

Exercise 3.2

Hess's Law

- a) $c = b - a$
b) The enthalpy change of a chemical reaction is the same irrespective of the number of steps required to achieve that change.
- $\Delta H = -2249 \text{ kJ mol}^{-1}$
- $\Delta H = +682 \text{ kJ mol}^{-1}$
- $\Delta H = -39.2 \text{ kJ mol}^{-1}$
- $\Delta H = -286 \text{ kJ mol}^{-1}$
- $\Delta H = -132 \text{ kJ mol}^{-1}$
- $\Delta H = -91 \text{ kJ mol}^{-1}$
- $\Delta H = -316 \text{ kJ mol}^{-1}$
- $\Delta H = -86 \text{ kJ mol}^{-1}$
- $\Delta H = -160 \text{ kJ mol}^{-1}$
- $\Delta H = -2881 \text{ kJ mol}^{-1}$
- $\Delta H = -275 \text{ kJ mol}^{-1}$
- $\Delta H = +53 \text{ kJ mol}^{-1}$
- $\Delta H = -2051 \text{ kJ mol}^{-1}$

Exercise 3.3

Equilibrium

- a) Equilibrium will move to the right.
b) Equilibrium will move to the right.
- a) The brown colour will fade.
b) The brown colour will become more intense.
c) The brown colour will become more intense.
d) No visible change.
- a) The equilibrium will move to the right.
b) The equilibrium will move to the left.
c) The equilibrium will move to the left.

- a) The brown colour will fade and become more yellow because the equilibrium will move in its exothermic direction.
b) The brown colour will fade and become more yellow because the equilibrium will move in the direction which produces a smaller number of molecules.
- a) The forward reaction is endothermic.
b) The equilibrium will move to the left if the pressure is increased. The formation of methane and steam reduces the number of molecules in the equilibrium mixture, which will oppose the applied increase in pressure.
c) i) The rate of formation of synthesis gas will increase.
ii) The composition of the equilibrium mixture will be unchanged.
- a) i) The equilibrium will move to oppose the decrease in temperature so the reaction proceeds in its exothermic direction.
ii) If the pressure is increased, the equilibrium will move to oppose the change and reduce the overall number of molecules, i.e. will move in its forward direction.
b) i) If the temperature is reduced below 300°C , the reaction will be too slow to be economical.
ii) The use of pressures greater than 70 atmospheres will require much more expensive plant and pumping equipment. The improvement in yield would not justify the additional capital cost.
- a) The equilibrium will move to the left.
b) The equilibrium will move to the right.
c) The equilibrium will move to the right.
- a) Reaction (1) ii) *no effect*
Reaction (2) iii) *→ right*
Reaction (3) i) *left*
Reaction (4) i) *left*
b) The equilibrium will move to the left.

9. a) hydrogen chloride
 b) The increase in concentration of hydrogen chloride drives the equilibrium to the left and reduces the concentration of magnesium oxide which would form.
10. a) High pressure will cause the equilibrium in reaction **A** to move to the right, but the equilibrium would move to the left in reaction **B**.
 b) Since each reaction is exothermic, high temperatures will move the equilibria to the left, decreasing the yield. The higher temperature for reaction **B** is consistent with the need to reach equilibrium quickly but is not favourable in terms of yield.
11. a) Bleaching efficiency would be reduced.
 b) Bleaching efficiency would be reduced.
 c) no effect
 d) Bleaching efficiency would be increased.
12. a) At equilibrium, equal numbers of iodine molecules move from the KI solution through the interface into the chloroform as move in the opposite direction.
 b) When more chloroform is added, the iodine solution is diluted. The number of molecules of iodine passing through the interface from the chloroform to the KI solution is reduced. There will be a net transfer of iodine molecules from the KI solution into the chloroform until equilibrium is re-established.
13. a) The addition of dilute sulphuric acid would move the equilibrium to the left and more calcium sulphate would precipitate out.
 b) Addition of barium chloride would cause the sulphate ion to precipitate out as barium sulphate. The equilibrium would move to the right and more calcium sulphate would dissolve.
14. *a) Increasing temperature would cause both processes to move in their endothermic direction to oppose the applied change. The equilibria would both move to the ~~left~~ right.
 b) At atmospheric pressure the equilibrium position of the Contact process is sufficiently far to the right to make the process economical. Increasing the pressure would increase capital costs by more than is commercially justified.
 In the Haber process, the yield of ammonia at atmospheric pressure is very low and the increased yield at 200 atmospheres justifies the additional capital cost.
- c) Increasing the pressure beyond 200 atmospheres in the Haber process will increase the yield of ammonia. There will be increased capital cost involved in using heavier walled pressure vessels and pumping machinery which will make the higher pressure process less economical.
15. a) The use of higher pressure will move the equilibrium to the right and increase the yield of methanol.
 b) i) exothermic
 ii) Since the yield is lower at 500 °C than at 300 °C the equilibrium has moved to the left at higher temperatures. The reaction must therefore be endothermic in the direction which decreases the yield.
16. a) The colour would intensify since the addition of $H^+(aq)$ will drive the equilibrium to the left.
 b) Silver nitrate will remove $Br^-(aq)$ from the equilibrium mixture as $AgBr(s)$. The equilibrium will move to the right and the brown colour will decrease in intensity.
17. a) 600 atmospheres, 200 °C
 b) i) Since the number of molecules on the left hand side of the equation is greater than the number of molecules on the right, increase of pressure will drive the equilibrium to the right and give higher yields.
 ii) The reaction is exothermic in the forward direction. Increase in temperature will cause the equilibrium to move in its endothermic direction and decrease the yield.
 c) A temperature of 400 °C is the best compromise to obtain adequate yield and a fast enough reaction. 200 atmospheres pressure is used since it is not commercially justified to incur increased capital costs in installing plant designed to operate at higher pressures.