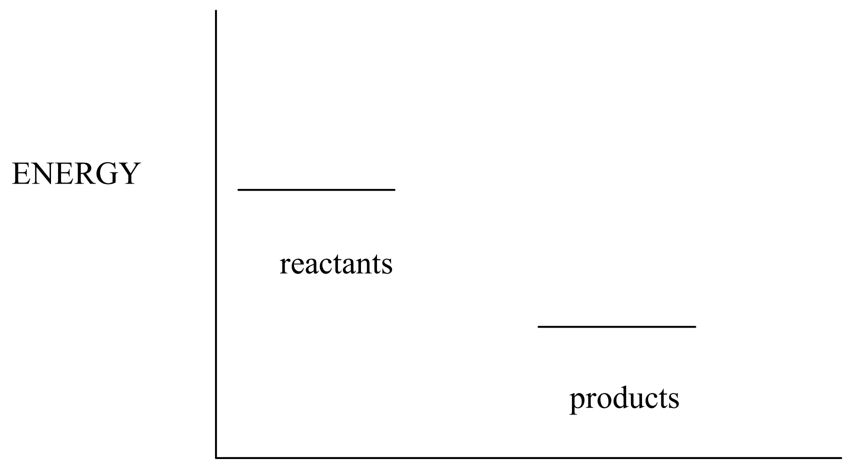
Factors that affect the distribution of elements on earth

Two things determine why and when chemical reacts. Molecules can react when the energy of the products (under conditions of constant pressure, this kind of energy is technically called "Gibbs Free Energy" and often symbolized with a "G") is lower than the energy of the reactants.



Whether they actually do react or not depends on factors that control the *rate* of the reaction. It is possible for a reaction to be energetically "downhill" but to occur so slowly that it will not happen during a human lifetime.

It is also possible for reactions to occur that are energetically uphill AS LONG AS ENERGY IS ADDED TO THE SYSTEM. Sources of energy in the environment include thermal energy, photons, and of course inside organisms the energy that comes from the metabolism of food.

Molecules will tend to react until they reach EQUILBRIUM. At equilibrium, the distribution between reactants and products is at an optimum for that particular system. For reactions with large differences between the energies of the products and reactants, equilibrium will tend towards an "all-or-nothing" situation where either all products are converted to reactants or all reactants are converted to products. For many other reactions, however, the lowest energy state will be one in which they are still some products and some reactants.

For a hypothetical chemical reaction: aA + bB → cC + dD the equilibrium constant is defined as:

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

As should be apparent from the equation, there will be an infinite number of combinations of equilibrium concentrations. What matters is that the ratio of products and reactants is constant when the system reaches its lowest energy point. Until the system does reach equilibrium, there will still be a force pushing the system to continue reactant. Again, the extent to which those reactions occur will depend on the factors that control the rates of the reaction.

The equilibrium constant is related to the free energy difference in the system in the following manner.

$\Delta G^0 = -RT\ln K$

It is often not easy to tell if a system is or is not at equilibrium. This is particularly true of complex systems in the environment. However, it is still useful for environmental scientists to consider the equilibrium state because that tells us where the system is heading.

There are some systems whose equilibrium expressions are of particular interest to environmental scientists. These are briefly described below.

Equilibrium between gas and liquid (temperature) (Henry's law)

g $\leftrightarrow$ aq Kh = [aq]/(g)

Equilibrium between solid and ions dissolved in solution (Ksp)
Salt $\leftrightarrow$ A+ + B- Ksp = [A+][B-]

Acid and base dissociation constants (Ka and Kb)

Acid = HA HA $\leftrightarrow H^+ + A^-$ $K_a = \frac{[A^-][H^+]}{[HA]}$

Base = B B + $H_2O \leftrightarrow BH^+ + OH^-$ $K_b = \frac{[BH^+][OH^-]}{[B]}$

Vapor pressure is the pressure of a chemical in gas form above the liquid form of the same chemical. The greater the vapor pressure of a compound (at a given temperature) the more volatile the compound is. Vapor pressure is generally related to molecular weight but not always – intermolecular forces have profound effects on vapor pressure.

There are rules that govern the solubility of salts, although if you can look up the solubility constant for a given compound you can predict how much it will dissolve in water. For those of you with limited background in chemistry, ionic solids are the primary solids that dissolve in water to any extent. They are made up of positively and negatively charged ions – for example table salt is NaCl, which is made up of sodium cations (Na^+) and chloride anions (Cl^-). Metals in their elemental form do not dissolve in water. Organic compounds – these are things like oils and plant matter – do not mix well with water. The extent to which organic compounds mix in water at all is an important quality in determining the toxicity of organic compounds.