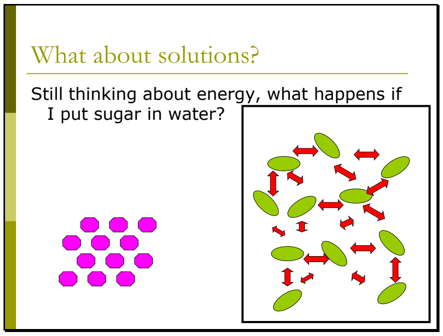
Slide 1

Properties of Solutions

It's all about the interactions.

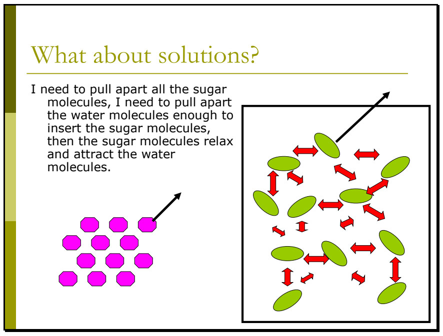
Slide 2



What about solutions?

Still thinking about energy, what happens if I put sugar in water?

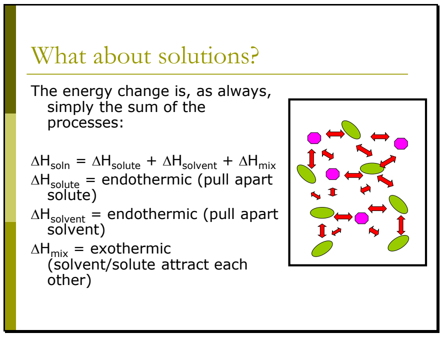
Slide 3



What about solutions?

I need to pull apart all the sugar molecules, I need to pull apart the water molecules enough to insert the sugar molecules, then the sugar molecules relax and attract the water molecules.

Slide 4



What about solutions?

The energy change is, as always, simply the sum of the processes:

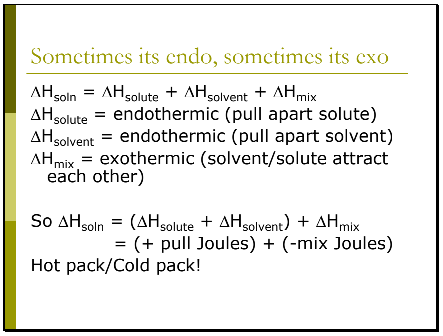
$\Delta H_{soln} = \Delta H_{solute} + \Delta H_{solvent} + \Delta H_{mix}$

ΔH_{solute} = endothermic (pull apart solute)

$\Delta H_{solvent}$ = endothermic (pull apart solvent)

ΔH_{mix} = exothermic (solvent/solute attract each other)

Slide 5



Sometimes its endo, sometimes its exo

$\Delta H_{soln} = \Delta H_{solute} + \Delta H_{solvent} + \Delta H_{mix}$

ΔH_{solute} = endothermic (pull apart solute)

$\Delta H_{solvent}$ = endothermic (pull apart solvent)

ΔH_{mix} = exothermic (solvent/solute attract each other)

So $\Delta H_{soln} = (\Delta H_{solute} + \Delta H_{solvent}) + \Delta H_{mix}$

= (+ pull Joules) + (-mix Joules)

Hot pack/Cold pack!

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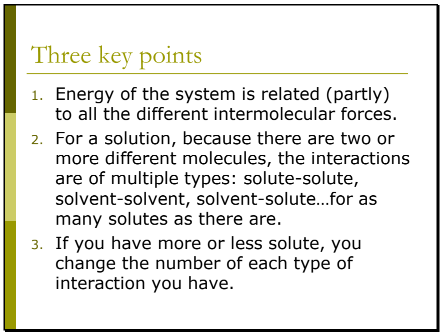

Three key points

1. Energy of the system is related (partly) to all the different intermolecular forces.
2. For a solution, because there are two or more different molecules, the interactions are of multiple types: solute-solute, solvent-solvent, solvent-solute…for as many solutes as there are.
3. If you have more or less solute, you change the number of each type of interaction you have.

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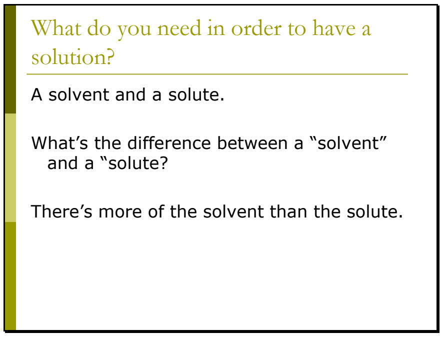

What do you need in order to have a solution?

A solvent and a solute.

What's the difference between a "solvent" and a "solute?

There's more of the solvent than the solute.

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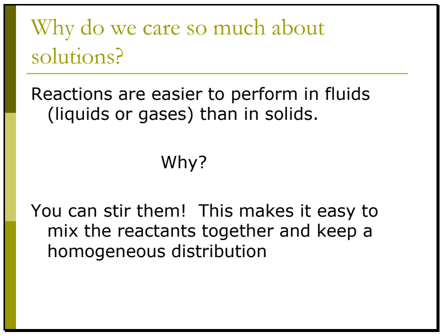

Why do we care so much about solutions?

Reactions are easier to perform in fluids (liquids or gases) than in solids.

Why?

You can stir them! This makes it easy to mix the reactants together and keep a homogeneous distribution

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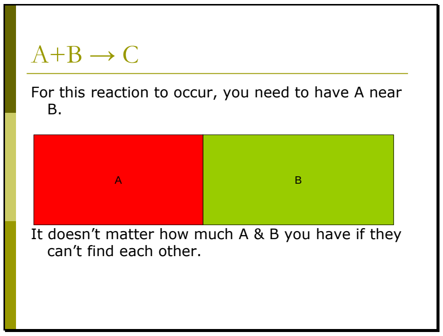
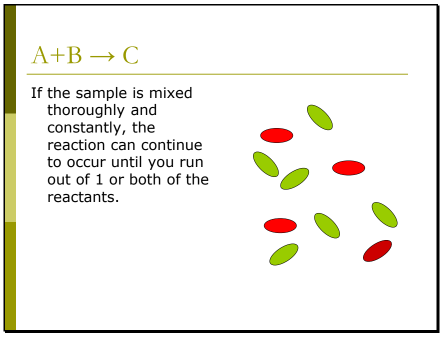


$A+B \rightarrow C$

For this reaction to occur, you need to have A near B.

It doesn't matter how much A & B you have if they can't find each other.

Slide 10



A+B → C

If the sample is mixed thoroughly and constantly, the reaction can continue to occur until you run out of 1 or both of the reactants.

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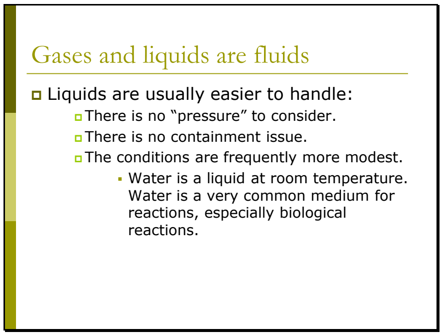
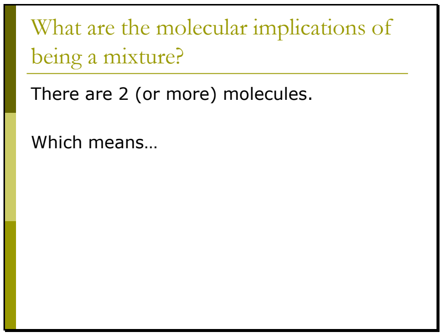


Gases and liquids are fluids

- Liquids are usually easier to handle:
  - There is no “pressure” to consider.
  - There is no containment issue.
  - The conditions are frequently more modest.
    - Water is a liquid at room temperature. Water is a very common medium for reactions, especially biological reactions.

Slide 12



What are the molecular implications of being a mixture?

There are 2 (or more) molecules.

Which means…

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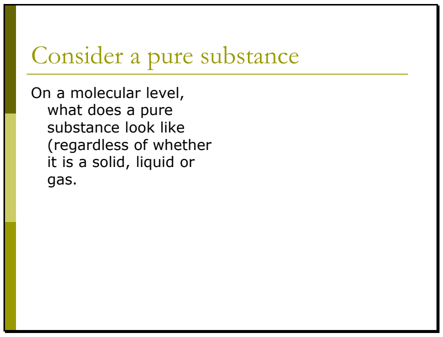

Consider a pure substance

On a molecular level, what does a pure substance look like (regardless of whether it is a solid, liquid or gas.

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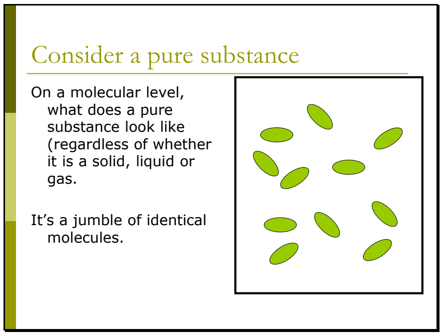

Consider a pure substance

On a molecular level, what does a pure substance look like (regardless of whether it is a solid, liquid or gas.

It's a jumble of identical molecules.

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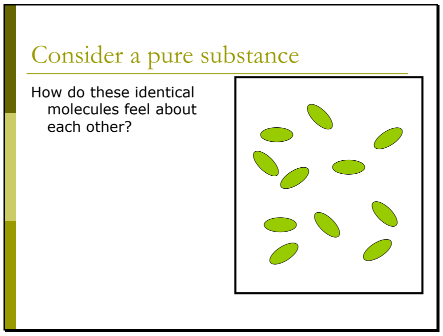

Consider a pure substance

How do these identical molecules feel about each other?

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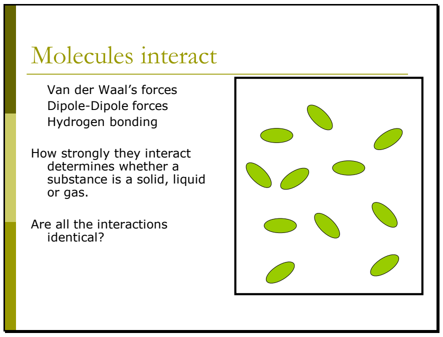

Molecules interact

- Van der Waal's forces
- Dipole-Dipole forces
- Hydrogen bonding

How strongly they interact determines whether a substance is a solid, liquid or gas.

Are all the interactions identical?

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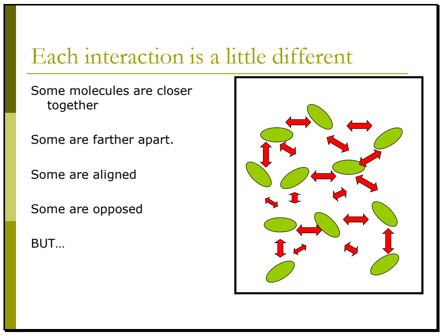

Each interaction is a little different

Some molecules are closer together

Some are farther apart.

Some are aligned

Some are opposed

BUT…

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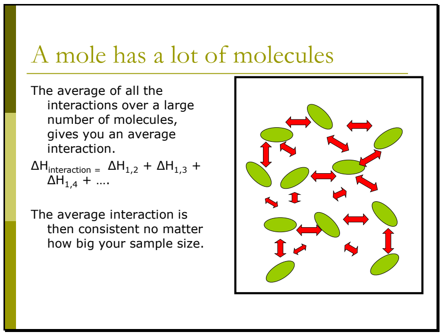

A mole has a lot of molecules

The average of all the interactions over a large number of molecules, gives you an average interaction.

$\Delta H_{interaction} = \Delta H_{1,2} + \Delta H_{1,3} + \Delta H_{1,4} + \ldots.$

The average interaction is then consistent no matter how big your sample size.

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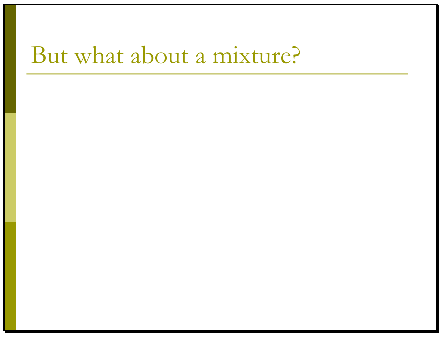
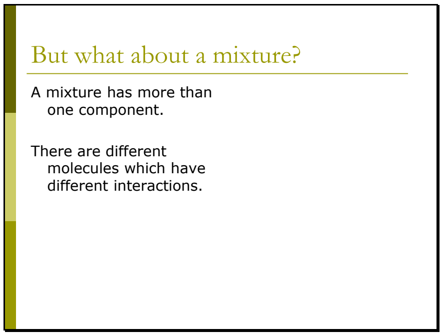


But what about a mixture?

Slide 20



But what about a mixture?

A mixture has more than one component.

There are different molecules which have different interactions.

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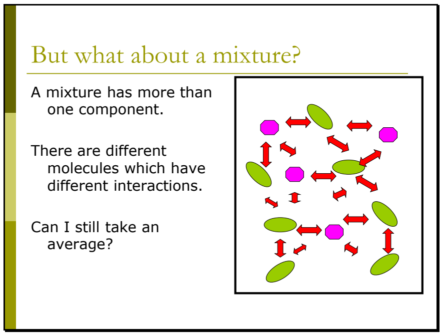

But what about a mixture?

A mixture has more than one component.

There are different molecules which have different interactions.

Can I still take an average?

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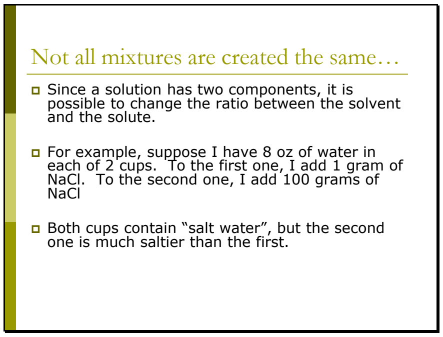

Not all mixtures are created the same…

- Since a solution has two components, it is possible to change the ratio between the solvent and the solute.
- For example, suppose I have 8 oz of water in each of 2 cups. To the first one, I add 1 gram of NaCl. To the second one, I add 100 grams of NaCl
- Both cups contain "salt water", but the second one is much saltier than the first.

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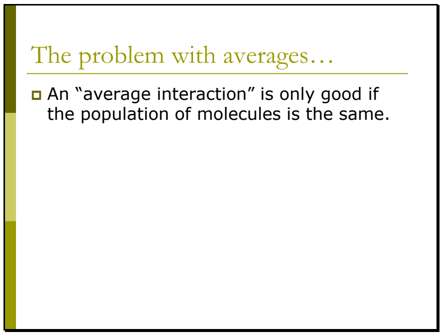

The problem with averages…

- An "average interaction" is only good if the population of molecules is the same.

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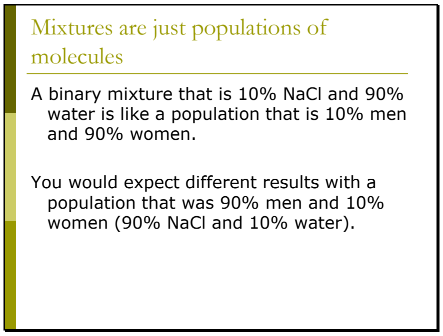

Mixtures are just populations of molecules

A binary mixture that is 10% NaCl and 90% water is like a population that is 10% men and 90% women.

You would expect different results with a population that was 90% men and 10% women (90% NaCl and 10% water).

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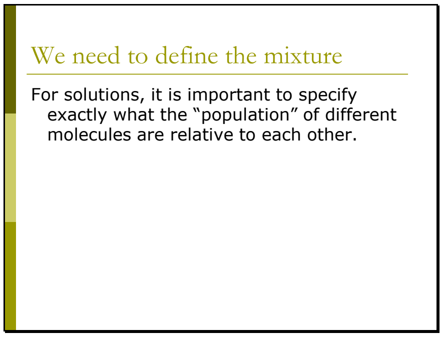

We need to define the mixture

For solutions, it is important to specify exactly what the “population” of different molecules are relative to each other.

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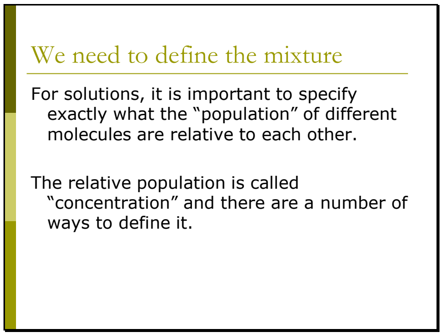

We need to define the mixture

For solutions, it is important to specify exactly what the “population” of different molecules are relative to each other.

The relative population is called “concentration” and there are a number of ways to define it.

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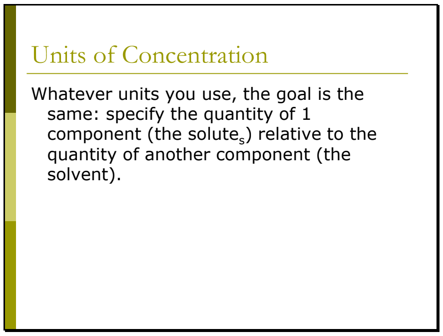

Units of Concentration

Whatever units you use, the goal is the same: specify the quantity of 1 component (the solute$_s$) relative to the quantity of another component (the solvent).

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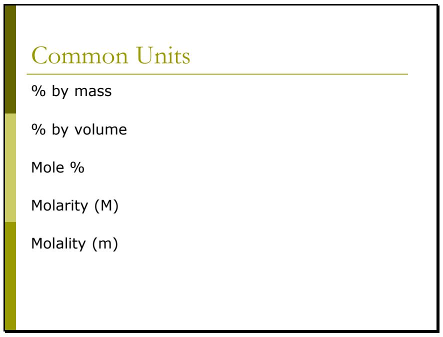

Common Units

% by mass

% by volume

Mole %

Molarity (M)

Molality (m)

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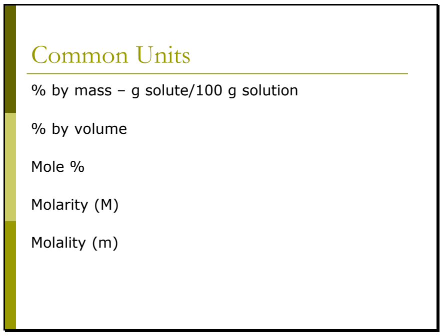


Common Units

% by mass – g solute/100 g solution

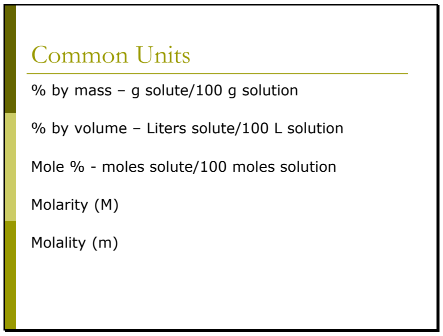
% by volume

Mole %

Molarity (M)

Molality (m)

Slide 30



Common Units

% by mass – g solute/100 g solution

% by volume – Liters solute/100 L solution

Mole % - moles solute/100 moles solution

Molarity (M)

Molality (m)

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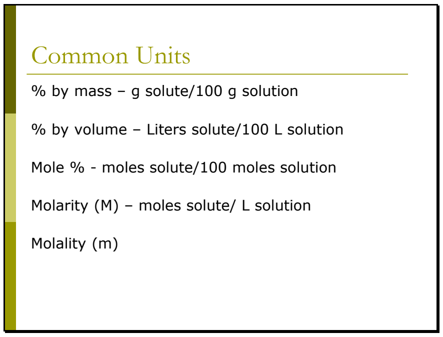


Common Units

% by mass – g solute/100 g solution

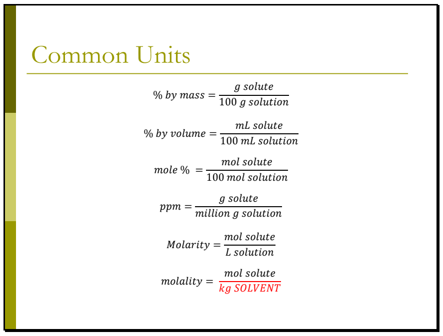
% by volume – Liters solute/100 L solution

Mole % - moles solute/100 moles solution

Molarity (M) – moles solute/ L solution

Molality (m)

Slide 32



Common Units

$$\% \; by \; mass = \frac{g \; solute}{100 \; g \; solution}$$

$$\% \; by \; volume = \frac{mL \; solute}{100 \; mL \; solution}$$

$$mole \; \% = \frac{mol \; solute}{100 \; mol \; solution}$$

$$ppm = \frac{g \; solute}{million \; g \; solution}$$

$$Molarity = \frac{mol \; solute}{L \; solution}$$

$$molality = \frac{mol \; solute}{kg \; SOLVENT}$$

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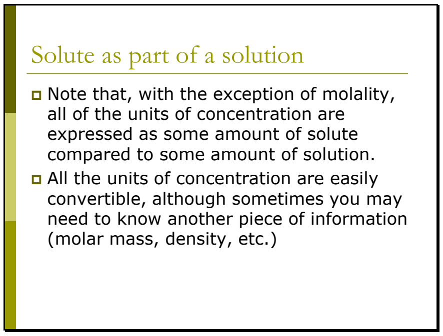

Solute as part of a solution

- Note that, with the exception of molality, all of the units of concentration are expressed as some amount of solute compared to some amount of solution.
- All the units of concentration are easily convertible, although sometimes you may need to know another piece of information (molar mass, density, etc.)