

Gas-Phase and Heterogeneous Equilibria

Answer key with worked solutions

A. Writing K

1. K_p expressions.

$$(a) K_p = \frac{(P_{\text{SO}_3})^2}{(P_{\text{SO}_2})^2 P_{\text{O}_2}} \quad (b) K_p = \frac{(P_{\text{NO}_2})^2}{(P_{\text{NO}})^2 P_{\text{O}_2}}$$
$$(c) K_p = P_{\text{H}_2\text{O}} \text{ (the vapour pressure; liquid left out)} \quad (d) K_p = P_{\text{NH}_3} P_{\text{HCl}} \text{ (solid left out)}$$

2. Δn .

(a) -1 : K_p smaller than K_c (b) -1 : smaller (c) $+1$: K_p larger than K_c (d) $+2$: larger. At 25°C , $RT = 24.47$, which is greater than 1, so a positive Δn makes K_p larger and a negative Δn makes it smaller.

B. Calculating K_p and K_c

3. K_p from pressures.

$$K_p = \frac{(1.2)^2}{(0.20)^2 \times 0.10} = \frac{1.44}{0.0040} = \mathbf{360}$$

4. K_c to K_p .

$$RT = 0.08206 \text{ L atm/(mol K)} \times 1000 \text{ K} = 82.06 \text{ L atm/mol}; \Delta n = -1$$
$$K_p = 280 \times (82.06)^{-1} = \mathbf{3.41}$$

5. K_p to K_c .

$$RT = 0.08206 \text{ L atm/(mol K)} \times 298.15 \text{ K} = 24.47 \text{ L atm/mol}; \Delta n = +1$$
$$K_c = \frac{K_p}{(RT)^{\Delta n}} = \frac{0.15}{24.47} = \mathbf{6.1 \times 10^{-3}}$$

C. Q and ICE tables

6. Q and direction.

$Q = \frac{(0.50)^2}{0.10 \times 0.10} = 25$. Q (25) is less than K (50), so the reaction goes **forward**, making more HI.

7. ICE table.

ICE (atm): N_2O_4 : $1.00 - x$; NO_2 : $2x$.

$$\frac{(2x)^2}{1.00 - x} = 0.15$$

$$4x^2 + 0.15x - 0.15 = 0$$

$$x = \frac{-0.15 + \sqrt{0.15^2 + 4 \times 4 \times 0.15}}{2 \times 4} = 0.176$$

$P_{\text{NO}_2} = 2 \times 0.176 = 0.352 \text{ atm}$; $P_{\text{N}_2\text{O}_4} = 1.00 - 0.176 = 0.824 \text{ atm}$. Check: $(0.352)^2 \div 0.824 = 0.150 \checkmark$

D. Challenge

8. Limestone in a sealed container.

$K_p = P(\text{CO}_2)$, which is fixed at a given temperature. (a) Adding more solid CaCO_3 does **not change** $P(\text{CO}_2)$: solids are not in the K expression. (b) Removing CO_2 makes Q less than K, so more CaCO_3 decomposes until **$P(\text{CO}_2)$ returns** to the value of K_p .