Equilibrium

Reaction Quotient – Q and ICE Tables

The Reaction Quotient

If a reaction mixture containing both reactants and products is not at equilibrium, how can we determine in which direction it will proceed?

The answer is to compare the current concentration ratios to the equilibrium constant.

The concentration ratio of the products (raised to the power of their coefficients) to the reactants (raised to the power of their coefficients) is called the **reaction quotient, *Q*.**

Significance of the Reaction Quotient

For the gas phase reaction

$a\text{A} + b\text{B} \Leftrightarrow c\text{C} + d\text{D}$

the **reaction quotient** is:

$$Q_c = \frac{[\text{C}]^c[\text{D}]^d}{[\text{A}]^a[\text{B}]^b} \qquad Q_p = \frac{P_\text{C}^c P_\text{D}^d}{P_\text{A}^a P_\text{B}^b}$$

Set up the same way as K, but the [ ] values you plug in are not necessarily the same as the ones at equilibrium.

The Reaction Quotient

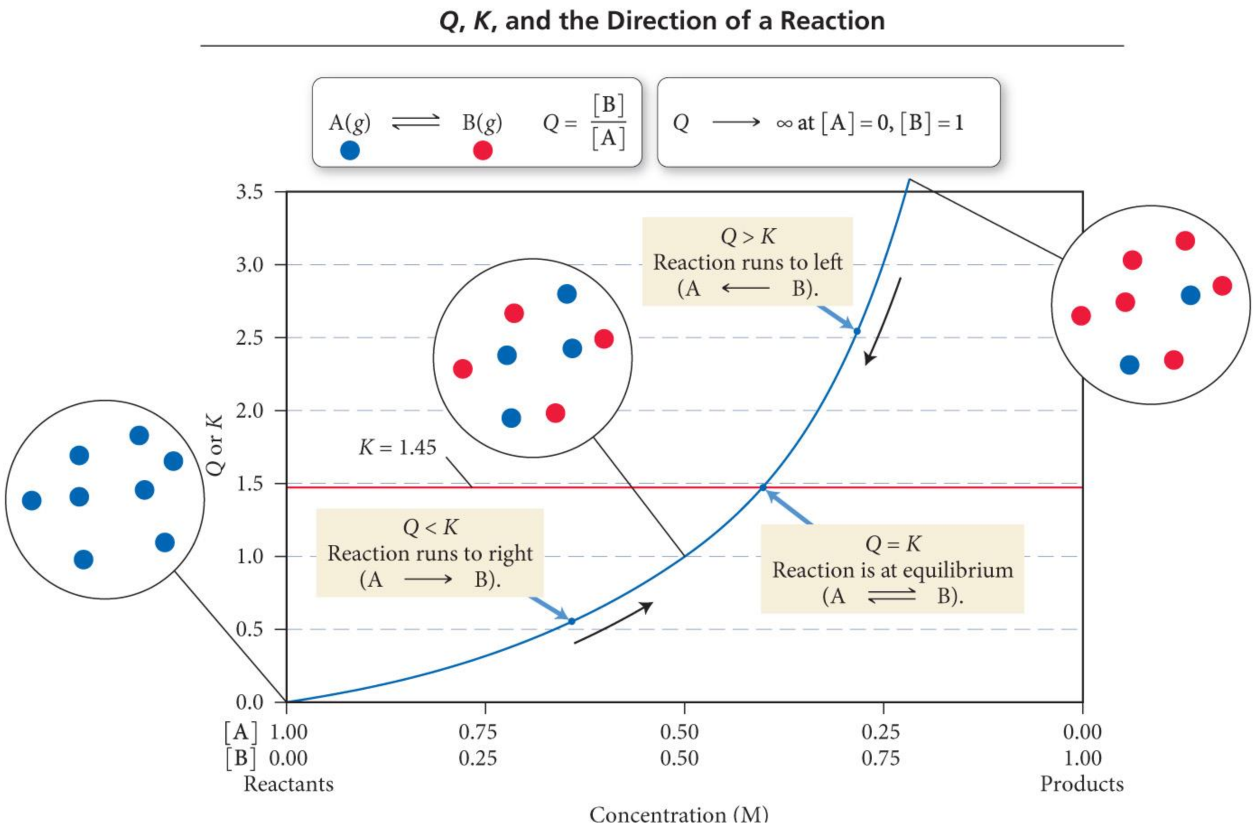
If ***Q* = *K***, the system is **at equilibrium**

If ***Q* > *K***, there are more products than when at equilibrium, **the system shifts to the left,** consuming products and forming reactants until equilibrium is achieved

If *Q* < *K*, there are more reactants than when at equilibrium, **the system shifts to the right,** consuming reactants and forming products until equilibrium is achieved

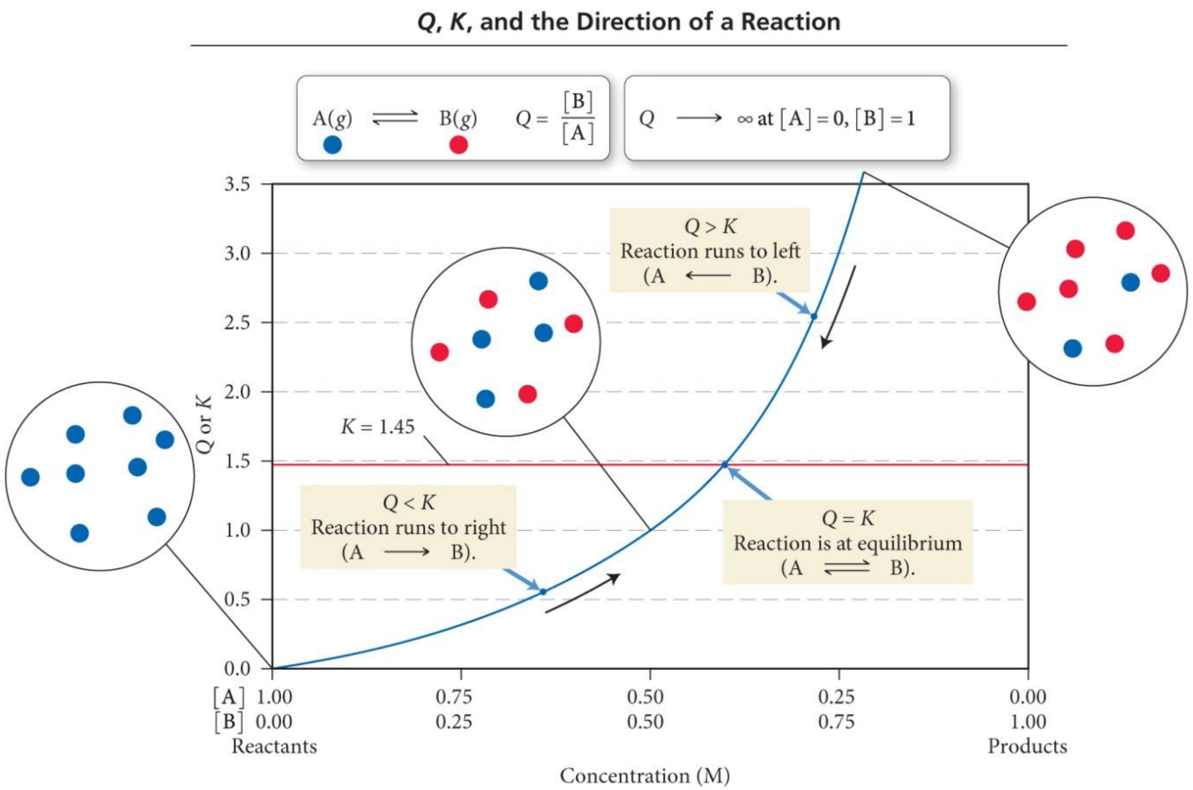
The Reaction Quotient – Predicating the Direction of Change

- If ***Q* > *K***, the reaction will proceed fastest in the **reverse** direction.
  - The products will decrease and reactants will increase.



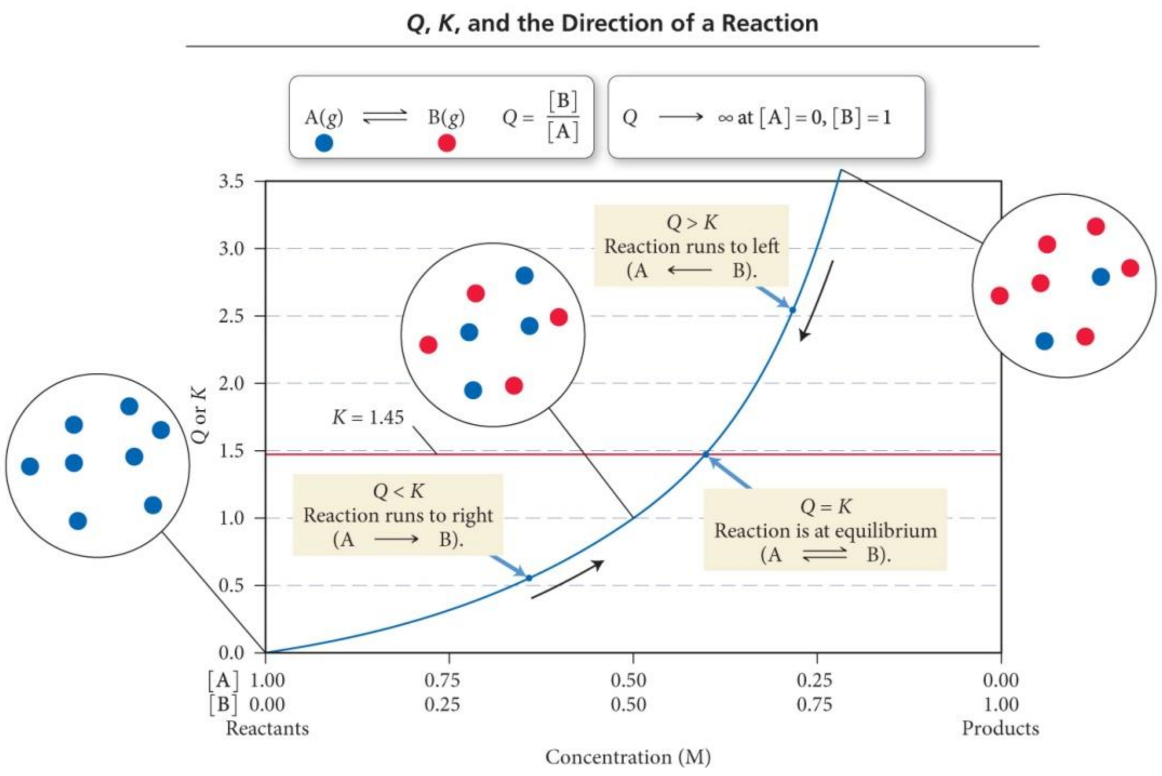
The Reaction Quotient – Predicating the Direction of Change

- If ***Q* < *K***, the reaction will proceed fastest in the **forward** direction.
  - The products will increase and reactants will decrease.



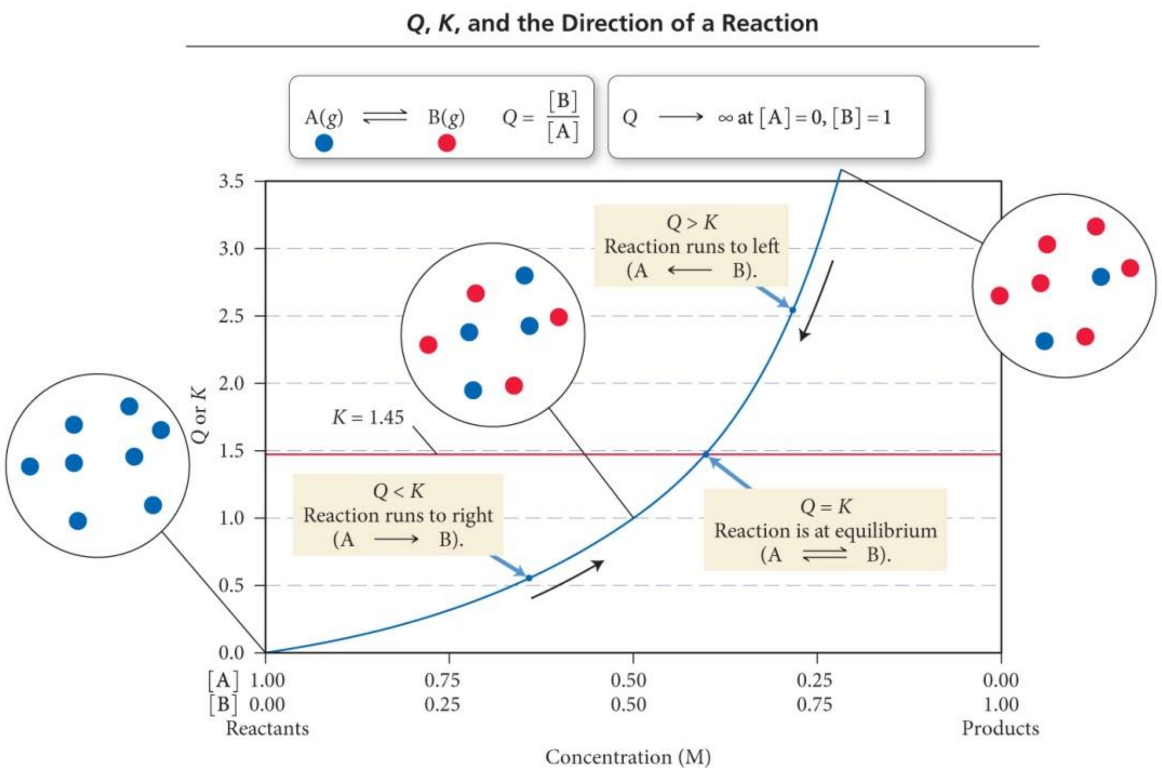
The Reaction Quotient – Predicating the Direction of Change

- If ***Q* =*K***, the reaction is **already at equilibrium!**
  - The products and reactants will not change.



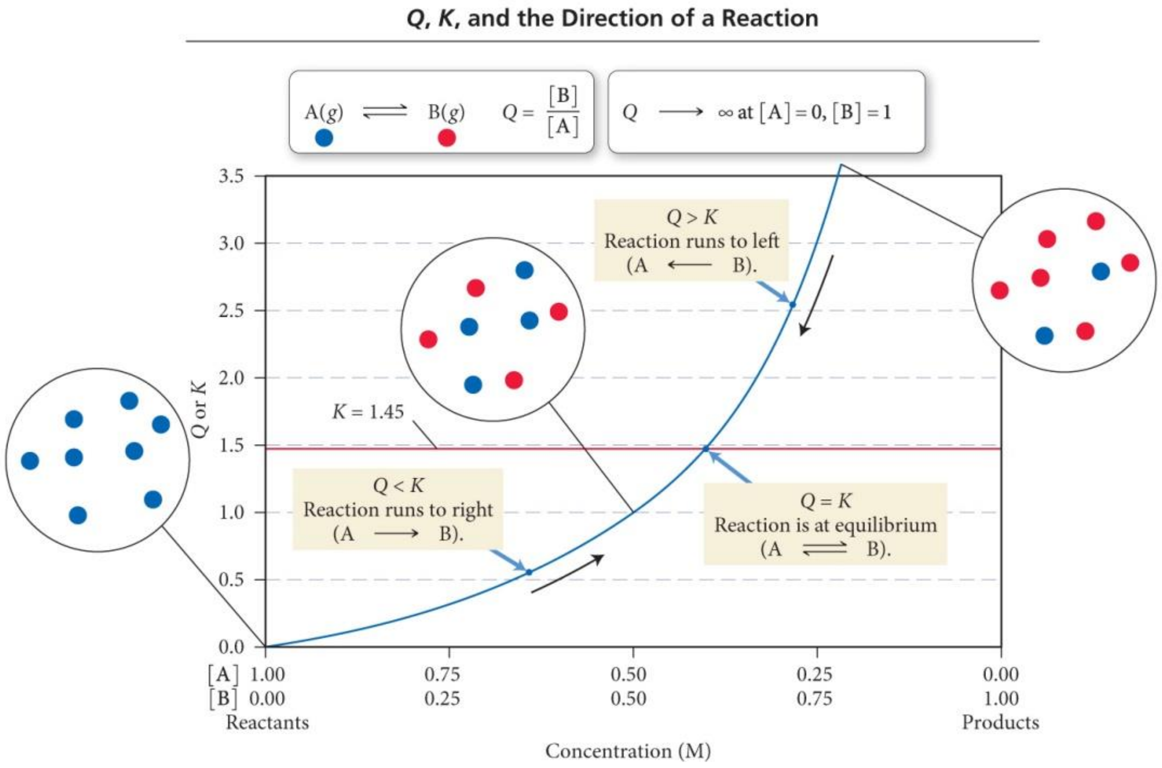
The Reaction Quotient – Predicating the Direction of Change

- If a reaction mixture contains just reactants, then **Q = 0**, and the reaction will proceed in the **forward direction**.



The Reaction Quotient – Predicating the Direction of Change

- If a reaction mixture contains just products, then **Q = ∞**, and the reaction will proceed in the **reverse direction**.



Solving for Equilibrium Concentrations

Consider this reaction at some temperature:

$H_2O(g) + CO(g) \leftrightarrows H_2(g) + CO_2(g)$ $K = 2.0$

Assume you start with 8 molecules of H_2O and 6 molecules of CO. How many molecules of H_2O, CO, H_2, and CO_2 are present at equilibrium?

Here, we learn about "ICE" – one the most important problem solving technique in the year.
You will use it a lot!

Solving for Equilibrium Concentration

$H_2O(g) + CO(g) \leftrightarrows H_2(g) + CO_2(g)$ $K = 2.0$

Step #1: Write the law of mass action for the rxn

$$2.0 = \frac{[H_2][CO_2]}{[H_2O][CO]}$$

Solving for Equilibrium Concentration

Step #2: We "ICE" the problem, beginning with the Initial concentrations

$$H_2O(g) + CO(g) \leftrightarrows H_2(g) + CO_2(g)$$

Initial:	**8**	**6**	**0**	**0**
Change:	**-x**	**-x**	**+x**	**+x**
Equilibrium:	**8-x**	**6-x**	**x**	**x**

Solving for Equilibrium Concentration

Step #3: Plug equilibrium concentrations into the equilibrium expression, and solve for x

$$H_2O(g) + CO(g) \leftrightarrows H_2(g) + CO_2(g)$$

Equilibrium:	**8-x**	**6-x**	**x**	**x**

$$2.0 = \frac{(x)(x)}{(8-x)(6-x)}$$

$$\boxed{x = 4}$$

Solving for Equilibrium Concentration

Step #3: Plug equilibrium concentrations into the equilibrium expression, and solve for x

$$H_2O(g) + CO(g) \leftrightarrows H_2(g) + CO_2(g)$$

Equilibrium:	**8-x**	**6-x**	**x**	**X**

$$x = 4$$

Answer	**8-4 = 4**	**6-4 = 2**	**4**	**4**

Some of These Can Get Really Tricky…

- Quadratic Equations
- Perfect squares
- Approximations – Remember the 5% rule from Honors Chemistry ????
- Crazy substitutions and rearrangements

But the concept is always the same!
You HAVE to practice to see crazy examples!