66 An aqueous solution is 8.50% ammonium chloride by mass. The density of the solution is 1.024 g/mL
Find: molality, mole fraction, molarity.

NH_4Cl : 53.491 g/mol H_2O: 18.016 g/mol

Find molality:

$$\frac{8.50\text{ g } NH_4Cl}{100\text{ g solution}} \longrightarrow \frac{\text{mol } NH_4Cl}{\text{kg } H_2O}$$

mass percent molality

Assume a basis of 100g solution, then find moles ammonium chloride:

$$8.50\text{ g } NH_4Cl \times \frac{\text{mol } NH_4Cl}{53.491\text{ g } NH_4Cl} = 0.158905236\text{4 mol } NH_4Cl$$

Find mass water:

$$100\text{ g solution} - 8.50\text{ g } NH_4Cl = 91.50\text{ g } H_2O = 0.09150\text{ kg } H_2O$$

So molality is:

$$\frac{0.1589052364\text{ mol } NH_4Cl}{0.09150\text{ kg } H_2O} = \boxed{1.74\text{ m } NH_4Cl}$$

Now, let's do mole fraction:

$$\frac{8.50\text{ g } NH_4Cl}{100\text{ g solution}} \longrightarrow \frac{\text{mol } NH_4Cl}{\text{mol } NH_4Cl + \text{mol } H_2O}$$

mass percent mole fraction ammonium chloride

If we keep the same basis, all we'll have to do is convert the mass of water to moles!

An aqueous solution is 8.50% ammonium chloride by mass. The density of the solution is 1.024 g/mL
Find: molality, mole fraction, molarity.

NH_4Cl : 53.491 g/mol H_2O: 18.016 g/mol

Find moles water:

$$91.50\,g\ H_2O \times \frac{mol\ H_2O}{18.016\,g\ H_2O} = 5.078818828\ mol\ H_2O$$

$$X_{NH_4Cl} = \frac{0.158905236\ mol\ NH_4Cl}{0.158905236\ mol\ NH_4Cl + 5.078818828\ mol\ H_2O} = \boxed{0.0303}$$

(If we want Xwater, Xwater = 1-Xammonium chloride)

Finally, let's find molarity:

$$\frac{8.50\,g\ NH_4Cl}{100\,g\ solution} \longrightarrow \frac{mol\ NH_4Cl}{L\ solution}$$

mass percent — molarity

If we keep the same basis of 100g solution, all we have to do is convert the 100g solution to volume using the given density!

$$100\,g\ solution \times \frac{mL}{1.024\,g} = 97.65625\ mL = 0.09765625\ L$$

$$\frac{0.158905236\ mol\ NH_4Cl}{0.09765625\ L} = \boxed{1.63\ M\ NH_4Cl}$$

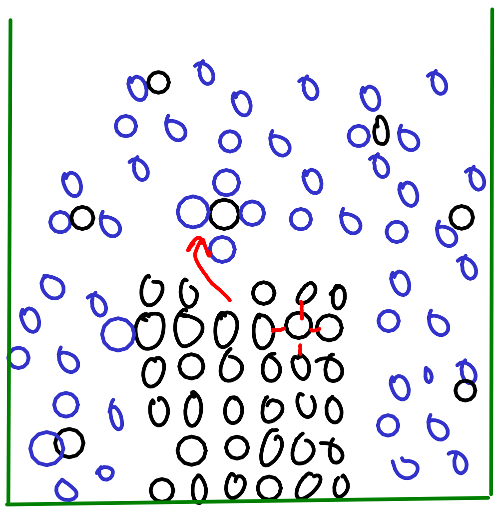
HOW THINGS DISSOLVE

- Let's look at how things dissolve into water, since aqueous solutions are quite common.

sucrose (table sugar)

$$C_{12}H_{22}O_{11}(s) \overset{H_2O}{\rightleftharpoons} C_{12}H_{22}O_{11}(aq)$$

... what happens?



- Water molecules pull the sugar molecules out of the sugar crystal and into solution.

- Attractions between sugar molecules and water allow this to happen.

- The solubility of the sugar depends on how well water and sugar interact (HYDRATION) versus how well the sugar molecules are held in the crystal (LATTICE ENERGY)

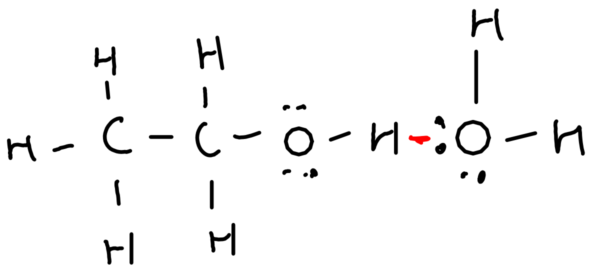
- "like dissolves like": Substances held together by similar (or at least compatible) kinds of attractive forces can dissolve in each other. Substances that are held together by very different kinds of attractive forces will not dissolve in one another!

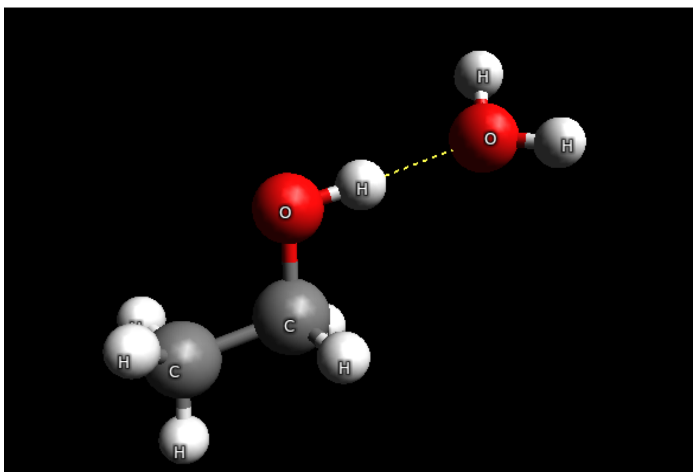
Consider WATER:

HYDROGEN BONDS

↓

Water mixes well with other substances that can hydrogen bond, like ETHANOL!





Hydrogen bond between ethanol and water

POLAR

↓

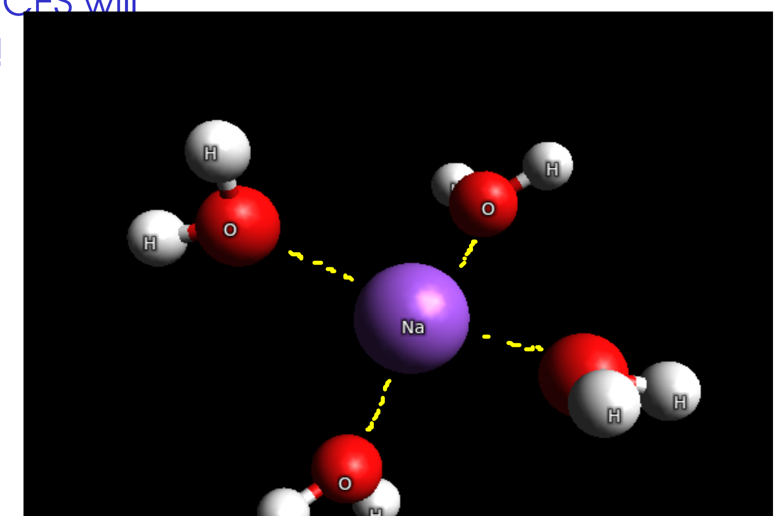
Water can dissolve polar substances!

(SUCROSE is polar!)

↓

Since IONIC BONDS are also interactions between opposite charges (You can think of an ionic bond here as an extreme case of dipole-dipole interaction), many IONIC SUBSTANCES will also dissolve in water!

$Na^+ - Cl^-$



Ion-dipole interactions between sodium ion and water

SMALL (little London force)

↓

large and/or nonpolar solutes do not dissolve well in water!

(example: OILS and WAXES)

MOLECULAR AND IONIC SOLUTIONS

- MOLECULAR solutions:

Contain MOLECULES dissolved in one another.

(1) - Any mixture of GASES

- all gases mix with one another, since gas molecules (effectively) do not interact with one another.

(2) - Liquids

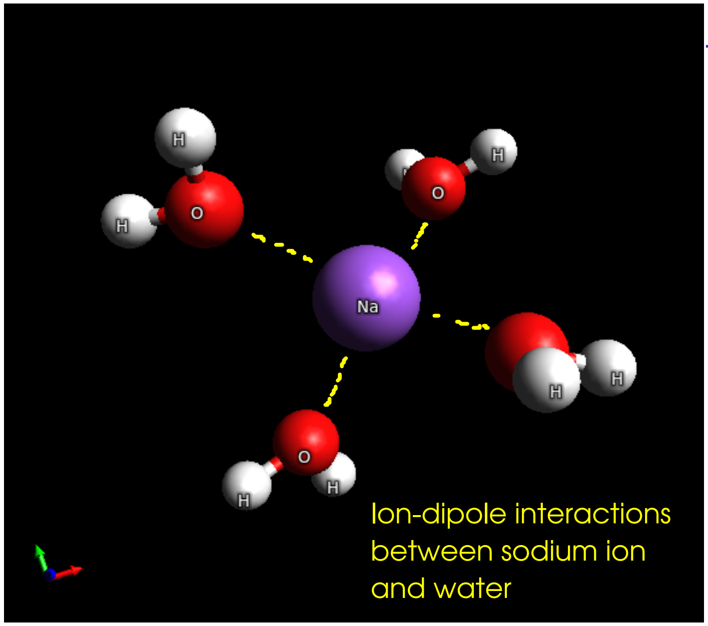
- Liquids dissolve well in one another only if they are held together by similar kinds of forces

(3) - Solids and liquids

- MOLECULAR SOLIDS will dissolve well in liquids if they are held together by similar forces.
- IONIC SOLIDS will sometimes dissolve in POLAR liquids, but not in nonpolar liquids
- COVALENT NETWORK solids don't generally dissolve well in other substances

IONIC solutions

- form when ions from IONIC SUBSTANCES interact with POLAR solvents - often WATER.



The charged ends of the water molecule HYDRATE the ions.

vs.

- The solubility of an ionic compound depends on whether HYDRATION (attraction of water molecules for an ion) is greater than LATTICE ENERGY - the attrraction of ions in a crystal lattice for one another..

- SMALLER IONS are usually easier to enclose in water than larger ones, and ions with larger charges are attracted to water molecules.

- But solubility is also determined by LATTICE ENERGY - which holds the solid ionic compound together. Ions with high charges tend to be strongly attracted to other ions in a crystal, meaning lattice energy is high. Smaller ions also tend to have higher lattice energies. Lattice energy and hydroation are competing trends!

COLLIGATIVE PROPERTIES

- properties unique to solutions.

- depend only on the CONCENTRATION of a solution and not the IDENTITY of the solute**

**ionic solutes: Remember that they dissociate into MULTIPLE IONS!

1. Freezing point depression
   - The freezing temperature of a SOLUTION gets lower as the CONCENTRATION of a solution increases.

2. Vapor pressure lowering
   - The vapor pressure of a solution (pressure of sovent vapor over a liquid surface) goes DOWN as solution concentration goes UP

3. Boiling point elevation
   - The boiling temperature of a solution increases as the concentration of the solution increases.

4. Osmotic pressure
   - The pressure required to PREVENT the process of osmosis

FREEZING POINT DEPRESSION

$$\Delta T_f = K_f \times c_m$$

- c_m: concentration of solute (molality)
- K_f: Freezing point depression constant (for SOLVENT)
- ΔT_f: Freezing point depression: The amount the freezing temperature is LOWERED by the solute.

- Applications: In chemistry, this effect is often used to determine the molecular weight of an unknown molecule.