Solutions:
An Introduction

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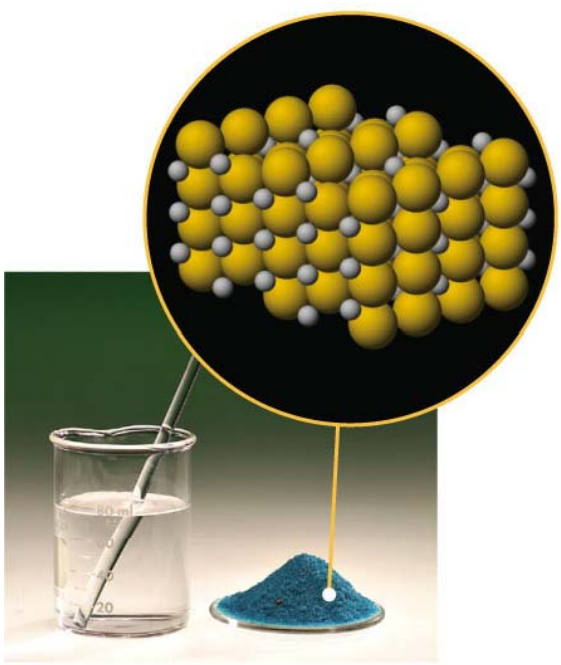
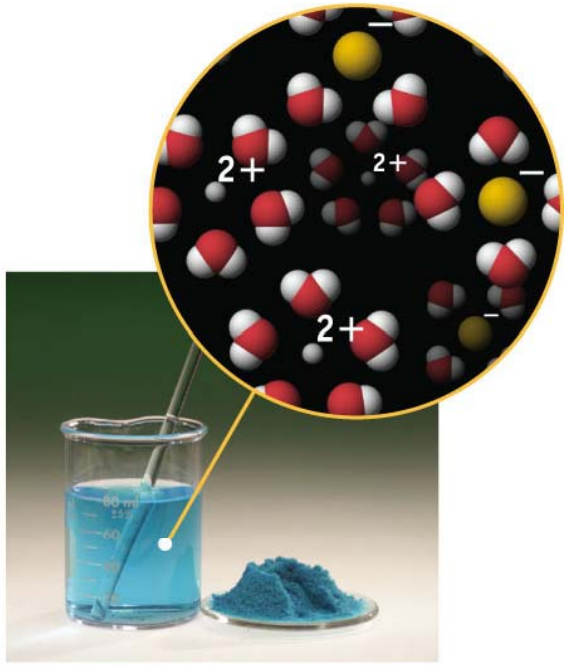


(a) Copper(II) chloride, the solute, is added to water, the solvent.



(b) Interactions between water molecules and Cu^{2+} and Cl^- ions allow the solid to dissolve. The ions are now sheathed with water molecules.

A solution is a **HOMOGENEOUS** mixture of 2 or more substances in a single phase.

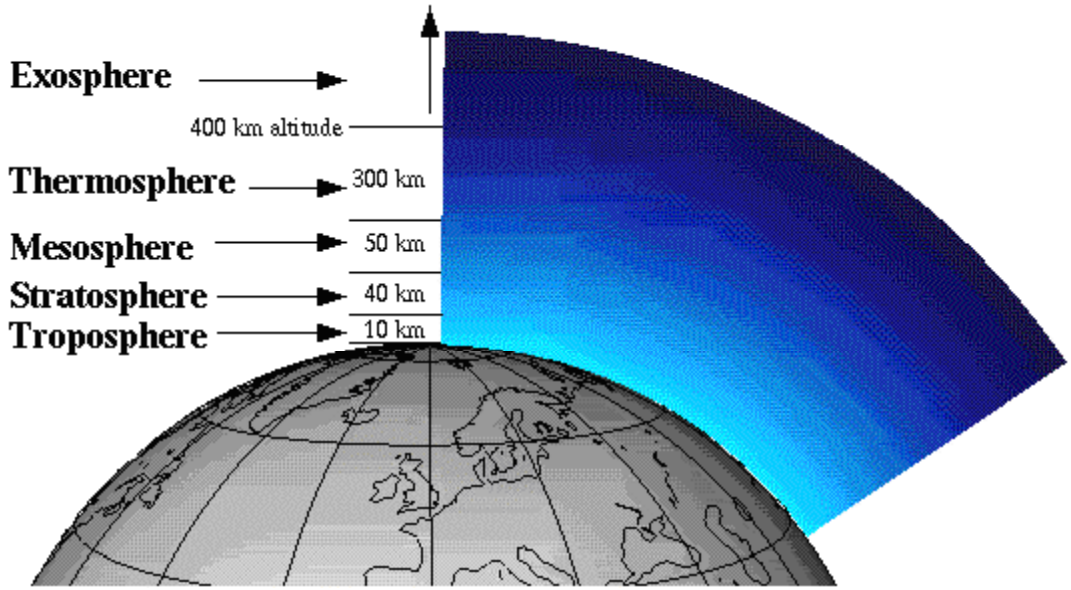
One constituent is usually regarded as the **SOLVENT (usually water)** and the others as **SOLUTES**.

Solutions

- **In a solution, the solute is dispersed uniformly throughout the solvent.**

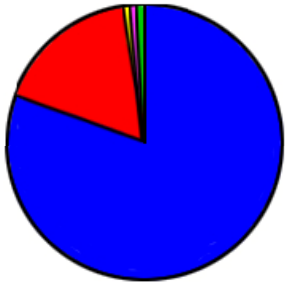
State of Solution	State of Solvent	State of Solute	Example
Gas	Gas	Gas	Air
Liquid	Liquid	Gas	Oxygen in water
Liquid	Liquid	Liquid	Alcohol in water
Liquid	Liquid	Solid	Salt in water
Solid	Solid	Gas	Hydrogen in palladium
Solid	Solid	Liquid	Mercury in silver
Solid	Solid	Solid	Silver in gold

Solutions: Gases mixed with gases



Dry Air Expressed in Volumes	
Nitrogen (N_2)	78.1%
Oxygen (O_2)	20.9%
Argon (A)	0.9%
Carbon dioxide (CO_2)	0.035%
Others	0.065%

Others : Neon (Ne)
Helium (He)
Krypton (Kr)
Hydrogen (H_2)
Xenon (Xe)
Ozone (O_3)
Radon (Rn)



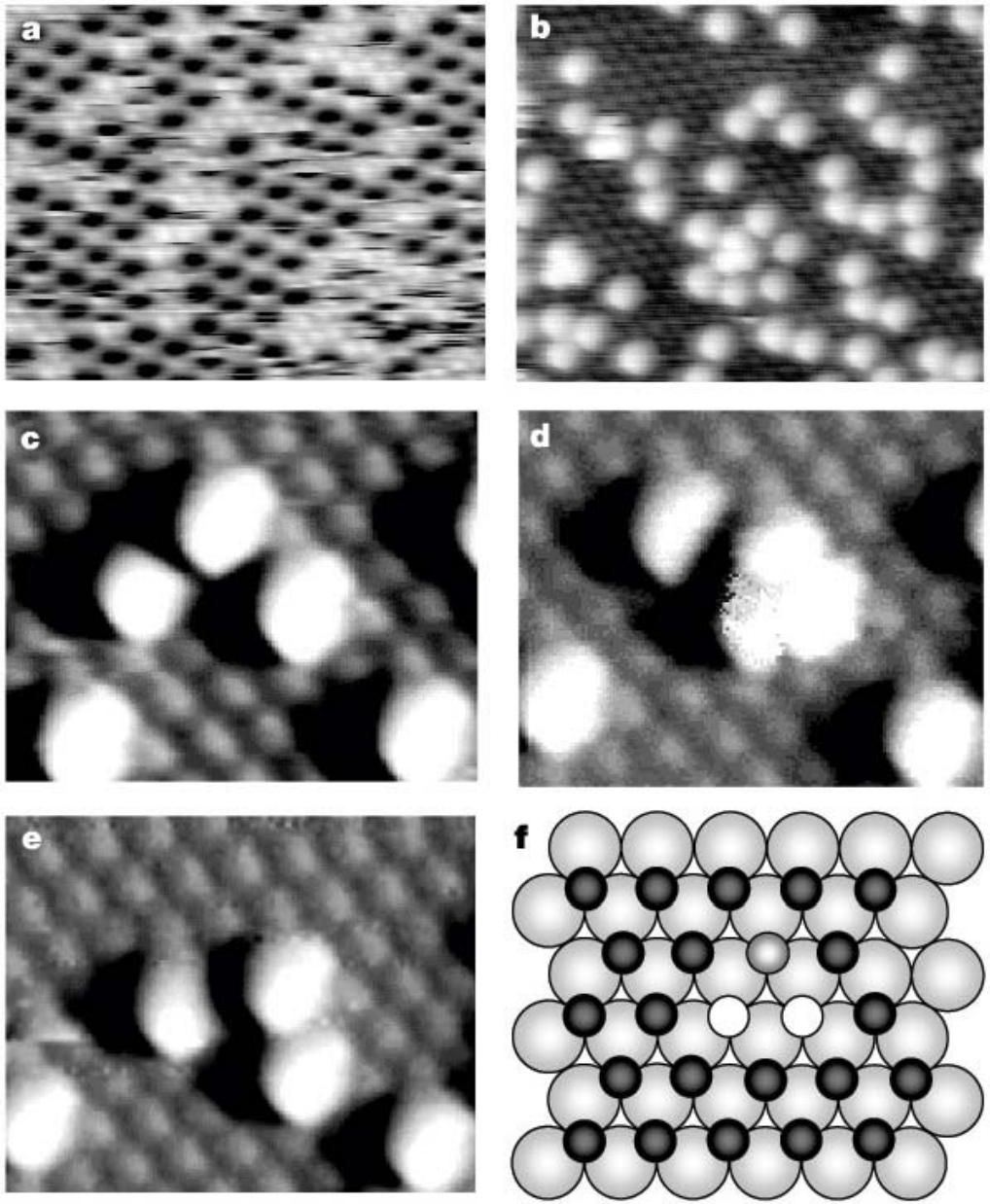
Solutions:
Gas mixed with liquid

Solutions: Liquid mixed with liquid

Solutions: Solid mixed with liquid

Solutions: Gas mixed with solid

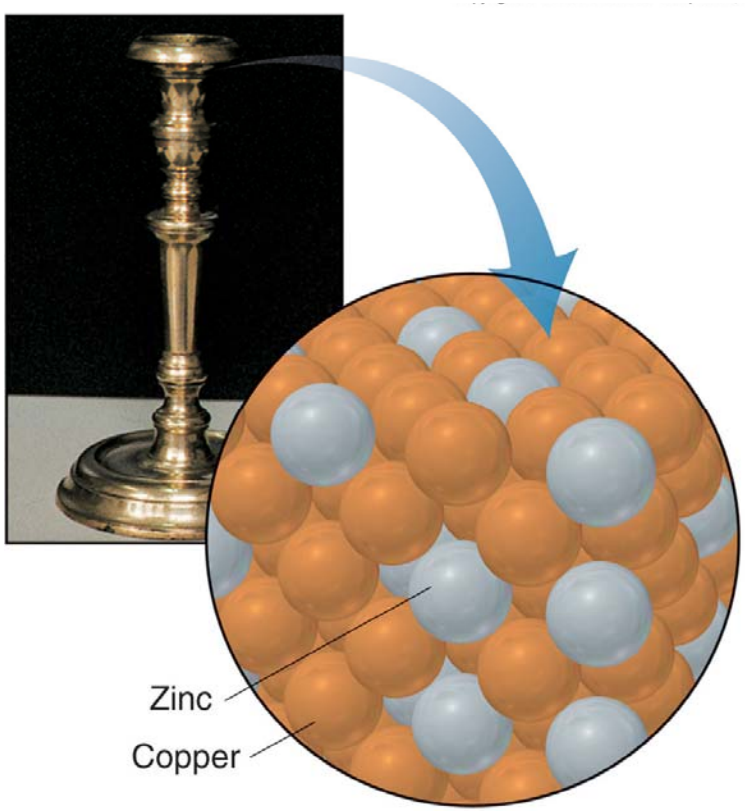
Photomicrographs of Hydrogen on palladium



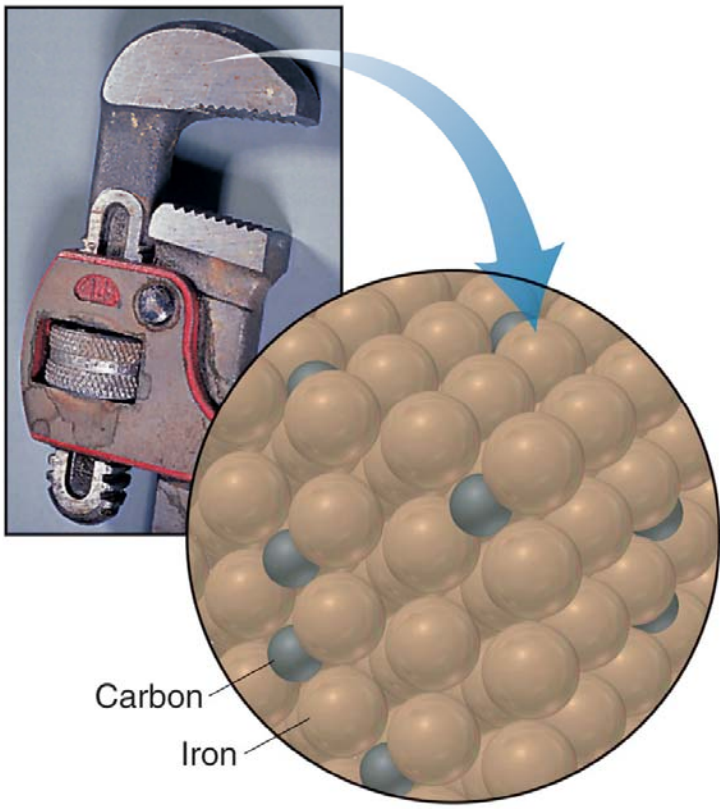
Solutions:
Liquid mixed with solid

(a mercury amalgam with gold)

Solutions:
Solid mixed with solid (alloys)



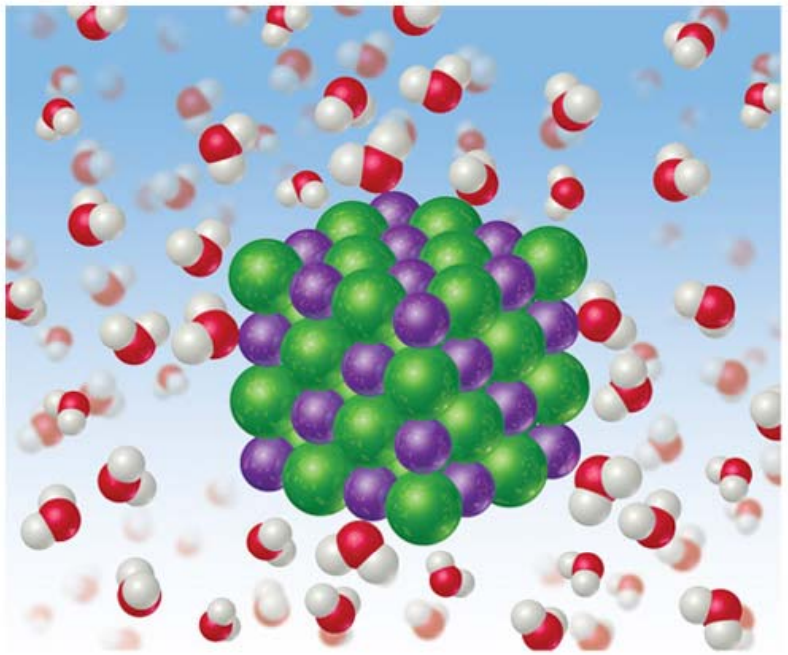
Brass: a substitution alloy



Carbon steel: an interstitial alloy

Intermolecular Forces
Why does a substance dissolve?

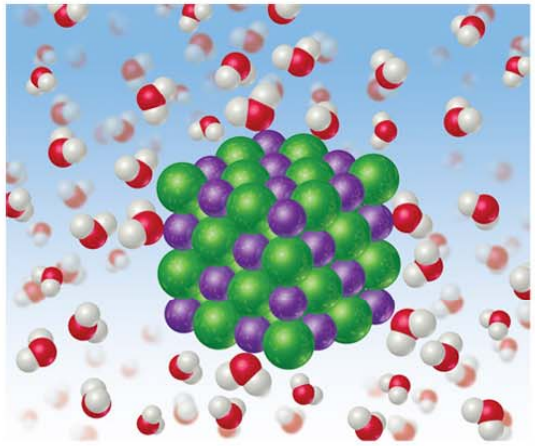
The intermolecular forces between solute and solvent particles must be strong enough to compete with those between solute particles and those between solvent particles.



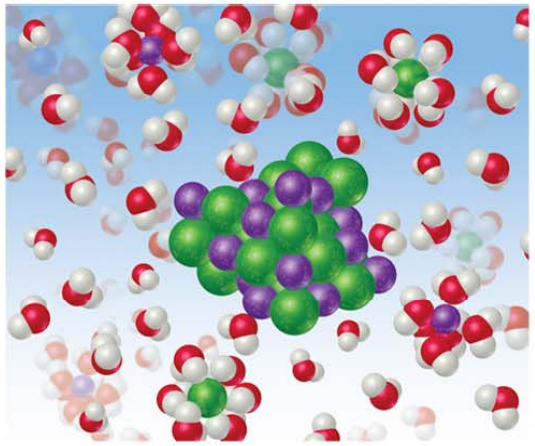
How Does a Solution Form?

In this example, we have an ionic solid, NaCl, and a polar solvent, H_2O.

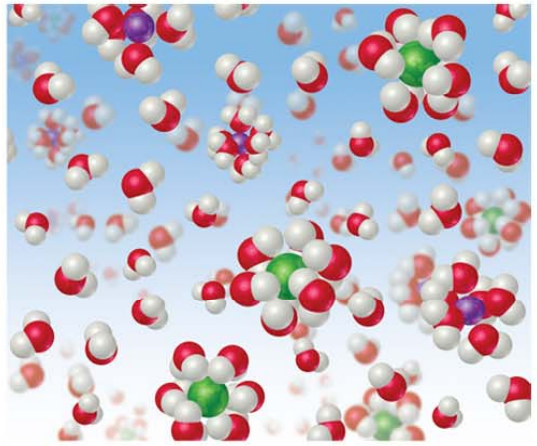
The solution forms because the solvent pulls solute particles apart and surrounds, or solvates, them. In water this is called hydration.



Solute (NaCl) in water



The solute is dissolving



Hydrated ions in solution

Solutions

- **Just because a substance disappears when it comes in contact with a solvent, it doesn't mean the substance dissolved.**
- **Dissolution is a physical change — you can get back the original solute by evaporating the solvent.**
- **If you can't, the substance didn't dissolve, it reacted.**

Water as a Solvent

- **How water dissolves molecular compounds:**
  - **When the nonpolar part of an organic molecule is considerably larger than the polar part, the molecule no longer dissolves in water.**

    For example ethanol, CH_3CH_2OH is soluble in water but butanol $CH_3CH_2CH_2CH_2OH$ is not

Factors Affecting Solubility

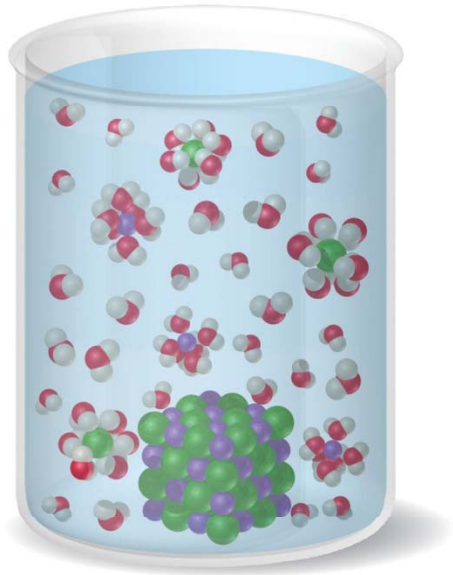
- **Chemists use the axiom "like dissolves like":**
  - **Polar and ionic substances tend to dissolve in polar solvents.**
  - **Nonpolar substances tend to dissolve in nonpolar solvents.**

TABLE 13.3 Solubilities of Some Alcohols in Water and in Hexane*

Alcohol	Solubility in H_2O	Solubility in C_6H_{14}
CH_3OH (methanol)	∞	0.12
CH_3CH_2OH (ethanol)	∞	∞
$CH_3CH_2CH_2OH$ (propanol)	∞	∞
$CH_3CH_2CH_2CH_2OH$ (butanol)	0.11	∞
$CH_3CH_2CH_2CH_2CH_2OH$ (pentanol)	0.030	∞
$CH_3CH_2CH_2CH_2CH_2CH_2OH$ (hexanol)	0.0058	∞
$CH_3CH_2CH_2CH_2CH_2CH_2CH_2OH$ (heptanol)	0.0008	∞

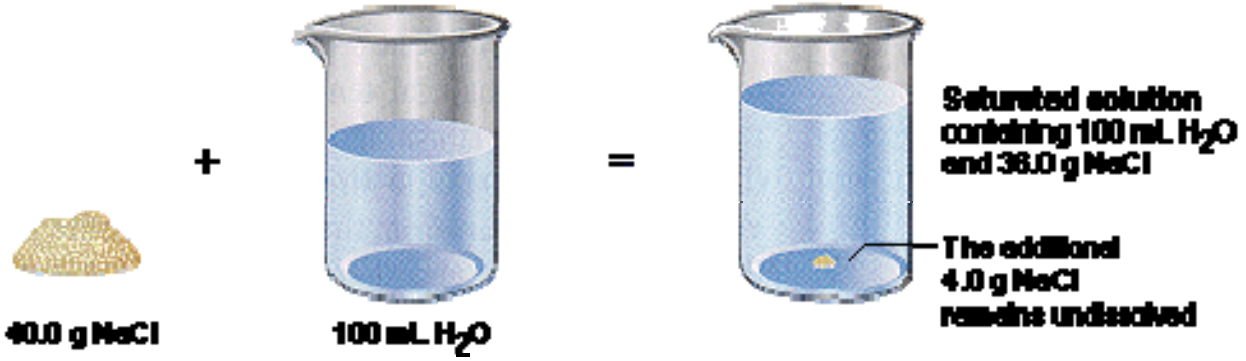
*Expressed in mol alcohol/100 g solvent at 20°C. The infinity symbol indicates that the alcohol is completely miscible with the solvent.

Types of Solutions



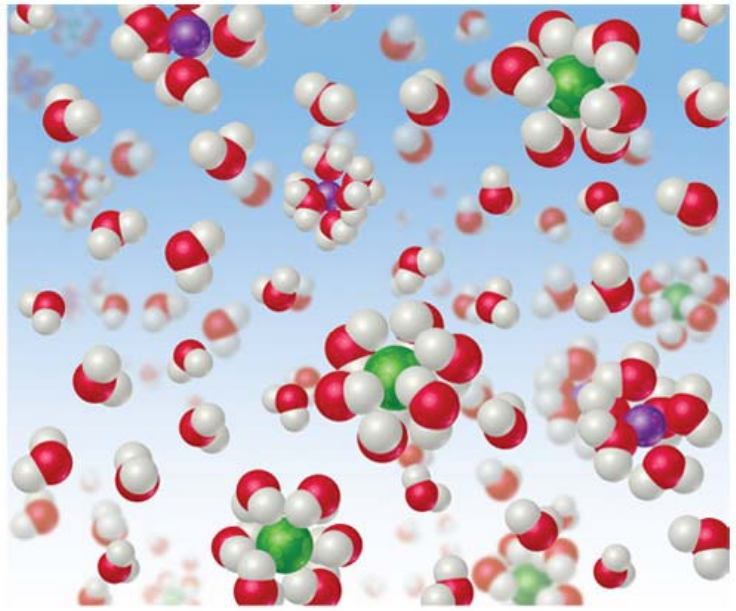
Saturated

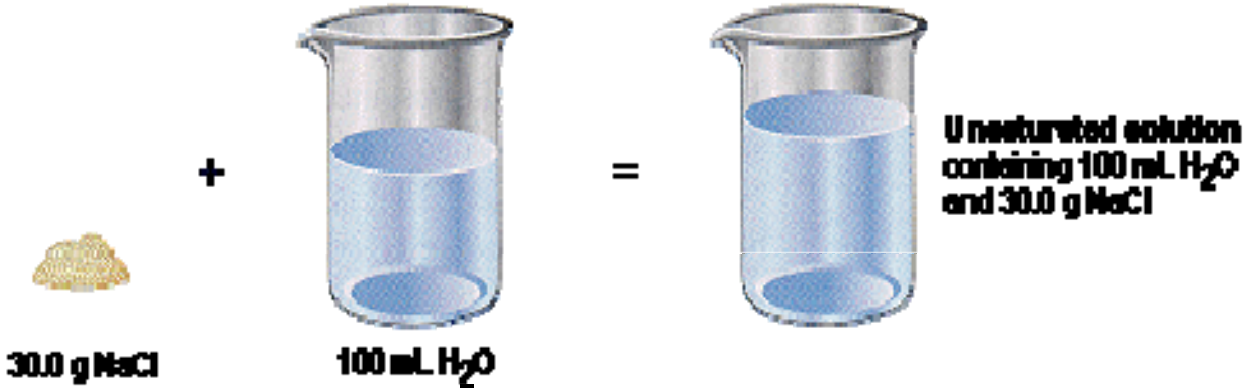
- Solvent holds as much solute as is possible at that temperature.
- To insure saturation, a small amount of solute remains undissolved on the bottom of the container
- Dissolved solute is in dynamic equilibrium with solid solute particles.



Types of Solutions

- **Unsaturated**
  - Less than the maximum amount of solute for that temperature is dissolved in the solvent.
  - The amount of solute in the solution can vary from a small amount to almost saturated





Types of Solutions

- **Supersaturated**
  - **Solvent holds more solute than is normally possible at that temperature.**
  - **These solutions are unstable; crystallization can usually be stimulated by adding a “seed crystal” or scratching the side of the flask.**



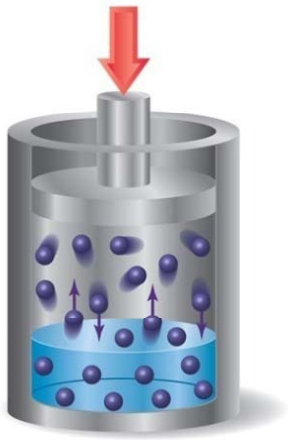

Gases in Solution

- In general, the solubility of gases in water increases with increasing mass.
- Larger molecules have stronger dispersion forces.

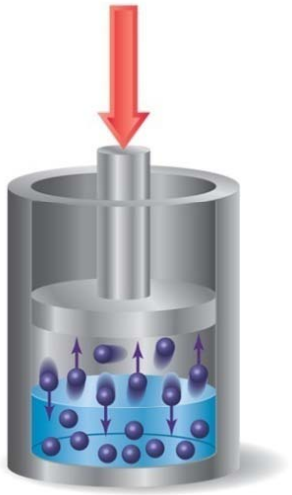
TABLE 13.2 Solubilities of Gases in Water at 20°C, with 1 atm Gas Pressure

Gas	Solubility (*M*)
N_2	0.69×10^{-3}
CO	1.04×10^{-3}
O_2	1.38×10^{-3}
Ar	1.50×10^{-3}
Kr	2.79×10^{-3}

Gases in Solution



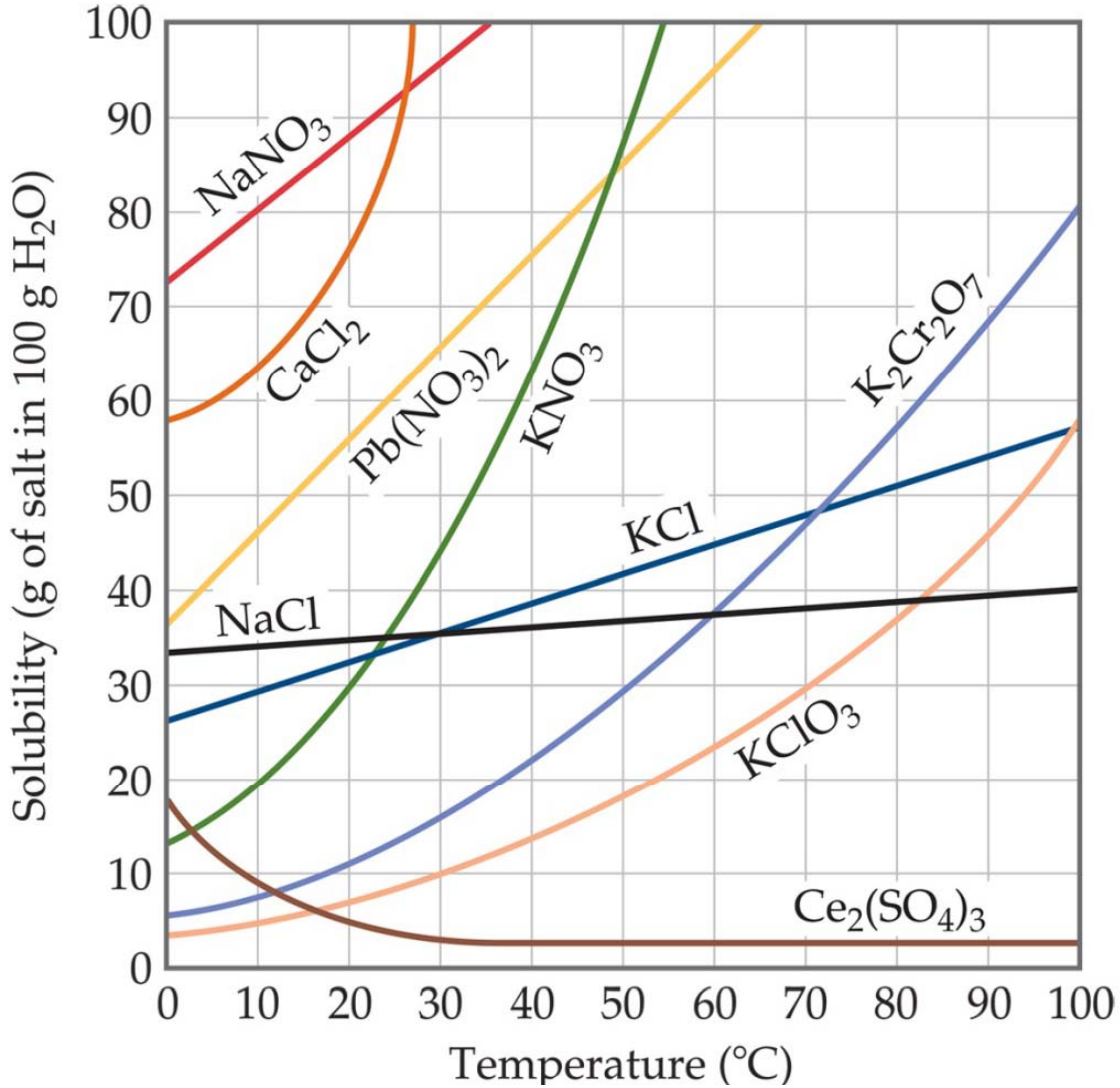
(a)



(b)

- The solubility of liquids and solids does not change appreciably with pressure.
- The solubility of a gas in a liquid is directly proportional to its pressure in contact with the liquid.

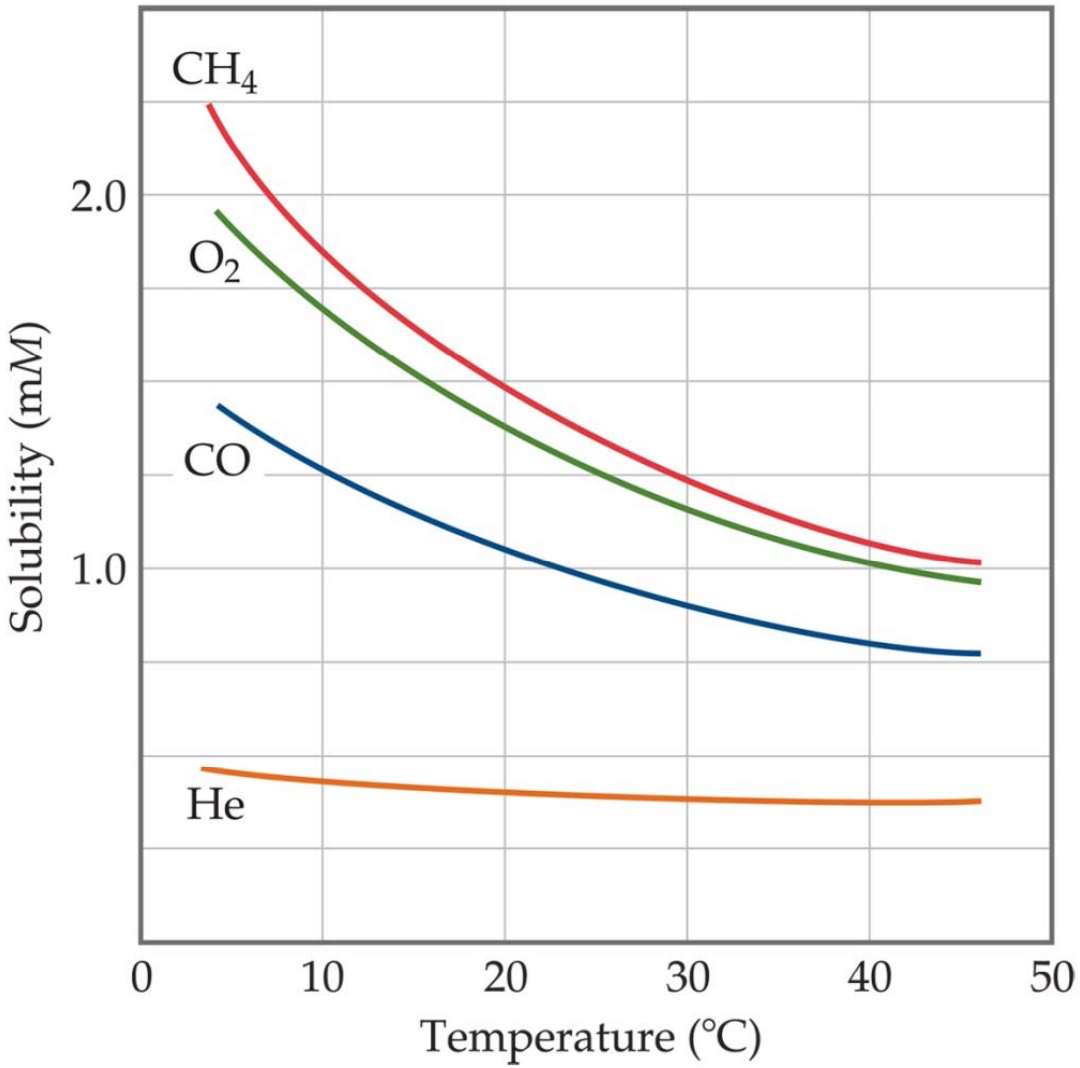
Temperature



Generally, the solubility of solid solutes in liquid solvents increases with increasing temperature.

Temperature

- **The opposite is true of gases:**
  - **Carbonated soft drinks are more "bubbly" if stored in the refrigerator.**
  - **Warm lakes have less O_2 dissolved in them than cool lakes.**



Expressing Concentrations of Solutions

Percent, %

Can be expressed as:

Percent by mass, $\%_{(m/m)}$

Percent by volume, $\%_{(v/v)}$ for solutions of liquids

Percent mass-volume, $\%_{(m/v)}$ for solids in liquids

$$\% \text{ of A} = \frac{\text{amount of A in solution}}{\text{total amount of solution}} \times 100$$

Most commonly, we use percent by mass

Parts per Million and Parts per Billion

Parts per Million (ppm)

$$\text{ppm} = \frac{\text{mass of A in solution}}{\text{total mass of solution}} \times 10^6$$

Parts per Billion (ppb)

$$\text{ppb} = \frac{\text{mass of A in solution}}{\text{total mass of solution}} \times 10^9$$

Molarity (*M*)

$$M = \frac{\text{mol of solute}}{\text{L of solution}}$$

An alternate equation is

$$M = \frac{g_{solute} \times 1000\,{}^{mL}\!/_{L}}{MW_{solute} \times mL_{solution}}$$

- Note: Because volume is temperature dependent, Molarity can change with temperature.

Electrolytes

Strong electrolyte: a compound that dissociates completely to ions in an aqueous solution.

Compound	Dissociates to	No. of ions per formula unit
$NaCl$	Na^+ and Cl^-	2
$CaCl_2$	Ca^{2+} and 2 Cl^-	3
K_2SO_4	2 K^+ and SO_4^{2-}	3
$Mg_3(PO_4)_2$	3 Mg^{2+} and 2 PO_4^{3-}	5

Ionic substances dissociate into the ions and polyatomic ions used in writing the chemical formulas of the compounds

Weak electrolyte: a compound that only partially dissociates to ions in an aqueous solution.

An example is acetic acid, $HC_2H_3O_2$, which exists as $HC_2H_3O_2$ molecules, H^+ and $C_2H_3O_2^-$ in water solution