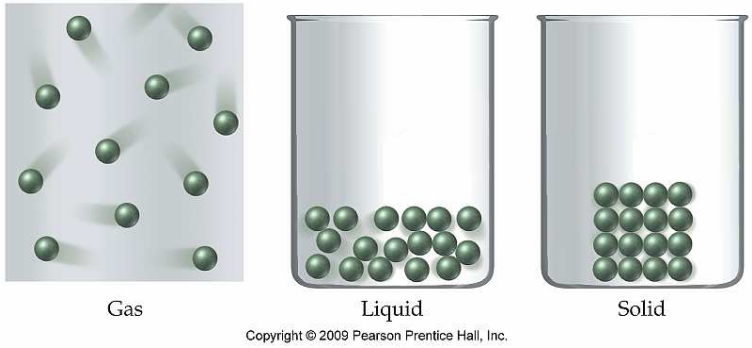
Phase	**Density**	**Compressibility**	**Reason**
(g)			
(l)			
(s)			



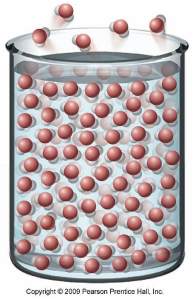
Phase	**Shape**	**Fluid or rigid?**	**Reason**
(g)			
(l)			
(s)			

Intermolecular forces: forces that attract one molecule to other molecules around it

If there were no intermolecular forces, what phase would all molecular substances be?

In order to convert liquid to gas, the intermolecular forces that hold the molecules close to each other in the liquid must be overcome.

In a sample of room-temperature water, the molecules with the highest energy will move the fastest.



When a faster molecule finds the surface, it launches into the gas phase - this process is called:

$H_2O(l) \rightarrow H_2O(g)$

Evaporation is **endothermic** - heat energy is absorbed into the liquid in order to overcome the intermolecular forces so a molecule can break away from the rest.

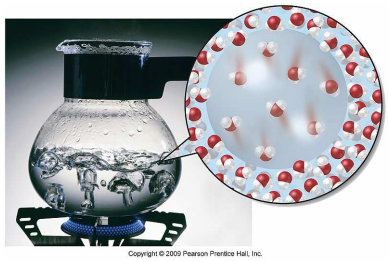
The opposite process, $H_2O(g) \rightarrow H_2O(l)$ is called:

It gives off heat because the gas molecules slow down - this is an **exothermic** process.

Boiling and the heating curve

Heating a liquid makes it molecules move:

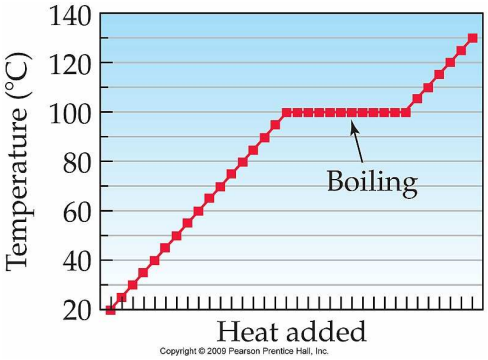
Eventually, they will all be moving fast enough to break free into the gas phase - even those in the interior of the liquid (not just at the surface like in evaporation).
This process is called:



Heat added to a liquid can do one of two things:

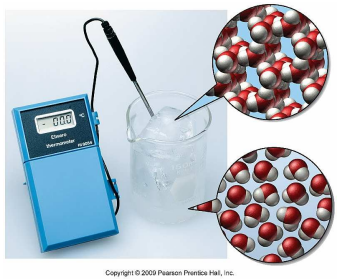
1. Raise the temperature
2. Perform a phase change

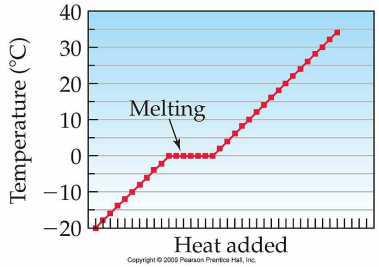
…but only one at a time!!



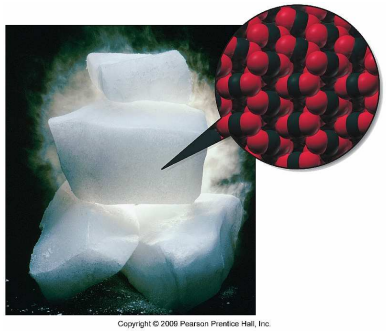
Is boiling endothermic or exothermic?

Melting, freezing, sublimation





Melting: $H_2O(\ ) \rightarrow H_2O(\ )$ endothermic *or* exothermic?
Freezing: $H_2O(\ ) \rightarrow H_2O(\ )$ endothermic *or* exothermic?
Sublimation: $H_2O(\ ) \rightarrow H_2O(\ )$ endothermic *or* exothermic?



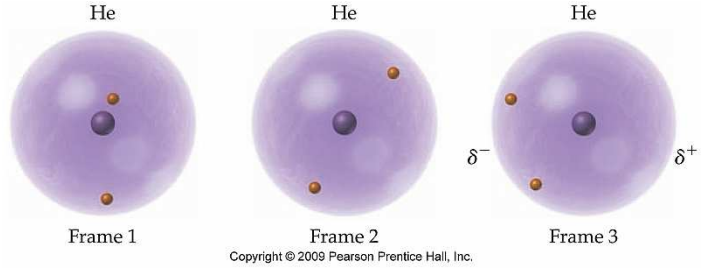
$CO_2(s)$ →

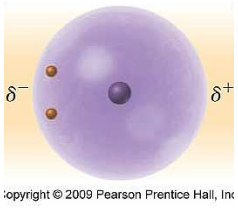
Dispersion force

There are 3 types of intermolecular forces:

1. Dispersion force
2. Dipole-dipole force
3. Hydrogen bonding

Dispersion force: (sometimes called London force) present between *all molecules*.





Strength of dispersion forces and boiling point

You can estimate the strength of a molecule's dispersion force by calculating its **molar mass**.

	MM	Strength of dispersion forces
I_2		
Br_2		
Cl_2		

Boiling point: temp where ( ) becomes ( )

If a substance has relatively **strong** intermolecular forces, it will have a relatively _____ boiling point

Which has the highest boiling point, I_2, Br_2, or Cl_2?

Which has the lowest boiling point, I_2, Br_2, or Cl_2?

Dipole-dipole forces are attractions between opposite dipoles of **polar** molecules.

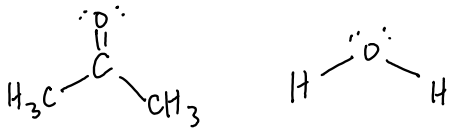
Which has the higher boiling point, CH_2O or CH_3CH_3?

Polarity determines **miscibility** - whether or not two liquids will mix.

Only substances with similar polarities will mix.

(a) (b) (c)

Consider acetone and water:



MM:

Dispersion:

Polar?

Dipole forces?

Experimental boiling point:

One of these molecules has **hydrogen bonding**, an extra-strong dipole force resulting from an **electropositive H:**

O—H N—H F—H

Hydrogen bonding is much stronger than dispersion forces and regular dipole-dipole forces.

To rank compounds in order of boiling point:

1. Find compounds with **H-bonding** - they will have higher bp's than compounds without H-bonding
2. Use molar mass to determine **dispersion forces** (a difference of less than 10 is not significant)
3. Use polarity to determine **dipole-dipole forces**

The compound with the strongest intermolecular forces will have the _____ boiling point!

Which has a higher boiling point, dimethyl ether (CH_3OCH_3) or ethanol (CH_3CH_2OH)?

Rank these in order of increasing boiling point, with 1 as the lowest and 3 as the highest:
CH_3Cl, CH_3OH, CH_3CH_3

Rank these in order of increasing boiling point, with 1 as the lowest and 4 as the highest:
CH_2F_2, CH_3OH, CH_3CH_2OH, N_2.

Types of solids

	Molecular	**Ionic**	**Metallic**
Made of:			
Elements:			
Held together by:			
Charges?			
Melting point:			

Ice

Table salt

Gold