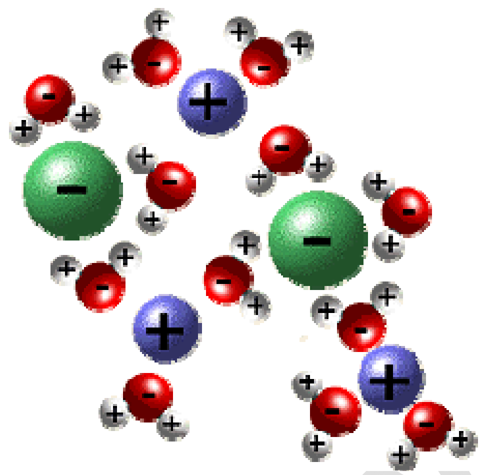
Name ___________________ **Chemistry** **___/___/___**

Solutions

Solutions are stable homogeneous mixtures which means they are consistent throughout and do not separate under normal conditions. **Suspensions** are mixtures that appear to be uniform throughout while they are being stirred but separate when agitation ceases. Suspensions differ from solutions in that the particles in a suspension are usually larger than 100 nm. In a solution, the particle size is usually smaller than 1 nm. Clay in water is an example of a suspension. While it is being stirred, the clay-water mixture appears uniform throughout, but the clay will fall to the bottom when the mixture is left to settle. Suspensions are not solutions; they are only heterogeneous mixtures. Colloids are mixtures containing particles that are intermediate in size (1nm – 100 nm) between those of suspensions and solutions. Paint, aerosol sprays and smoke are examples of colloids.

Solid, liquid & gaseous solutions all exist. An example of a solid solution is brass, which is a mixture of solid copper and solid zinc. Brass is also considered an **alloy**, which is a mixture of elements with an overall metallic property. Air, which is a mixture of nitrogen, oxygen, water vapor, argon, carbon dioxide and a few other trace gases, is an example of a gaseous solution where gases dissolve in gases. Ocean water, which contains water, sodium chloride, calcium bicarbonate and other inorganic salts, is an example of a liquid or aqueous solution where solids are dissolved in a liquid. Another solution is soda, which is a solution where a gas is dissolved in a liquid.

Solutions are composed of a **solute**, the substance that gets dissolved, and a **solvent**, the substance that does the dissolving. When the solute mixes homogeneously a **solution** is formed. A solid solute that dissolves in solution is called **soluble**; a solid solute that only partially dissolves in solution is **partly soluble**; a solid solute does not dissolve in a solvent is **insoluble**. When referring to the solubility of liquid or gases in one another, a different set of terms is used. If two or more liquids or gases dissolve in one another, they are said to be **miscible**. If two or more gases or liquids do not dissolve in one another they are said to be **immiscible**. For example: Salt is soluble in water. Ethyl alcohol is miscible in water. Sand is insoluble in water. Oil is immiscible in water.

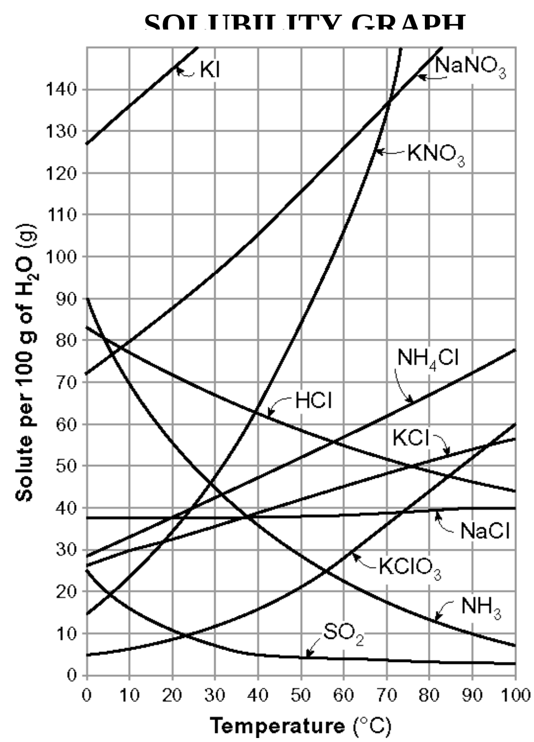


Most ionic compounds are soluble in water. The strong ionic bonds that hold ionic compounds together are overcome by polar water molecules and the ionic compounds separate into ions. The cation (positively charged ion) is attracted to the negative end of the water molecule (oxygen) and the anion (negatively charged ion) is attracted to the positive ends of the water molecule (hydrogens). When ionic compounds break into ions in solution, they are said to **dissociate**. The dissociation of sodium chloride in water can be seen in the diagram here:

$$NaCl(s) \xrightarrow{H_2O(l)} Na^+(aq) + Cl^-(aq)$$

Solubility of molecular compounds is a little different. Generally a polar solute will dissolve in a polar solvent and a non-polar solute will dissolve in a non-polar solvent. To sum this up, scientists say **LIKE DISSOLVES LIKE**. This means a polar compound like ammonia (NH_3) will dissolve in a polar solvent like water. Oils which are non-polar do not dissolve in water. Dry cleaners use a non-polar solvent to remove oil left in clothes. Ionic compounds generally dissolve in polar solvents but do not dissolve in non-polar solvents.

Even for very soluble substances there is a limit to the amount of solute that can dissolve in a given amount of solution. When a solution holds as much solute as it possibly can at a given temperature, the solution is considered **saturated**. If a solution contains less than the maximum amount of solute that it can possibly hold at a given temperature, the solution is called **unsaturated**. If a solution contains more than the maximum amount of solute in solution at a given temperature, the solution is said to be **supersaturated**. The usual way to supersaturate a solution is to heat it up, add the maximum amount of solute for that temperature and then cool the solution down.



The chart to the right shows the solubility of various substances in 100 grams of water at various temperatures. As a general rule, solids generally increase in solubility with an increase in temperature. Gases generally become less miscible in water as the temperature increases. Note that although most solids on the graph increase with an increase in temperature, gases like NH_3 and SO_2 actually decrease with an increase in temperature.

Sometimes scientists use the terms **concentrated** and **dilute** to refer to a solution. These are qualitative terms which are only slightly informative. A concentrated solution contains a relatively large amount of solute dissolved in solution. A dilute solution contains a relatively small amount of solute dissolved in solution. Later this chapter we will calculate the **concentration** of a solution using molarity. **Molarity** is the number of moles of a solute per liter of solution.

$$\text{Molarity(M)} = \frac{\text{moles of solute}}{\text{liters of solution}}$$

Several factors affect the rate at which a solute dissolves in a solvent.

- **Agitation** - shaking or stirring a solution brings fresh solvent in contact with the solute. Thus, dissolving occurs faster. This is why people stir their coffee or tea after adding sugar.
- **Temperature** – increasing the temperature of a solvent causes the particles to increase their speed and thus the amount collisions between the solvent and solute. This is similar to the affect stirring has on the solution.
- **Surface Area** – breaking up a solute into smaller pieces exposes more of its surface to the solvent. This causes a ground up solvent to dissolve faster than a solute that is all one piece.

Note that the three factors above only affect the rate at which a soluble substance will dissolve in a solvent. The methods will not make an insoluble solvent dissolve in solution. In some cases a suspension will occur but particles will then settle out of solution. **Emulsions** are colloidal dispersions of liquids in liquids. An emulsifying agent is necessary for the formation of an emulsion and for maintaining its stability. **Emulsifying agents** stabilize an emulsion that would normally separate into different phases. In cooking emulsifying agents are used to hold oil and water together, two substances that normally do not mix. Some emulsifying agents include: Arabic gum, carrageenan, polysorbates and xanthan gum. Emulsifying agents work as a bridge between substances that do not mix by having a polar and non-polar end and thus being able to dissolve in both types of substances. Soap is another example of an emulsifying agent. To remove oil from our skin, we need a substance that can attach to oil as well as to the water we wash with.

Homework:

Use the information above to answer the following questions.

1. Give an example of a solution.

2. Give an example of a suspension.

3. Give an example of a colloid.

4. Compare the size of the particles in a solution, suspension and a colloid.

5. Stainless steel is 80.6% iron, 18.0% chromium 0.4% carbon and 1.0% nickel. Is this a solution? Explain.

6. Give an example of a solid solute in a liquid solution.

7. Give an example of a gas solute in a liquid solution.

8. What is another name for a liquid solution?

9. What two parts make up solutions?

10. When should the term soluble be used and when should the term miscible be used?

11. What is it called when ionic compounds break into ions in solution?

12. Write an equation to show how potassium iodide would dissociate in water.

13. What is the rule to determine whether two substances will dissolve in one another?

14. Carbon tetrachloride is non-polar. Will it dissolve in water or oil? Explain.

15. Does sodium chloride dissolve in oil? Explain.

16. How do you make a supersaturated solution?

17. Generally as the temperature increases does the solubility of ionic compounds in water increase or decrease?

18. Generally as the temperature increases does the solubility of gases in water increase or decrease?

19. Would a saturated solution be considered concentrated or dilute?

20. What is the formula for calculating molarity?

21. What is the symbol used to represent molarity?

22. What three factors affect the rate at which a substance dissolves in a solvent?

23. Can the three factors that speed up the rate at which a substance dissolves in solvent cause an insoluble substance to be soluble?

24. What is the purpose of emulsifying agents?

25. How do emulsifying agents work?

26. Name three emulsifying agents.

Use the chart on the right to answer the following questions.

27. How many grams of $KClO_3$ can be dissolved in 100 grams of water at 50°C?

28. Which substance on the chart is most soluble in 100 grams of water at 20°C?

29. Which substance on the chart is least soluble in 100 grams of water at 10°?

30. Which substance on the chart is least affected by the increase in temperature?

31. Which substance on the chart is most affected by an increase in temperature?

32. Which three substances become less soluble in water as the temperature increases?

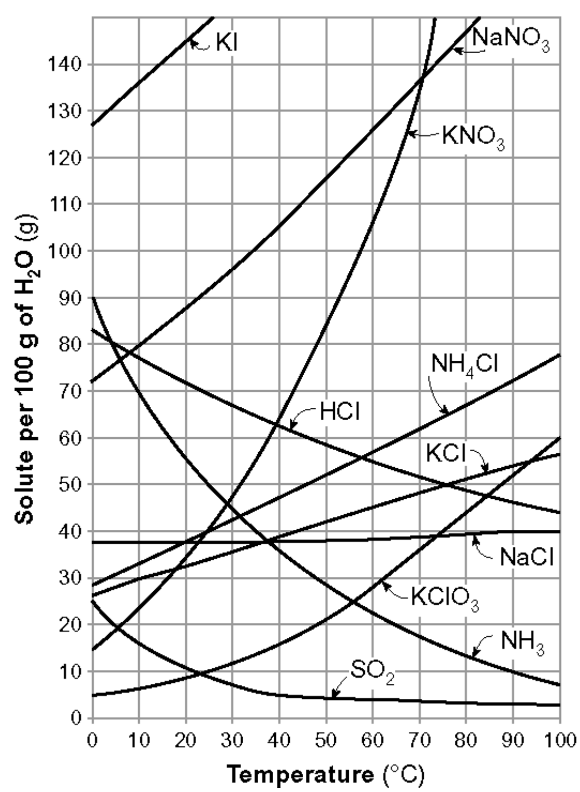
33. How many grams of HCl can be dissolved in 50 grams of water at 50°C?

34. If 30 grams of KNO_3 are added to 100 grams of water at 50°C, is the solution unsaturated, saturated or supersaturated?

35. If 70 grams of KCl are added to 100 grams of water at 60°C, is the solution unsaturated, saturated or supersaturated?

36. A solution is prepared where 40 grams of NaCl is added to 100 grams of water at 90°C. The solution is then cooled to 40°C. Is the solution unsaturated, saturated or supersaturated?

SOLUBILITY GRAPH



37. How many grams of ammonium chloride are needed to add to 50 grams of water at 60°C to make a saturated solution?

Solve each of the following molarity problems. Give your answer with the correct number of significant figures.

38. A saline solution contains 12.0 moles of NaCl per 2.00 L of solution. What is its molarity?

39. A 800. mL salt solution contains 0.700 moles of NaCl. What is the molarity of the solution?

40. How many moles of solute are present in 1.5 L of 0.20 M Na_2SO_4?

41. How many moles of calcium chloride are necessary to make 250. mL of 2.00M solution?

42. What is the molarity of a sodium hypochlorite bleach that contains 12.5 moles of NaOCl in 2.00 L of solution?

43. How many liters of water do you need to dissolve 5.00 moles of sodium chloride into if you want to produce a 6.00 molar solution?

44. How many grams of table sugar (sucrose: $C_{12}H_{22}O_{11}$) will be needed to make 3.50 L of a 1.15M solution?

45. How many grams of sodium chloride (NaCl) will be needed to make 75.0 mL of 0.250 M solution?

46. If I used 188 g of $CaCl_2$ to make 2.60 liters of solution, what will be the Molarity of the solution?

47. If somebody gave me 200. grams of Na_2SO_4 and I made a solution with a volume of 500. mL, what would its molarity be?

48. If I put 20.0 grams of sugar ($C_{12}H_{22}O_{11}$) in water and made 500. mL of solution, what is the molarity?

49. How many L of solution would you need if you wanted to make a 6.0 Molar solution and all you had was 50.0 grams of $AlBr_3$?