Mixtures: Solutions and Colloids

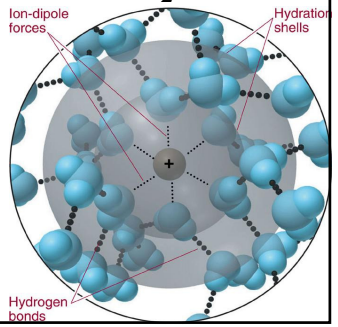
– Solutions – homogeneous mixtures (a single phase)
– Colloids – heterogeneous mixtures (two or more phases)

13.1 Types of Solutions and Solubility

– **Solvent** – the substance that dissolves; usually the most abundant component of the mixture; has the same physical state as the solution
– **Solute** – the substance that is dissolved
– **Solubility (*S*)** – the maximum amount of solute that can be dissolved in a given amount of solvent or solution
– **Concentration** of solute – various units are used

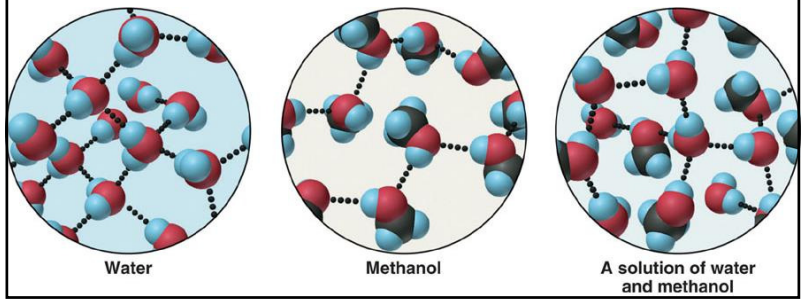
Intermolecular Forces in Solution

- All types of ***IF***s in pure substances also occur in solutions (in addition, ion-dipole forces are very common)
- **Ion-dipole** forces – present in solutions of ionic compounds in polar solvents such as H_2O
  – **Hydration** (solvation)
  • The water dipoles pull the ions away from the ionic crystal and surround them (typical coord. numbers 4 or 6)
  • There is a short range order around the ions consisting of H-bonded shells of water molecules



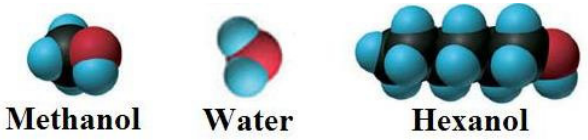
- **Dipole-dipole** forces – present in solutions of polar molecules in polar solvents such as H_2O
- **H-bonding** forces – present in solutions of O- and N-containing molecules (sugars, alcohols, amino acids, …) in protic solvents such as H_2O
- **Ion-induced dipole** forces – solutions of ionic compounds in less polar or non-polar solvents
- **Dipole-induced dipole** forces – present in solutions of polar molecules in non-polar solvents or non-polar molecules in polar solvents
- **Dispersion** forces – present in all solutions (most important for solutions of non-polar molecules in non-polar solvents)

- The **"like dissolves like rule"** – substances with similar types of ***IF***s dissolve in each other well
  – Strong solute-solvent ***IF***s lead to better solubility (lower the total energy of the system)
  – The solute-solvent ***IF***s created during dissolution must have comparable strength to the solute-solute and solvent-solvent ***IF***s destroyed in this process



Example:

- Water dissolves well alcohols (ROH) with short hydrocarbon chains (R) → methanol, ethanol, …
  - Strong H-bonding ***IF***s in the solute and the solvent are replaced with strong solute-solvent H-bonding ***IF***s
- Water does not dissolve well alcohols (ROH) with long hydrocarbon chains (R) → hexanol, …
  - Strong H-bonding in water is replaced with weaker ***IF***s between the water dipole and the large non-polar hydrocarbon chains (R) → (H-bonding with the OH part of the alcohol is a smaller fraction of the total ***IF***s)



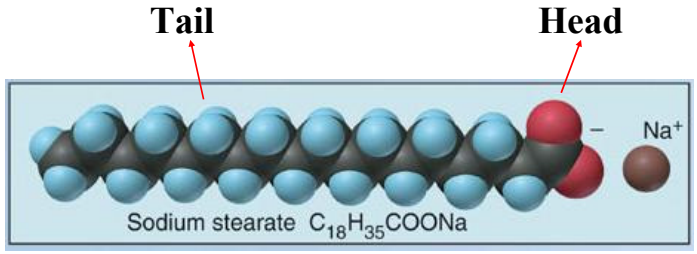
Example:

What is a better solvent for diethyl ether (CH_3CH_2-O-CH_2CH_3), water or propanol ($CH_3CH_2CH_2OH$)?

- Both water and propanol interact with ether through H-bonding
- Propanol and ether interact well through dispersion forces (similar non-polar hydrocarbon chains)
- Water can't interact well through dispersion forces with the hydrocarbon portion of ether

⇒ Propanol is a better solvent for ether

- **Soaps** – Na^+ salts of long chain carboxylic acids
  - Long, non-polar hydrocarbon "tail" → hydrophobic
  - Small, polar-ionic carboxyl "head" → hydrophilic
  - The polar head dissolves in water; the non-polar tail dissolves in grease → washing action
- **Detergents** – contain surfactants (surface-active compounds) → similar to soaps

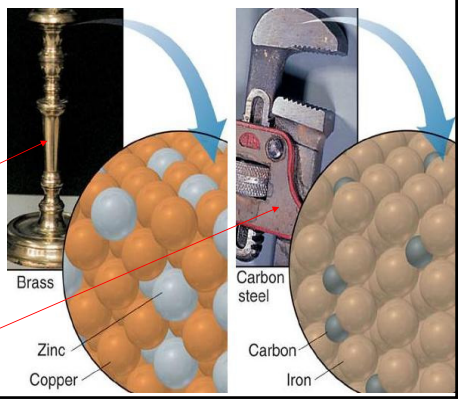


- **Liquid solutions** – the solvent is a liquid
  - Solid-liquid and liquid-liquid solutions
    - Some salts and polar molecular compounds dissolve well in water and short chain alcohols
    - Less polar solids dissolve well in less polar solvents like acetone, chloroform, ether, …
    - Non-polar substances dissolve best in non-polar solvents like hexane, benzene, …
  - Gas-liquid solutions
    - Non-polar gases have poor solubility in water
    - Some gases dissolve in water through chemical reactions (HCl, CO_2, SO_2, …)
- **Gaseous solutions** – the solvent is a gas
  - Gas-gas solutions – gases mix in all proportions

- **Solid solutions** – the solvent is a solid
  - Gas-solid solutions – gas molecules penetrate the crystal lattices of some metals (H_2/Pd, O_2/Cu, …)
  - Solid-solid solutions – homogeneous alloys, waxes, …

➢**Substitutional** alloys – the atoms of one element take some of the positions in the lattice of another element

➢**Interstitial** alloys – the atoms of one element fit into the gaps of the lattice of another element



Example:

Quick cleaning of laboratory glassware:

➢ Cleaning a sample tube with a salt residue

Wash with water → dissolves salt (ion-dipole forces)

Wash with ethanol → dissolves water (H-bonding)

Wash with acetone → dissolves ethanol (dipole-dipole, dispersion forces)

Dry → acetone evaporates easily (low T_b)

➢ Cleaning a sample tube with an oily residue

Wash with hexane → dissolves oil (dispersion forces)

Wash with acetone → dissolves hexane (dispersion and dipole-induced dipole forces)

Dry → acetone evaporates easily (low T_b)