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# Properties of Solutions

It's all about the interactions.

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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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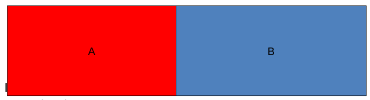
## A+B → C

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




each other.

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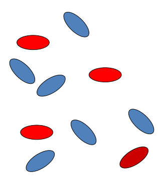
## A+B → C

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.

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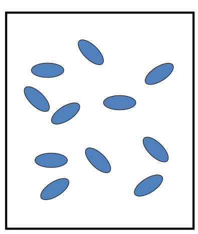
On a molecular level, what does a pure substance look like (regardless of whether it is a solid, liquid or gas.

It's a jumble of identical molecules.



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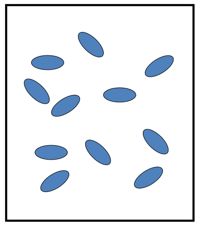
## Consider a pure substance

How do these identical molecules feel about each other?



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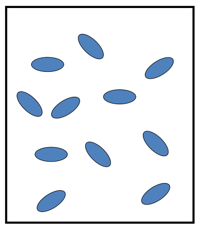
## Molecules interact

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

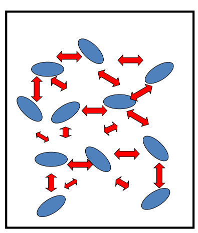
Some molecules are closer together

Some are farther apart.

Some are aligned

Some are opposed

BUT…



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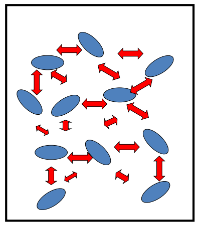
## A mole has a lot of molecules

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

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

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



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## But what about a mixture?

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A mixture has more than one component.

There are different molecules which have different interactions.

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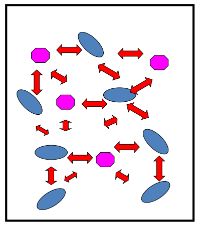
Can I still take an average?



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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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## The problem with averages…

- An “average interaction” is only good if the population of molecules is the same.
- Dumb example: Suppose I take a poll: “How many bras did you buy this year?”
- If I ask 1000 people at random and get an average of 1.00, could I then conclude that 300 million Americans buy 300 million bras per year?

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## It’s all about statistics…

I ask 1000 people at random and get an average of 1.00, could I then conclude that 300 million Americans buy 300 million bras per year?

The key is “random”. If it is a random sample that is large enough to represent the entire population, I’m good as gold.

But….

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## Same poll, different population

I ask 1000 men, “How many bras did you buy this year?”

I get an average of 0.

Does that mean no bras were sold in the U.S. this year?

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## Same poll, different population

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I get an average of 0.

Does that mean no bras were sold in the U.S. this year?

Of course not – the sample population isn’t the same as the entire population!

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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

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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)

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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)

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)

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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) – moles 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.)