

Answers to Exercise 7.2

Reaction Quotients vs. Equilibrium Constants

1. An equilibrium constant (K) relates the activities of products and reactants when the system is at equilibrium. A reaction quotient (Q) relates the activities of products and reactants at any time.

The equilibrium constant is essentially the reaction quotient when the system is at equilibrium. As such, you can only calculate K from activities of products and reactants for the system at equilibrium (or from other types of thermodynamic data).

- 2.
- (a) $Q < K$
 - (b) $Q > K$
 - (c) $Q = K$

- 3.
- (a) **Step 1: Write equilibrium constant expression**

$$K = \frac{a_{N_2O_4(g)}}{(a_{NO_2(g)})^2}$$

Step 2: Calculate activities from partial pressures of each gas

$$a_{NO_2(g)} = \frac{p_{NO_2(g)}}{1 \text{ bar}} = \frac{0.261 \text{ bar}}{1 \text{ bar}} = 0.261 \quad a_{N_2O_4(g)} = \frac{p_{N_2O_4(g)}}{1 \text{ bar}} = \frac{0.459 \text{ bar}}{1 \text{ bar}} = 0.459$$

Step 3: Calculate equilibrium constant from equilibrium activities

$$K = \frac{a_{N_2O_4(g)}}{(a_{NO_2(g)})^2} = \frac{0.459}{(0.261)^2} = 6.74$$

Step 4: Check your work

Does your answer seem reasonable? Are sig. fig. correct?

Partial pressures of the reactants and products were of the same order of magnitude, so expect an equilibrium constant that is neither very large nor very small.

- (b) **Step 1: Write reaction quotient expression**

$$Q = \frac{a_{N_2O_4(g)}}{(a_{NO_2(g)})^2}$$

Step 2: Calculate activities from partial pressures of each gas

$$a_{NO_2(g)} = \frac{p_{NO_2(g)}}{1 \text{ bar}} = \frac{0.452 \text{ bar}}{1 \text{ bar}} = 0.452 \quad a_{N_2O_4(g)} = \frac{p_{N_2O_4(g)}}{1 \text{ bar}} = \frac{0.763 \text{ bar}}{1 \text{ bar}} = 0.763$$

Step 3: Calculate reaction quotient from current activities

$$Q = \frac{a_{N_2O_4(g)}}{(a_{NO_2(g)})^2} = \frac{0.763}{(0.452)^2} = 3.73$$

Step 4: Compare Q to K

$$Q = 3.73 \text{ and } K = 6.74$$

Therefore, $Q < K$

Therefore the reaction is favoured in the forward direction.

Step 5: Check your work

Does your answer seem reasonable? Are sig. fig. correct?

Partial pressures of the reactants and products were of the same order of magnitude, so expect an equilibrium constant that is neither very large nor very small.

4. **Step 1: Calculate the concentration of each ion after both solutions are combined (but before any reaction occurs)**

0.500 L of 0.025 M $Pb(NO_3)_2(aq)$ mixed with 0.500 L of 0.045 M $NaI(aq)$ gives 1.000 L of a solution containing 0.0125 mol $Pb^{2+}_{(aq)}$, 0.025 mol $NO_3^-_{(aq)}$, 0.0225 mol $Na^+_{(aq)}$, and 0.0225 mol $I^-_{(aq)}$,

Step 2: Calculate activities of reactants and products (can omit spectator ions)

$$a_{PbI_2(s)} = 1$$

$$a_{Pb^{2+}_{(aq)}} = \frac{M_{Pb^{2+}_{(aq)}}}{1 \frac{mol}{L}} = \frac{0.0125 \frac{mol}{L}}{1 \frac{mol}{L}} = 0.0125$$

$$a_{I^-_{(aq)}} = \frac{M_{I^-_{(aq)}}}{1 \frac{mol}{L}} = \frac{0.0225 \frac{mol}{L}}{1 \frac{mol}{L}} = 0.0225$$

Step 3: Calculate reaction quotient from current activities

$$Q = \frac{(a_{Pb^{2+}_{(aq)}})(a_{I^-_{(aq)}})^2}{a_{PbI_2(s)}} = \frac{(0.0125)(0.0225)^2}{1} = 6.3 \times 10^{-6}$$

Step 4: Compare Q to K

$$Q = 6.3 \times 10^{-6} \text{ and } K = 7.1 \times 10^{-9}$$

Therefore, $Q > K$

Therefore the reaction is favoured in the reverse direction.

Therefore, a precipitate will form.

Step 5: Check your work

Does your answer seem reasonable? Are sig. fig. correct?