2. EQUILIBRIUM CONSTANTS

UNIT 3 – CHEMICAL EQUILIBRIUM

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EQUILIBRIUM LAW

equilibrium law the mathematical description of a chemical system at equilibrium

equilibrium constant (*K*) a constant numerical value defining the equilibrium law for a given system; units are not included when giving the value of *K*

Figure 1 Cato Maximilian Guldberg (1836–1902) and Peter Waage (1833–1900) first proposed the equilibrium law in 1864.

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QUANTIFYING EQUILIBRIUM - K

An equilibrium system, at any given temperature, can be described by an equilibrium expression and its resulting equilibrium constant.

$$aA + bB \rightleftharpoons cC + dD$$

$$K = \frac{\text{Products}}{\text{Reactants}} \qquad K = \frac{[C]^c[D]^d}{[A]^a[B]^b}$$

Equilibrium Constant = a number

Equilibrium Expression = equation

ONLY (aq) and (g) are included! (l) and (s) are **NOT**!

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USING THE EQUILIBRIUM EXPRESSION

$H_2(g) + I_2(g) \leftrightarrows 2HI(g)$ @ 25°C

Initial concentration (mol/L)		
$[H_2(g)]$	$[I_2(g)]$	$[HI(g)]$
2.00	2.00	0
Equilibrium concentration (mol/L)		
$[H_2(g)]$	$[I_2(g)]$	$[HI(g)]$
0.442	0.442	3.119

$$K = \frac{[HI(g)]^2}{[H_2(g)][I_2(g)]}$$

$$K = \frac{(3.119)^2}{(0.442)(0.442)}$$

$$K = 49.8$$

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THE SIZE OF K HAS MEANING

Big K = [Reactants] < [Products] @ Eq’m

$$K = \frac{\text{products}}{\text{reactants}} = \textbf{BIG}$$

Eq’m is PRODUCT FAVOURED

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THE SIZE OF K HAS MEANING

Small K = [Reactants] > [Products] @ Eq’m

$$K = \frac{\text{products}}{\text{reactants}} = \textbf{SMALL}$$

Eq’m is REACTANT FAVOURED

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THE SIZE OF K HAS MEANING

K = 1 … [Products] = [Reactants] @ Eq'm

$$K = \frac{\text{products}}{\text{reactants}} = 1$$

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EXAMPLE 1

Write the equilibrium expression for the following reaction:

$$4\ NH_3(g) + 7\ O_2(g) \leftrightarrow 4\ NO_2(g) + 6H_2O(g)$$

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EXAMPLE 2

The following reaction happens in a closed container at a constant temperature. At equilibrium, the concentrations of each chemical are 1.50 x 10^{-5} mol/L $N_2(g)$, 3.45 x 10^{-1} mol/L $H_2(g)$, and 2.00 x 10^{-4} mol/L $NH_3(g)$. Calculate the equilibrium constant.

$$N_2(g) + 3\,H_2(g) \leftrightarrow 2\,NH_3(g)$$

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PUTTING IT ALL TOGETHER…

When 0.800 moles of SO_2 and 0.800 moles of O_2 are placed in a 2.00 L container and allowed to reach equilibrium, the equilibrium $[SO_3]$ is found to be 0.300 mol/L. Calculate the K value for this reaction at this temperature.

$$2\,SO_{2\ (g)} + O_{2\ (g)} \leftrightharpoons 2\,SO_{3\ (g)}$$

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