

General Equilibrium

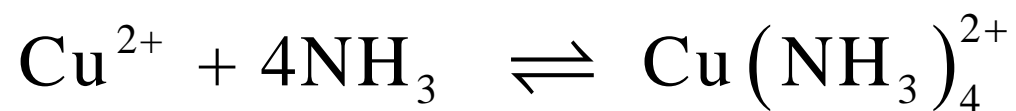
How to set up and solve equilibrium problems
Part I - writing the reaction quotient “Q”

General Equilibria - an introduction

The equilibrium expressions, which are about to be demonstrated, are derived from thermodynamics. In the sequence of this course, the question of how to setup and use these expressions is presented before involving thermodynamics. In the section on thermodynamics, the rationale for such expressions will be explained.

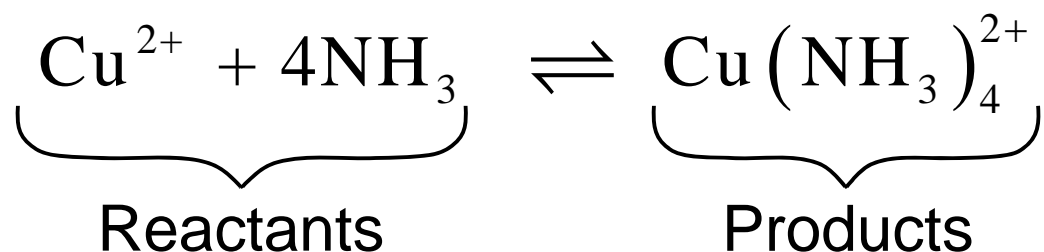
General Equilibria - an introduction

To illustrate the methodology, an example reaction will be considered. Any reaction that can be in dynamic equilibrium would do for this purpose, so consider the equilibrium:



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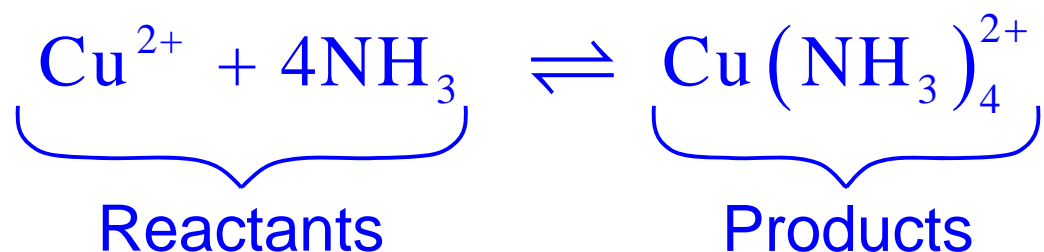
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Definitions: Recall that the definition of the reactants is the chemical on the left side of the double arrow . The products are on the right side of the written equation.

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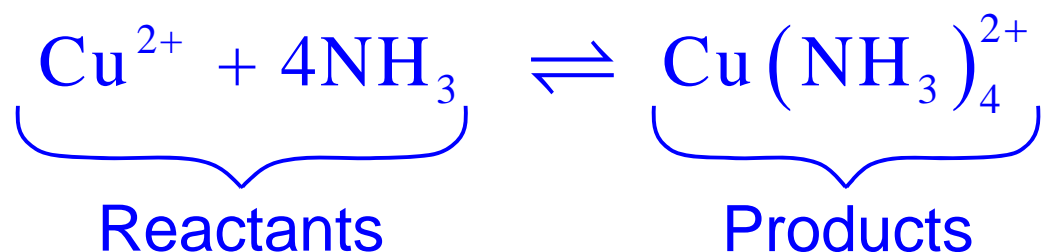


The equilibria expression consists of two parts:

Q = the product of the concentrations of products divided by the product of the concentrations of the reactants.

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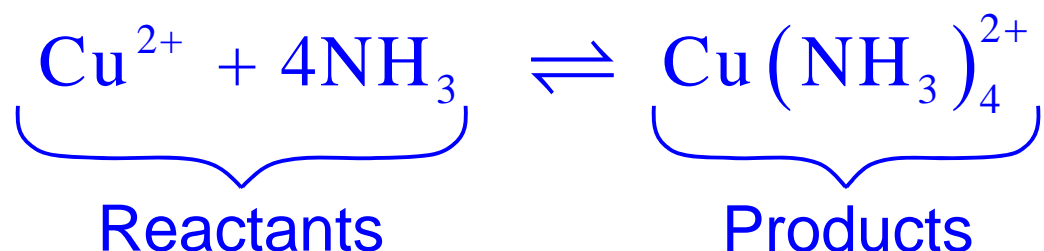
Q = the product of the concentrations of products divided by the product of the concentrations of the reactants.

In this case there is only one product, so in the numerator:

$$Q = \frac{[\text{Cu}(\text{NH}_3)_4^{2+}]}{\quad}$$

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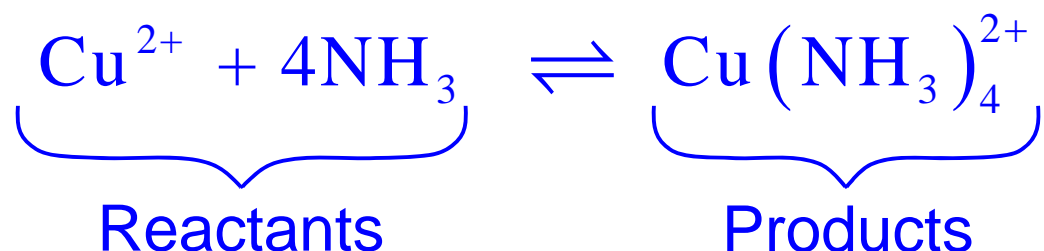
Q = the product of the concentrations of products divided by the product of the concentrations of the reactants.

In the denominator, there is one Cu^{2+} ion:

$$Q = \frac{[\text{Cu}(\text{NH}_3)_4^{2+}]}{[\text{Cu}^{2+}]}$$

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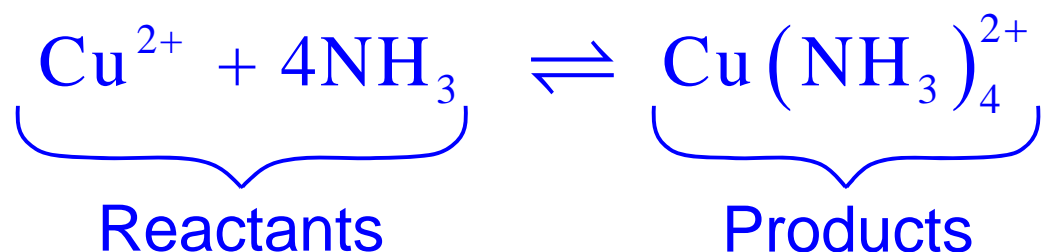
but there are 4 NH₃ molecules - all four must be multiplied:

$$Q = \frac{[\text{Cu}(\text{NH}_3)_4^{2+}]}{[\text{Cu}^{2+}][\text{NH}_3]^4}$$

In other words, NH₃ concentration is raised to the 4th power

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Concentrations are designated by placing the chemical symbol in square brackets, “[]”. This is a convention that you must use. There are two others. All three are:

For solute species “X” molarity is written “[X]”*

For gas species “Y” the pressure in atm is written “ P_Y ”‡

For all others “Z” the mole fraction is written as “ X_Z ”.

* in Q: $[X] \equiv C_X / (1 \text{ M})$ ‡ and $P_Y \equiv P_Y / (1 \text{ atm})$

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This equation is generalized in the form:

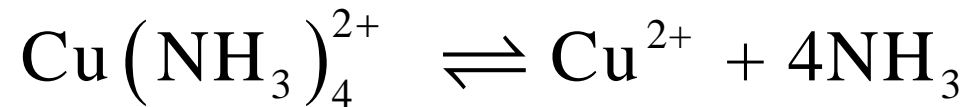
$$Q = \frac{\prod \text{products}}{\prod \text{reactants}}$$

The symbol \prod means “the product of”.

General Equilibria - an introduction

$$Q = \frac{\Pi \text{ products}}{\Pi \text{ reactants}}$$

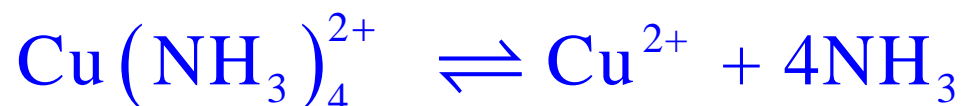
Example 2: Write Q for the reaction:



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Notice that this is the previous reaction turned around. The reactants and products have been switched. This make no difference, simply follow the formulation.

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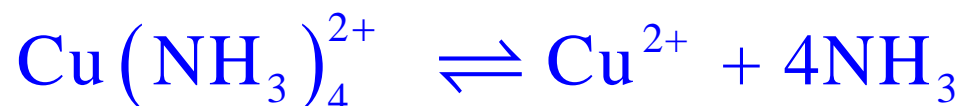
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$$Q = \frac{[\text{Cu}^{2+}][\text{NH}_3]^4}{[\text{Cu}(\text{NH}_3)_4^{2+}]}$$

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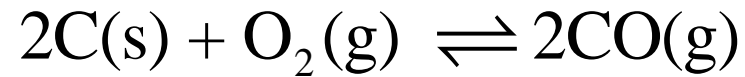
Cu^{2+} and NH_3 are products and therefore both in the numerator

$\text{Cu}(\text{NH}_3)_4^{2+}$ is the reactant and is therefore in the denominator.

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$$Q = \frac{\Pi \text{ products}}{\Pi \text{ reactants}}$$

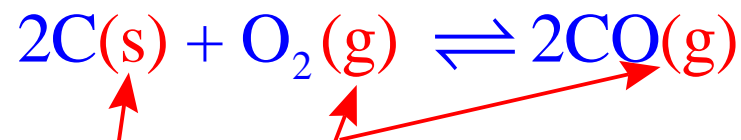
Example 3: Write Q for the reaction:



General Equilibria - an introduction

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Notice the symbols (s) and (g) in this example. Even though there probably is no confusion, these symbols mean “solid” and “gas”. The conventions for these symbols are:

(s) \equiv solid

(l) \equiv liquid

(g) \equiv gas

(aq) \equiv as a solute in water solution.

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Example 3: Write Q for the reaction:



The product is CO gas and the reactants are O₂ gas and carbon solid:

$$Q = \frac{P_{\text{CO}}^2}{X_{\text{C}} P_{\text{O}_2}}$$

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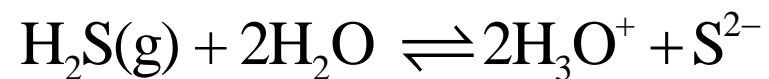
Usually, when a solid is written in a reaction it is pure and therefore its mole fraction is 1. Thus, this equation becomes:

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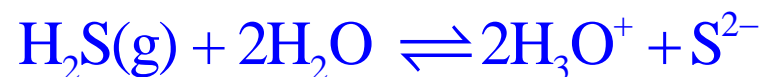
Example 4: Write Q for the reaction:



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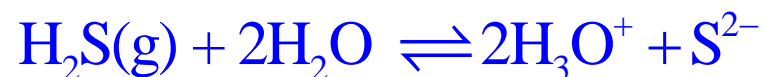


In this case the charged ions imply “(aq)”, so it is not necessary to write “(aq)”. Water is the solvent, and for most cases of a solvent the mole fraction is nearly 1.

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The Q is therefore (with $X_{\text{H}_2\text{O}} = 1$):

$$Q = \frac{[\text{H}_3\text{O}^+]^2 [\text{S}^{2-}]}{P_{\text{H}_2\text{S}}}$$

General Equilibrium

How to set up and solve equilibrium problems
Part I - writing Q

THE END of Part I

Go on to Part II - solving problems using $K = Q$