1. Sulphur dioxide and oxygen were mixed in a 2:1 mol ratio and sealed in a flask with a catalyst. The following equilibrium was established at temperature *T*

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad \Delta H^{\ominus} = -196\,kJ\,mol^{-1}$$

The partial pressure of sulphur dioxide in the equilibrium mixture was 24 kPa and the total pressure in the flask was 104 kPa.

(a) Deduce the partial pressure of oxygen and hence calculate the mole fraction of oxygen in the equilibrium mixture.

(b) Calculate the partial pressure of sulphur trioxide in the equilibrium mixture.

(c) Write an expression for the equilibrium constant, *K*p, for this reaction. Use this expression to calculate the value of *K*p at temperature *T*1 and state its units.

(d) When equilibrium was established at a different temperature, *T*2, the value of *K*p was found to have increased. State which of *T*1 and *T*2 is the lower temperature and explain your answer.

(e) In a further experiment, the amounts of sulphur dioxide and oxygen used, the catalyst and the temperature, *T*1, were all unchanged, but a flask of smaller volume was used. Deduce the effect of this change on the yield of sulphur trioxide and on the value of *K*p.

2. When a mixture of 0.345 mol of PCl3 and 0.268 mol of Cl2 was heated in a vessel of fixed volume to a constant temperature, the following reaction reached equilibrium.

$$PCl3(g) + Cl2(g) \rightarrow PCl5(g) \quad \Delta H = -93\ kJmol{-}1$$

At equilibrium, 0.166 mol of PCl5 had been formed and the total pressure was 225 kPa.

(a) (i) Calculate the number of moles of PCl3 and of Cl2 in the equilibrium mixture.

(ii) Calculate the total number of moles of gas in the equilibrium mixture.

(b) Calculate the mole fraction and the partial pressure of PCl3 in the equilibrium mixture.

(c) (i) Write an expression for the equilibrium constant, *K*p, for this equilibrium.

(ii) The partial pressures of Cl2 and PCl5 in the equilibrium mixture were 51.3kPa and 83.6 kPa, respectively, and the total pressure remained at 225 kPa. Calculate the value of *K*p at this temperature and state its units.

(d) State the effect on the mole fraction of PCl3 in the equilibrium mixture if

(i) the volume of the vessel were to be increased at a constant temperature,

(ii) the temperature were to be increased at constant volume.

3. At high temperatures, SO2Cl2 dissociates according to the following equation.

$$SO_2Cl_2(g) \rightleftharpoons SO_2(g) + Cl_2(g) \qquad \Delta H^{\ominus} = +93 \text{ kJ mol}^{-1}$$

When 1.00 mol of SO2Cl2 dissociates, the equilibrium mixture contains 0.75 mol of Cl2 at 673 K and a total pressure of 125 kPa.

(a) Write an expression for the equilibrium constant, *K*p, for this reaction.

(b) Calculate the total number of moles of gas present in the equilibrium mixture.

(c) (i) Write a general expression for the partial pressure of a gas in a mixture of gases in terms of the total pressure.

(ii) Calculate the partial pressure of SO2Cl2 and the partial pressure of Cl2 in the equilibrium mixture.

(d) Calculate a value for the equilibrium constant, *K*p, for this reaction and give its units.

(e) State the effect, if any, of an increase in temperature on the value of *K*p for this reaction. Explain your answer.

(f) State the effect, if any, of an increase in the total pressure on the value of *K*p for this reaction.

4. Nitrogen dioxide dissociates according to the following equation.

$$2NO2(g) \rightarrow 2NO(g) + O2(g)$$

When 21.3 g of nitrogen dioxide were heated to a constant temperature, *T*, in a flask of volume 11.5 dm3, an equilibrium mixture was formed which contained 7.04 g of oxygen.

(a) (i) Calculate the number of moles of oxygen present in this equilibrium mixture and deduce the number of moles of nitrogen monoxide also present in this equilibrium mixture.

(ii) Calculate the number of moles in the original 21.3 g of nitrogen dioxide and hence calculate the number of moles of nitrogen dioxide present in this equilibrium mixture.

(b) Write an expression for the equilibrium constant, *K*c, for this reaction. Calculate the value of this constant at temperature *T* and give its units.

(c) The total number of moles of gas in the flask is 0.683. Use the ideal gas equation to determine the temperature T at which the total pressure in the flask is 3.30 × 105 Pa. (The gas constant $R = 8.31\ \text{JK}-1\text{mol}-1$)

(d) State the effect on the equilibrium yield of oxygen and on the value of Kc when the same mass of nitrogen dioxide is heated to the same temperature T, but in a different flask of greater volume.