AP Chemistry Ultimate Review Packet
Unit 7: Equilibrium

Many chemical reactions are not unidirectional, but rather are equilibria:

$$A + B \rightleftharpoons C + D$$

- there is a *forward reaction* and a *reverse reaction*
- the equilibrium is dynamic, concentrations remain constant but this is because the rates of the forward and reverse reactions are equivalent
- physical processes like phase changes can also be equilibria

We can describe equilibria quantitatively using **reaction quotients (Q)**

$$mA + nB \rightleftharpoons xC + yD$$

$$Q = \frac{[C]^x[D]^y}{[A]^m[B]^n}$$

- Ratio of products to reactants each raised to the power of their stoichiometric coefficient
  - large Q = mostly products
  - small Q = mostly reactants
- Such a system will move until it reaches equilibrium
  - at this point the Q = K_c (equilibrium constant)

$$K_c = \frac{[C]^x[D]^y}{[A]^m[B]^n}$$

- Same expression as Q, but it is a constant value that represents proportions at equilibrium
- Comparing Q to K_c tells us which direction an equilibrium will shift

We can perform calculations to determine equilibrium concentrations
- Changes in concentration will always obey stoichiometry
- These changes can be represented algebraically

1. Calculate K_c given equilibrium concentrations. Easiest calculation, plug concentrations into the equilibrium expression and solve for the equilibrium constant.
2. Calculate a missing equilibrium concentration given the others and K_c. Again just plug everything in and solve for the unknown.
3. Calculate K_c given some initial concentrations and some equilibrium concentrations.
4. Calculate equilibrium concentrations given initial concentrations and K_c.
   - 3 and 4 are more difficult, may need to use an **ICE box**

	A	+	B	←→	C
Initial	1		1		0
Change	-x		-x		+x
Equilibrium	1-x		1-x		x

We can then plug the expressions representing equilibrium concentrations into the equilibrium expression and solve for X, which will allow us to assign the equilibrium concentrations algebraically. We may need to use the *quadratic formula* in order to do so.

AP Chemistry Ultimate Review Packet
Unit 7: Equilibrium

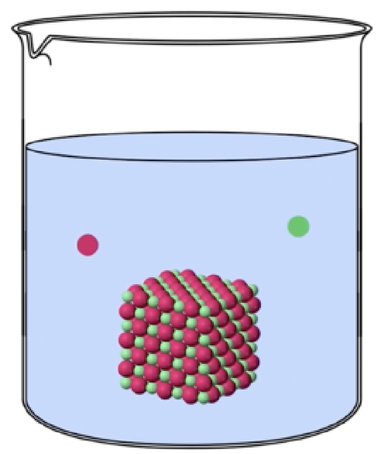
Le Chatelier's Principle

If a stress is placed on a system at equilibrium we describe the result using **Le Chatelier's principle**

- an equilibrium experiencing a stress will move so as to relieve that stress
- there are three types of stresses that can be placed on a system at equilibrium

1. **Change in concentration of a reactant or product**
    - reactant increases ⟶ equilibrium shifts right
    - reactant decreases ⟶ equilibrium shifts left
    - product increases ⟶ equilibrium shifts left
    - product decreases ⟶ equilibrium shifts right
2. **Change in pressure**
    - pressure increases ⟶ shift to side with fewer gas particles
    - pressure decreases ⟶ shift to side with more gas particles
    - if no difference in number of gas particles there is no shift
3. **Change in temperature**
    - must consult the change in enthalpy
        - if exothermic treat "heat" as a product
            - T goes up, shifts left; T goes down, shifts right
        - if endothermic treat "heat" as a reactant
            - To goes up, shifts right; T goes down, shifts left

Equilibria and Solubility



We can consider **dissolution** an equilibrium as well

- compounds regarded as insoluble still do *dissolve* to a tiny degree
- components of insoluble compounds can also *precipitate* from solution
- these equilibria are described by the solubility product constant (K_{sp})

    e.g. $AgCl(s) \rightleftharpoons Ag^+(aq) + Cl^-(aq)$ $K_{sp} = [Ag^+][Cl^-]$

    - solids are not included in the K_{sp} expression
- we can use ion concentrations to calculate K_{sp}
- we can use K_{sp} to calculate the molar solubility (mol/L formula unit dissolved)
- calculations may require use of an ICE box

We can control precipitation using the **common ion effect**, which is an application of Le Chatelier's principle that pertains to dissolution equilibria.
Consider the following equilibrium: $AgI(s) \rightleftharpoons Ag^+(aq) + I^-(aq)$

- if we want to promote precipitation of silver iodide we can introduce another ionic compound that has an ion in common with AgI
- add KI, addition of iodide ions causes equilibrium to shift left
- this shift will promote generation of reactant and thus precipitation