Pearson

# 15.5: Heterogeneous Equilibria: Reactions Involving Solids and Liquids

Many chemical reactions involve pure solids or pure liquids as reactants or products. Consider, for example, the reaction:

$$2\ \mathrm{CO}(g)\ \rightleftharpoons\ \mathrm{CO_2}(g) + \mathrm{C}(s)$$

We might expect the expression for the equilibrium constant to be:

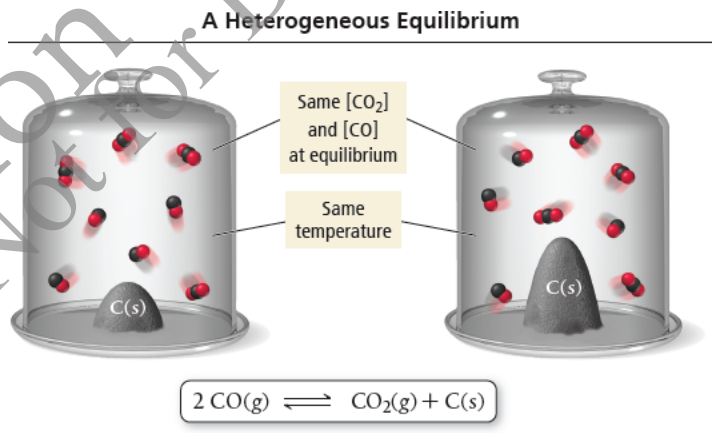
$$K_c = \frac{[\mathrm{CO_2}]\,[\mathrm{C}]}{[\mathrm{CO}]^2}\ \text{(incorrect)}$$

However, since carbon is a solid, its concentration is constant (if we double the amount of carbon, its *concentration* remains the same). The concentration of a solid does not change because a solid does not expand to fill its container. Its concentration, therefore, depends only on its density, which is constant as long as *some* solid is present (Figure 15.5). Consequently, pure solids—those reactants or products labeled in the chemical equation with an (*s*)—are not included in the equilibrium expression (because their constant value is incorporated into the value of *K*). The correct equilibrium expression for this reaction is therefore:

$$K_c = \frac{[\mathrm{CO_2}]}{[\mathrm{CO}]^2}$$

**Figure 15.5 Heterogeneous Equilibrium**

The concentration of solid carbon (the number of atoms per unit volume) is constant as long as some solid carbon is present. The same is true for pure liquids. For this reason, the concentrations of solids and pure liquids are not included in equilibrium constant expressions.




Similarly, the concentration of a pure liquid does not change. So, pure liquids—reactants or products labeled in the chemical equation with an (*l*)—are also excluded from the equilibrium expression. For example, consider the equilibrium expression for the reaction between carbon dioxide and water:

$$\mathrm{CO_2}\,(g)\ +\mathrm{H_2O}(l)\ \rightleftharpoons\ \mathrm{H^+}\,(aq)\ +\mathrm{HCO_3^-}\,(aq)$$

Since $\mathrm{H_2O}(l)$ is pure liquid, we omit it from the equilibrium expression:

$$K_c = \frac{[\mathrm{H^+}]\,[\mathrm{HCO_3^-}]}{[\mathrm{CO}_\ldots]}$$

$[CO_2]$

**Example 15.4** **Writing Equilibrium Expressions for Reactions Involving a Solid or a Liquid**

Write an expression for the equilibrium constant $(K_c)$ for the chemical equation.

$$CaCO_3(s) \rightleftharpoons CaO(s) + CO_2(g)$$

**SOLUTION** Because $CaCO_3(s)$ and $CaO(s)$ are both solids, omit them from the equilibrium expression.

$$K_c = [CO_2]$$

**FOR PRACTICE 15.4**

Write an equilibrium expression $(K_c)$ for the equation.

$$4\,HCI(g) + O_2(g) \rightleftharpoons 2\,H_2O(l) + 2\,Cl_2(g)$$

**Conceptual Connection 15.4** **Heterogeneous Equilibria, $K_p$ and $K_c$**

Interactive