**Equilibrium made easy**

How many equilibrium problems are there? Well, there is Keq, Kc, Kp, Kf, Kw, Ka, Kb, Ksp (not all of which have been on the AP exam). Below is a concept map showing how they are all related.

**Q**

The reaction quotient

Related by Kp=Kc(RT)n

**Keq**

General equilibrium expression

**Kw**

Equilibrium expression involving self- ionization of water

**Kf**

Equilibrium formation constant for a complex ion – has not been on the AP exam before.

**Ksp**

Solubility Product Equilibrium involving ionization of an insoluble compound (how much of the insoluble compound dissolves).

**Kb**

Equilibrium expression involving ionization of a weak base

**Ka**

Equilibrium expression involving ionization of a weak acid

**Kc**

Equilibrium expression involving molar concentrations

**Kp**

Equilibrium expression involving gas pressure

So how many equilibrium problems are there? The answer is very simple – there are two equilibrium problems.

Why are there only two types of problems? It doesn’t it matter if it is Kc, Kp, Ka, Kb, Kw, or Ksp there are only two problems.

* You are given the value of K.
* You are asked to determine the value of the equilibrium constant, K.

How often are they asked? Fifty percent of the questions will ask for the equilibrium constant and fifty percent of the questions you will be given the equilibrium constant. Why should we look at the “main” type of question?

**If you are given the K value then you know several things:**

* Means that you will have an “X” in the RICE table and you will have to find the “X”.
	+ Do NOT forget to write what “X” is equal to.
	+ If you were asked to find the [H+] then when you find “X” write something like
		- “X = 0.15 M = [H+]”
* Fill out the RICE table completely.
* Often the RICE table once filled-in will provide you some points.

**If you are asked for the K value, then you know:**

* Means that you will have all values to fill in the RICE table.
* Only four “methods” to provide you all the numbers for the RICE table:
	+ percent ionization (if aqueous) or dissociation (if a gas)
	+ pH (acid or base problem)
	+ Total pressure at equilibrium (gas equilibrium problems)
		- May simply be stated in the problem “at equilibrium the total pressure is found to be \_\_\_”
		- Has been given in a table of total pressure. Look to see where the pressure stops increasing to determine the total pressure.
	+ Giving a value for the equilibrium value
		- grams or moles 🡺 can find molarity (usually Kc problems)
		- grams or moles 🡺 can find pressure by using PV=nRT (Kp problems)
		- solubility value, either grams/liters or moles/liter (Ksp problems)
		- Has been given in a graph showing the change of concentration versus time. Look where the graph flattens out and remains constant. That is the equilibrium value for the reactant – they you can find the rest of the values for the RICE table.

**Method: Given a value (#1)**

NH3(*aq*) + H2O(*l*)  NH4+(*aq*) + OH-(*aq*)

In aqueous solution, ammonia reacts as represented above. In 0.0180 *M* NH3(*aq*) at 25OC, the hydroxide ion concentration, [OH-], is 5.60 x 10-4. In answering the following, assume that the temperature is constant at 25OC and the volumes are additive.

1. Write the equilibrium-constant expression for the reaction represented above.
2. Determine the pH of 0.0180 *M* NH3(*aq*)
3. Determine the value of the base ionization constant, Kb, for NH3(*aq*)

**R**

**I**

**C**

**E**

 NH3(*aq*) + H2O(*l*)  NH4+(*aq*) + OH-(*aq*)

**Method: Given a value (#2)**

Presenting the given value graphically:

2HI(*g*) H2(*g*) + I2(*g*)

After 1.0 mole sample of HI(*g*) is placed into an evacuated 1.0 L container at 700. K, the reaction represented above occurs. The concentration of HI(*g*) as a function of time is shown below.



(a) Write the expression for the equilibrium constant, Kc, for the reaction.

(b) What is [HI] at equilibrium?

(c) Determine the equilibrium concentrations of H2(*g*) and I2(*g*).

(d) On the graph above, make a sketch that shows how the concentration of H2(*g*) changes as a function of time.

(e) Calculate the value of the following equilibrium constants at 700.K

 (i) Kc

 (ii) Kp

**R**

**I**

**C**

**E**

 2HI(*g*) H2(*g*) + I2(*g*)

**Method: Given a pH value**

C6H5NH2*(aq)* + H2O*(l)*  C6H5NH3+*(aq)* + OH–*(aq)*

Aniline, a weak base, reacts with water according to the reaction represented above.

(a) Write the equilibrium constant expression, K*b*, for the reaction represented above.

(b) A sample of aniline is dissolved in water to produce 25.0 mL of 0.10 *M* solution. The pH of the solution is 8.82. Calculate the equilibrium constant, K*b*, for this reaction.

**R**

**I**

**C**

**E**

 C6H5NH2 + H2O  C6H5NH3+ + OH–

 0.10 0 0

**Method: Total pressure**

C(*s*) + CO2(*g*) 2 CO(*g*)

Solid carbon and carbon dioxide gas at 1,160 K were placed in a rigid 2.00 L container, and the reaction represented above occurred. As the reaction proceeded, the total pressure in the container was monitored.

When equilibrium was reached, there was still some C(*s*) remaining in the container. Results are recorded in the table below.

|  |  |
| --- | --- |
| **Time (hours)** | **Total Pressure of Gases in Container at 1,160 K (atm)** |
| 0.0 | 5.00 |
| 2.0 | 6.26 |
| 4.0 | 7.09 |
| 6.0 | 7.75 |
| 8.0 | 8.37 |
| 10.0 | 8.37 |

(a) Write the expression for the equilibrium constant, *Kp* , for the reaction.

(b) Calculate the number of moles of CO2(*g*) initially placed in the container. (Assume that the volume of the solid carbon is negligible.)

(c) For the reaction mixture at equilibrium at 1,160 K, the partial pressure of the CO2(*g*) is 1.63 atm. Calculate

(i) the partial pressure of CO(*g*) , and

(ii) the value of the equilibrium constant, *Kp* .

**R**

**I**

**C**

**E**

 C(*s*) + CO2(*g*) 2 CO(*g*)

**Method: Percent ionization/disassociation**

At 105°C, AsF5(g) decomposes into AsF3(g) and F2(g) according to the following chemical equation.

AsF5(g)  AsF3(g) + F2(g)

(a) A 55.8 g sample of AsF5(g) is introduced into an evacuated 10.5 L container at 105°C.

(i) What is the initial molar concentration of AsF5(g) in the container?

(ii) What is the initial pressure, in atmospheres, of the AsF5(g) in the container?

(b) In terms of molar concentrations, write the equilibrium-constant expression for the decomposition of AsF5(g).

(c) When equilibrium is established, 27.7 percent of the original number of moles of AsF5(g) has decomposed.

(i) Calculate the molar concentration of AsF5(g) at equilibrium.

(ii) Using molar concentrations, calculate the value of the equilibrium constant, Keq, at 105°C.

**R**

**I**

**C**

**E**

 AsF5(g)  AsF3(g) + F2(g)