Solubility

Solubility

- The maximum amount of solute that will dissolve in a given amount of solvent at a specified temperature and pressure

Unsaturated Solutions

- have the capacity to dissolve more of the solute

Saturated Solutions

- have dissolved the maximum amount of solute possible at a given temperature
  - This is defines the solubility of the solute in the solvent

Supersaturated Solutions

- contain more solute than is present in a saturated solution

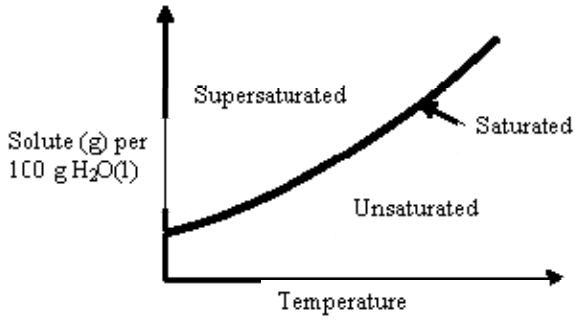
How does supersaturation work?

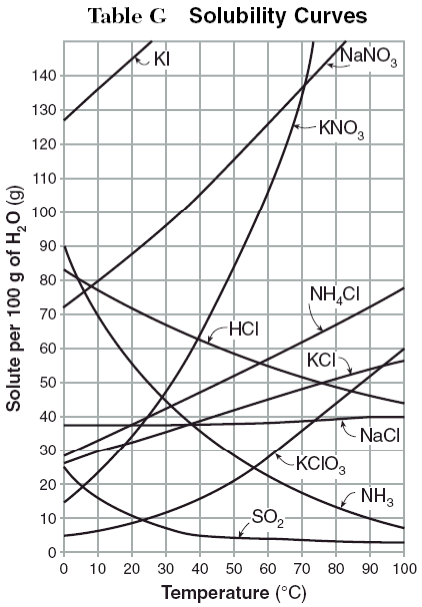
- We know that hot water dissolves more sugar than cold water.
- When we cool a saturated solution of hot sugar water, the water can no longer keep all of the sugar dissolved.
- Some sugar must crystallize from the solution.

- However, crystallization requires a nucleation site such as another sugar crystal or a speck of lint for the crystal to grow.
- If our container is scrupulously clean the crystals have no place to begin growth!
- But if we add a crystal of sugar to the supersaturated solution, the "extra" sugar will rapidly drop of out this metastable solution until the solution is again saturated.

Solubility Curve

- A solubility curve can be used to determine how much solute can be dissolved in a solvent at a given temperature





Example 1

- What is the solubility of potassium nitrate, KNO_3, at 44°C?
  - 72 g of solute/100 g of water

Example 2

- 25 g of potassium nitrate is dissolved in 50 g of water at 30°C. Determine whether this solution is saturated. If yes, explain why.

$$\frac{25\text{g}}{50\text{g of water}} = \frac{x}{100\text{g of water}}$$

$$x = 50\text{g}$$

  – If this value is transferred to the solubility curve graph, the point is exactly on the line, which means that the solution must be saturated at 30°C.

Example 3

- A solution contains 5.2 g of potassium nitrate, KNO_3, dissolved in 10 g of water at 40°C. What amount of KNO_3 would be required to saturate this solution?

$$\frac{5.2\text{g}}{10\text{g of water}} = \frac{x}{100\text{g of water}}$$

$$x = 52\text{g}$$

- From the solubility chart we see that 52 g is below the line (unsaturated)
- The saturated value is 64 g
- Therefore we can add 64-52=12 g more KNO_3 (in 100 g of water)

$$\frac{12\text{g}}{100\text{g of water}} = \frac{x}{10\text{g of water}}$$

$$x = 1.2\text{g}$$

Example 4

- A solution contains 33 g of KNO_3 in 30 g of water at 72°C. How much must this solution be cooled to saturate the solution?

$$\frac{33\text{g}}{30\text{g of water}} = \frac{x}{100\text{g of water}}$$

$$x = 110\text{g}$$

- If this data is transferred to the solubility curve graph, the point is to the right of the saturation curve.
- To saturate this solution, the temperature would need to be cooled to 58°C.

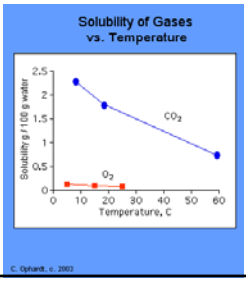
Temperature and Solubility

- Increase in solubility with temperature
  - Most common
  - If the heat given off in the dissolving reaction is less than the heat required to break apart the solid, the net dissolving reaction is endothermic (energy required)
  - The addition of more heat helps the dissolving reaction by providing energy to break bonds in the solid

- Decrease in solubility with temperature
  - Not very common
  - If the heat given off in the dissolving process is greater than the heat required to break apart the solid, the net dissolving reaction is exothermic (energy given off)
  - The addition of more heat (increases temperature) prevents the dissolving reaction since excess heat is already being produced by the reaction

How does a change in temperature affect the solubility of gases?

- As the temperature increases, the solubility of a gas decreases
- More gas is present in a solution with a lower temperature compared to a solution with a higher temperature

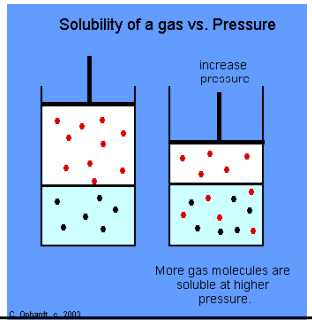


- Increased temperature causes an increase in kinetic energy
- The higher kinetic energy causes more motion in molecules which break intermolecular bonds and escape from solution
  - Carbon dioxide gas escaping faster from a carbonated drink as the temperature increases
  - Boiled water tastes flat because the dissolved oxygen has escaped

How does a change in pressure affect the solubility of gases?

- Liquids and solids exhibit practically no change of solubility with changes in pressure
- Gases increase in solubility with an increase in pressure

- If the pressure is increased, the gas molecules are "forced" into the solution since this will best relieve the pressure that has been applied
  - The number of gas molecules is decreased
  - The number of gas molecules dissolved in solution has increased



- Carbonated beverages
  - All carbonated beverages are bottled under pressure to increase the carbon dioxide dissolved in solution
  - When the bottle is opened, the pressure above the solution decreases
  - As a result, the solution effervesces and some of the carbon dioxide bubbles off

- Deep sea divers may experience a condition called the "bends" if they do not readjust slowly to the lower pressure at the surface
  - As a result of breathing compressed air and being subjected to high pressures caused by water depth, the amount of nitrogen dissolved in blood and other tissues increases
  - If the diver returns to the surface too rapidly, the nitrogen forms bubbles in the blood as it becomes less soluble due to a decrease in pressure

  - The nitrogen bubbles can cause great pain and possibly death.
  - To alleviate this problem somewhat, artificial breathing mixtures of oxygen and helium are used
    - Helium is only one-fifth as soluble in blood as nitrogen so there is less dissolved gas to form bubbles.

Henry's Law

- The solubility of a gas in a liquid is directly proportional to the pressure of that gas above the surface of the solution.
  - This law is most accurate for gases that do not dissociate in or react with the liquid
    - Henry's Law is accurate for dissolved oxygen gas but not, for instance, HCl, which easily dissociates in solution