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 H₂O
  - **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 H₂O
- **H-bonding** forces – present in solutions of O- and N-containing molecules (sugars, alcohols, amino acids, …) in protic solvents such as H₂O
- **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 *IFs* in the solute and the solvent are replaced with strong solute-solvent H-bonding *IFs*
- Water does not dissolve well alcohols (ROH) with long hydrocarbon chains (R) → hexanol, …
- Strong H-bonding in water is replaced with weaker *IFs* 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 *IFs*)

![Methanol, Water, Hexanol](image)

**Example:**

What is a better solvent for diethyl ether (CH₃CH₂-O-CH₂CH₃), water or propanol (CH₃CH₂CH₂OH)?

- 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

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**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

![Surfactant](image)

**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, CO₂, SO₂, …)

**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 (H₂/Pd, O₂/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 $\rightarrow$ dissolves salt (ion-dipole forces)
  Wash with ethanol $\rightarrow$ dissolves water (H-bonding)
  Wash with acetone $\rightarrow$ dissolves ethanol (dipole-dipole, dispersion forces)
  Dry $\rightarrow$ acetone evaporates easily (low $T_b$)
- Cleaning a sample tube with an oily residue
  Wash with hexane $\rightarrow$ dissolves oil (dispersion forces)
  Wash with acetone $\rightarrow$ dissolves hexane (dispersion and dipole-induced dipole forces)
  Dry $\rightarrow$ acetone evaporates easily (low $T_b$)