxide is a greenhouse gas [1] and so processes are designed to minimise its release into the atmosphere. [1] The carbon dioxide captured can be useful. [1] (For example: in systems to extinguish fires; in the solid state as a coolant in mobile refrigeration systems; to control pH levels in paper making and water treatment; and as a gas under pressure to increase the recovery of oil from oil wells.)

e) Hydrogen is used on a large scale to manufacture ammonia and methanol. It is used in oil refining (for example to remove sulfur). The gas is also been used on a small scale in fuel cells. (Any two for [2])