Chapter 7.5
Quantitative Changes in Equilibrium Systems

Learning Goals: I will be able to…

1. **determine** whether a system is at equilibrium or not using the reaction quotient (Q)
2. **determine** the shift required to bring a system to equilibrium based on the reaction quotient (Q)
3. **solve** problems related to equilibrium by **performing** calculations involving concentrations of reactants and products

Recall…

- For the reaction

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

- The equilibrium constant is:

$$K_{eq} = \frac{[C]^c[D]^d}{[A]^a[B]^b}$$

- We can use the above equation to solve for K_{eq}

OR

- We can use it, along with ICE table, to solve for equilibrium concentrations of any reactant or product in the reaction.

Example 1

The equilibrium constant for the below reaction is 16. initially 0.22 M of both $PCl_{3(g)}$ and $Cl_{2(g)}$ were placed into a container and allowed to reach equilibrium. What is the **equilibrium concentration** of each gas?

$$PCl_{3(g)} \quad + \quad Cl_{2(g)} \quad \leftarrow\rightarrow \quad PCl_{5(g)}$$

Approximation Method

- Sometimes, when our K value is very small compared to the initial concentrations, we are able to use an approximation method.
- Remember, when K is very small, it means that the reactants are favoured.
- We can make the assumption that **[A] – x = [A]** if we use a 5% error approximation as follows:

$$\frac{[\mathbf{A}]}{\mathbf{K_{eq}}} \geq \mathbf{500}$$

- In other words, so little of the reactants actually convert to products that the INITIAL concentration of the reactants is almost identical to the EQUILIBRIUM concentration of the reactants.
- You may use this approximation method for any question that looks like it might require the quadratic formula. If, however, you perform the above operation and the value is less than 500, the QUADRATIC FORMULA must be used.

Example 2

The equilibrium constant for the below reaction is 6.8×10^{-8}. Initially 0.50 M of N_2 gas and 0.25 M of O_2 gas were placed into a container and allowed to reach equilibrium. What is the **equilibrium concentration** of each gas?

$$N_{2(g)} \quad + \quad O_{2(g)} \quad \leftrightarrow \quad 2NO_{(g)}$$

NOTE: Even if you used the quadratic formula for this example, your final answers would be the same as above once you rounded to take significant digits into account!

The Reaction Quotient (Q)

- The **reaction quotient (Q)** is the ratio of the product of the concentrations of the products to the product of the concentrations of the reactants.
- For the reaction: $aA + bB \rightleftharpoons cC + dD$
- The reaction quotient $Q = \frac{[C]^c[D]^d}{[A]^a[B]^b}$
- The **instantaneous concentrations** (concentrations at a particular instant in time) is used to calculate the reaction quotient

Magnitude of Q

- The relative sizes of Q and K can give 3 possible predictions:

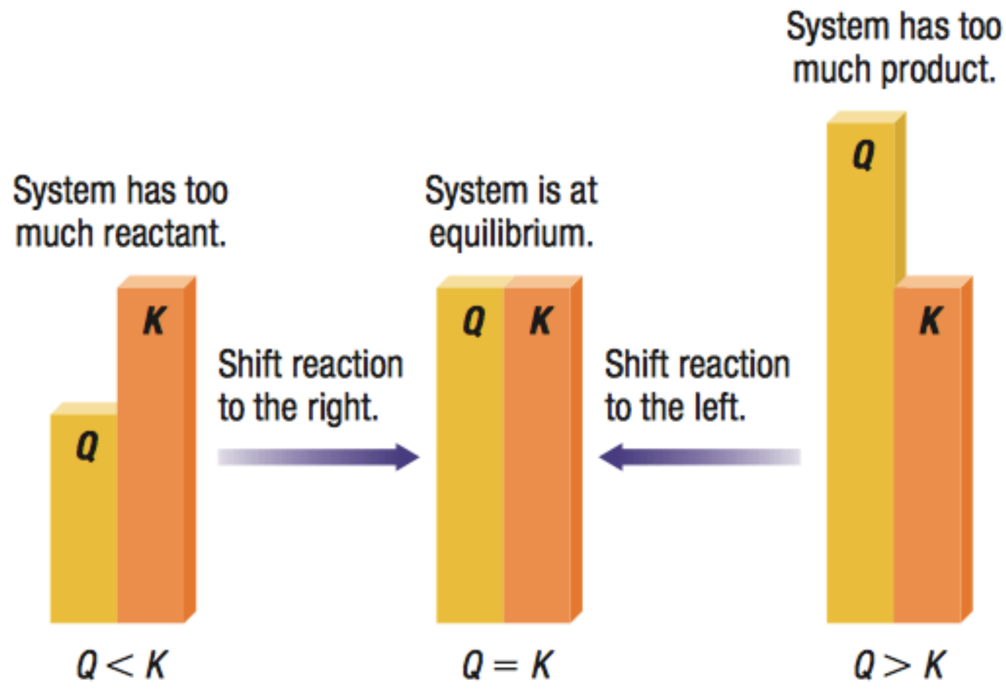

Figure 4 The relationship between reaction quotient, *Q*, and the equilibrium constant, *K*.

Example 3

For the synthesis of ammonia gas at 500°C in a closed vessel from nitrogen and hydrogen gas, the equilibrium constant is 6.01×10^{-2}. The balanced chemical equation for this reaction is

$$N_{2(g)} + 3H_{2(g)} \leftrightarrow 2NH_{3(g)}$$

For each of the following initial conditions, determine if the given concentrations represent an equilibrium. If not, predict the direction in which the reaction will proceed to reach equilibrium.

	$[NH_{3(g)}]$ (mol/L)	$[N_{2(g)}]$ (mol/L)	$[H_{2(g)}]$ (mol/L)
a)	1.00×10^{-3}	1.00×10^{-5}	2.00×10^{-3}
b)	2.00×10^{-4}	1.50×10^{-5}	3.54×10^{-1}
c)	1.00×10^{-4}	5.00	1.00×10^{-2}

Did You Learn?

- The magnitude of the equilibrium constant for a reaction, K, is directly proportional to the extent of that reaction.
- The reaction quotient, Q, is the product of the concentrations of the products, divided by the product of the concentrations of the reactants, for a chemical reaction that is not necessarily at equilibrium.
- Comparing the values of Q and K indicates whether a chemical reaction system is at equilibrium and, if not, the direction it will shift.

HOMEWORK

Required Reading:

p. 447 – 458

(remember to supplement your notes!)

Questions:

P. 452 #1-3

P. 454 #1-3

P. 458 #1-3

P. 459 #3-8