Worksheet 6.3: Solutions
The Haber process

No.	Answer
1	$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$; $\Delta H = -92.3$ kJ
2	Steam and methane are heated with air to high temperatures (between 700°C and 1100°C) and pressures (25–35 atm) in the presence of a nickel catalyst to produce carbon monoxide and hydrogen gas. The carbon monoxide formed is then reacted with more steam to produce carbon dioxide and more hydrogen gas: $CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g)$ $CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g)$ The carbon dioxide gas is absorbed by a suitable base, leaving a mixture of hydrogen and nitrogen (from the air) in the mole ratio 3:1.
3	Increased pressure, increased temperature, use of a catalyst and increased concentration of reactants would all increase its rate.
4	Increased pressure, decreased temperature, increased concentration of reactants and decreased concentration of product would increase its yield.
5	There is a temperature conflict. It is resolved by using a 'compromise' temperature of 450°C, which allows a satisfactory rate of reaction without compromising the yield too much. A catalyst is also used.
6	**a** Porous iron pellets with Al_2O_3 and KOH are used the catalyst. **b** It is a heterogeneous catalyst – the catalyst is solid but the reactants are gaseous.
7	They lower the activation energy by providing an alternative reaction pathway.
8	A similar profile to the one shown in Figure 6.6 on page 159 of the textbook.
9	**a** $n(N_2) = \frac{m}{M} = \frac{300\,000}{28.02} = 1.071 \times 10^4$ mol $n(NH_3) = 2 \times n(N_2) = 1.071 \times 10^4 \times 2 = 2.142 \times 10^4$ mol $m(NH_3) = n \times M = 2.142 \times 10^4 \times 17.034 = 3.65 \times 10^5$ g **b** $n(NH_3) = \frac{m}{M} = \frac{5.68 \times 10^6}{17.034} = 3.335 \text{ x } 10^5$ mol $n(N_2) = ½ \times n(NH_3) = ½ \times 3.335 \times 10^5 = 1.668 \times 10^5$ mol $m(N_2) = 1.668 \times 10^5 \times 28.02 = 4.67 \times 10^6$ g
10	Oxidation number of N in N_2 is 0, while in NH_3 it is –3. A decrease in oxidation number is reduction.
11	See Figure 6.26 on page 188 of the textbook.