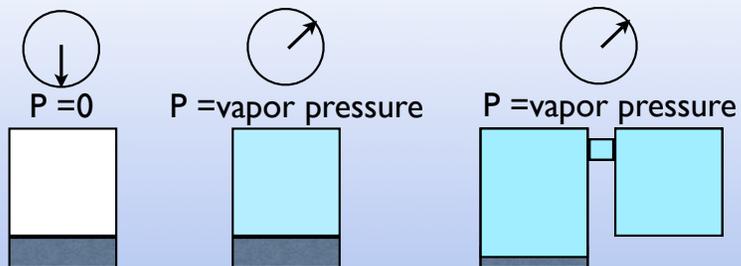


Let's look at how different properties affect vapor pressure



first all liquid

then comes to equilibrium with liquid + vapor with a pressure that is the vapor pressure

then add more volume

At equilibrium there is less liquid, but the same Pressure!

Quick Quiz

You have two containers. one has a total volume of 2 L and one has a total volume of 1 L. Into each you place 500 mL of liquid ether. They have the same temperature.



Which container has a higher pressure at equilibrium?

- A. the 2 L container
- B. the 1 L container
- C. they are exactly the same ←
- D. it depends on the temperature

Another Question

You have two containers. one has a total volume of 2 L and one has a total volume of 1 L. Into each you place 500 mL of liquid ether.



Which container has a greater number of ether molecules in the gas phase at equilibrium?

- A. the 2 L container ←
- B. the 1 L container
- C. they are exactly the same
- D. it depends on the temperature

If we stress the system it adjust to get back to equilibrium

Let's imagine a container with some liquid ethanol, when we look at the gas above the liquid

actual partial pressure of ethanol      partial pressure at equilibrium = vapor pressure

If  $P_{\text{ethanol}} > P_{\text{ethanol,eq}}$  then there are "too many" molecules in the gas phase. The gas will **condense** until you get to equilibrium

If  $P_{\text{ethanol}} < P_{\text{ethanol,eq}}$  then there are "too few" molecules in the gas phase. The liquid will **evaporate** until you get to equilibrium

If **all** the liquid evaporates before getting to equilibrium then the pressure will never get up to the equilibrium value

If  $P_{\text{ethanol}} = P_{\text{ethanol,eq}}$  the number molecules in the gas phase is "just right" The system is at equilibrium

Vapor Pressure is determined primarily from  $\Delta_{\text{vap}}H$   
 $\Delta_{\text{vap}}H$  depends on the intermolecular forces

Vapor Pressure is independent of volume  
 Neither the volume of the gas or liquid matter

To have the equilibrium both gas and liquid must be present

Vapor Pressure is a strong function of temperature

The Vapor Pressure is the  
**PARTIAL PRESSURE OF THAT SUBSTANCE!**

## Vapor Pressure as a function of Temperature

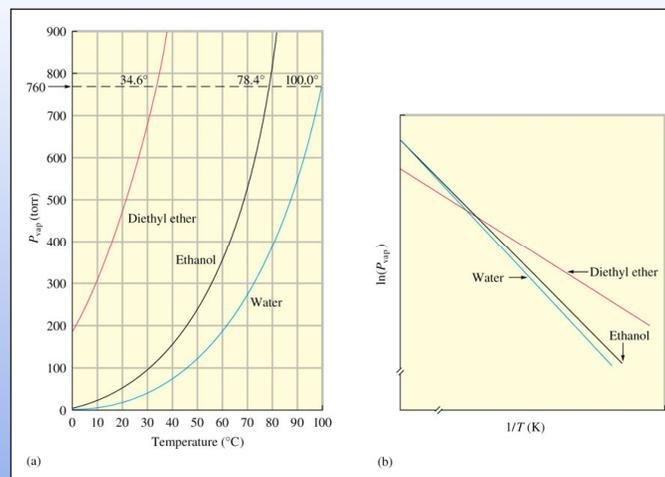


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How Does Vapor Pressure Change with T?

$$\ln\left(\frac{P_2}{P_1}\right) = -\frac{\Delta H_{\text{vap}}}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$$

The Clausius-Clapeyron Equation

Relates the vapor pressure  $P_1$  at temperature  $T_1$   
 to the vapor pressure  $P_2$  at temperature  $T_2$

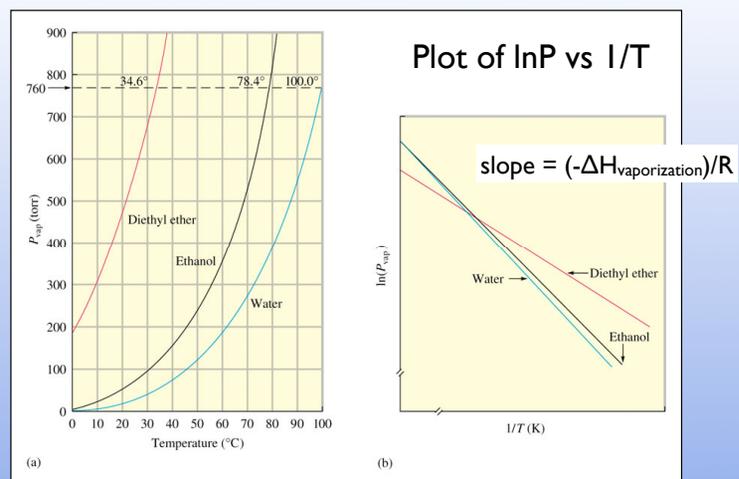


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## Boiling

What is the boiling point?

Definition: The boiling point is temperature at which the vapor pressure is equal to prevailing pressure

What is the normal boiling point?

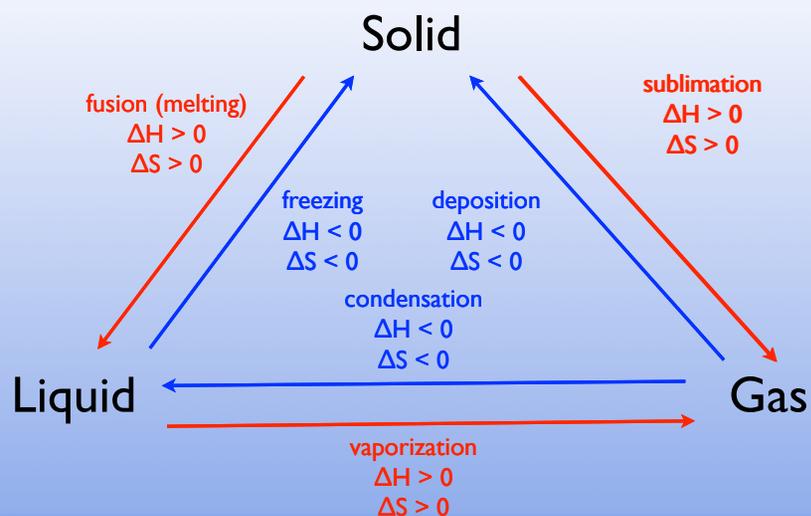
Definition: The normal boiling point is temperature at which the vapor pressure is equal to 1 atm

Note: at the boiling point the **partial** pressure of the substance is equal to the **total** pressure. It cannot get any higher (its the whole thing). At higher temperatures the liquid would have a higher vapor pressure. To achieve this you need to have a higher total pressure.

Given that the vapor pressure of water is 24 Torr at 25°C and that the normal boiling point of water is 100 °C, what is the enthalpy of vaporization of water?

Doc Cam

## The different phase transitions



## Phase Transitions

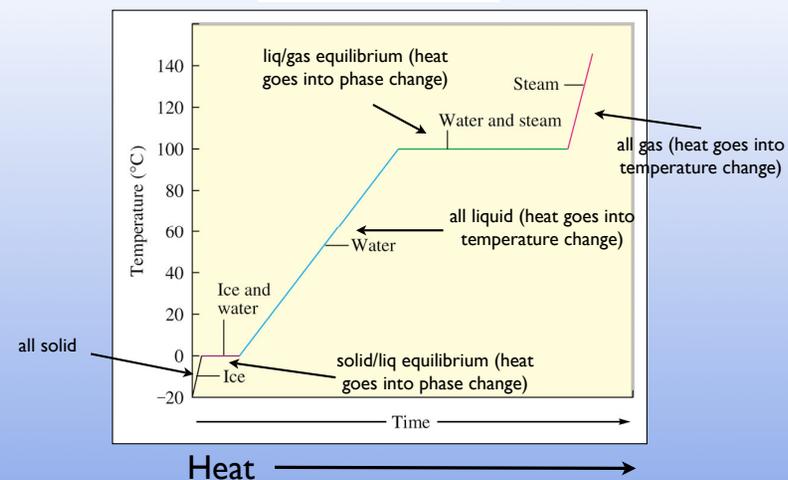


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## Previous Thermo

Single Phase  
energy into goes into temperature change  
at constant P

$q = \Delta H = C \Delta T$   
you need heat capacity of specific phase (sol, liq, gas)  
be careful with the units of heat capacity.  
you may need to multiply by a number of moles or a mass!

Phase Change  
energy into goes into phase change  
(the two phases have the same free energy  
but one is higher in enthalpy)

$q = \Delta H_{\text{transition}}$  for example  $q = \Delta H_{\text{fus}}$  for melting

## Phase Transitions

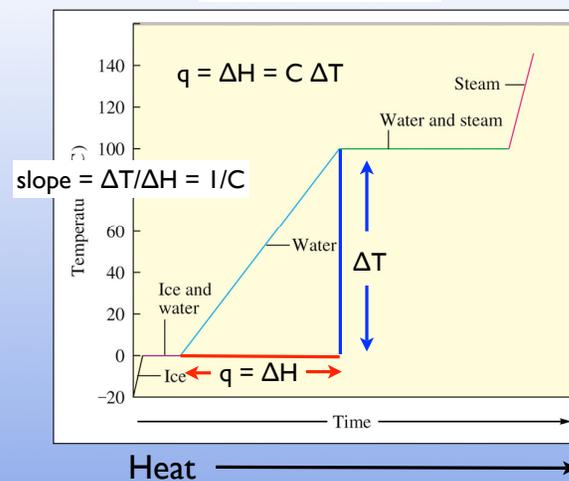


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## Phase Transitions

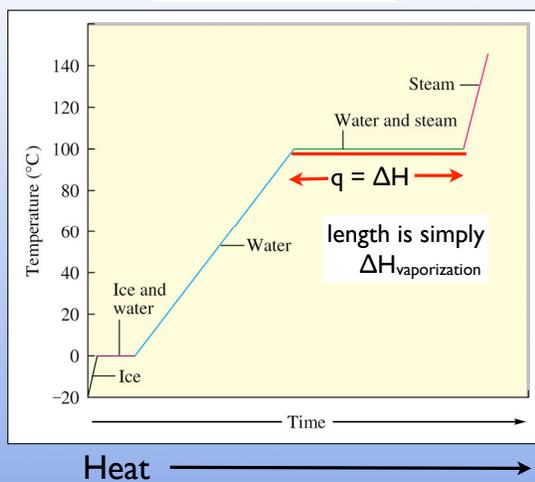


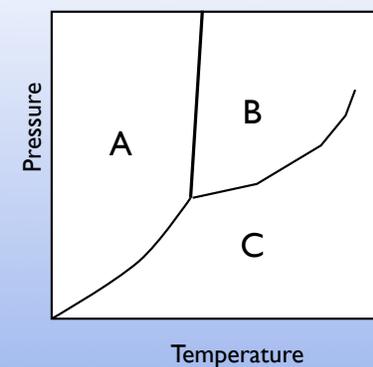
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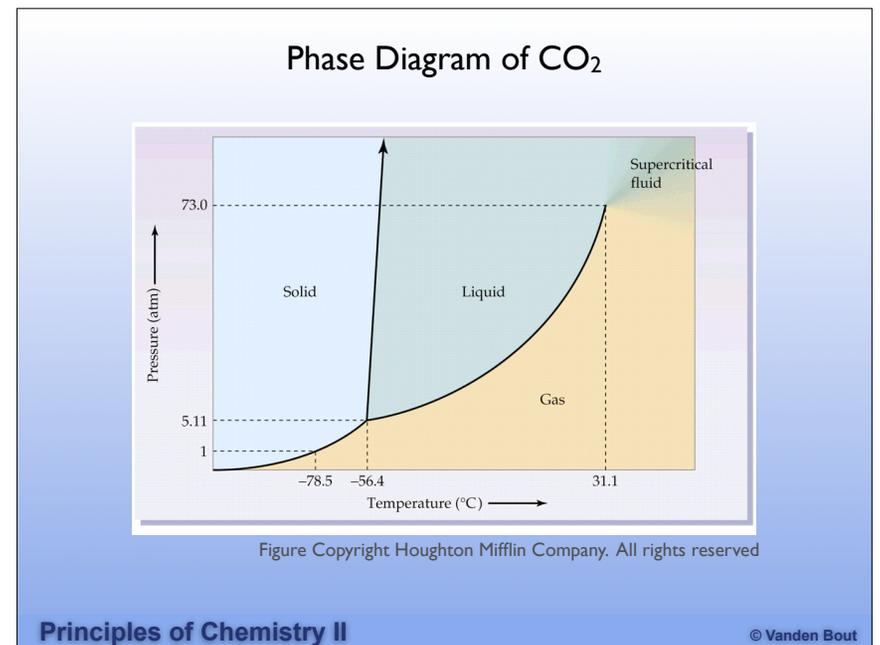
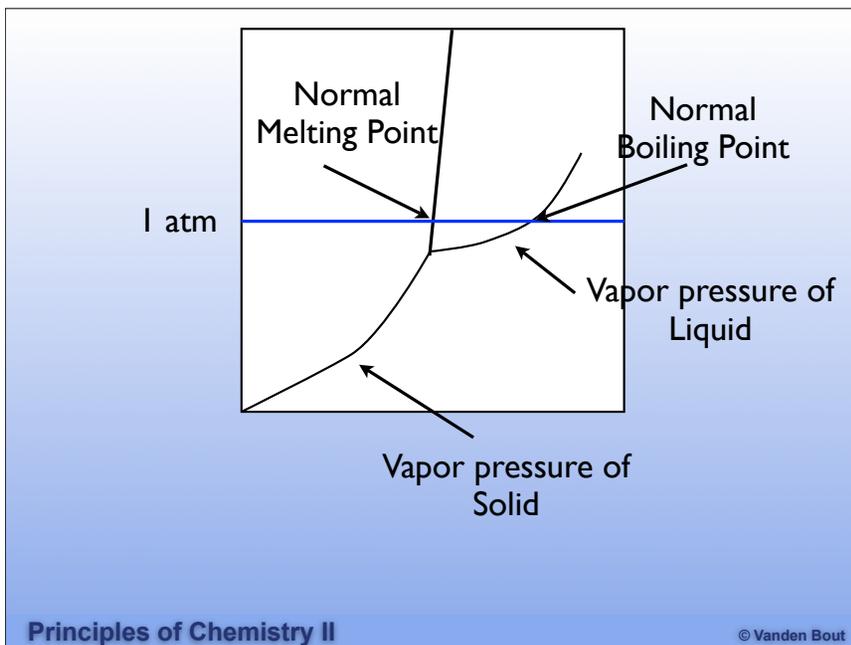
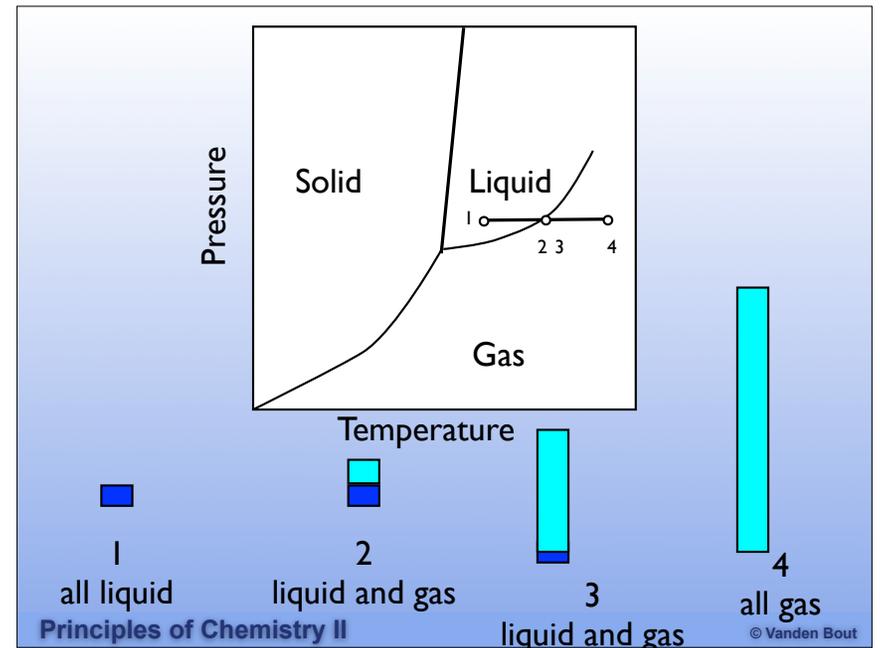
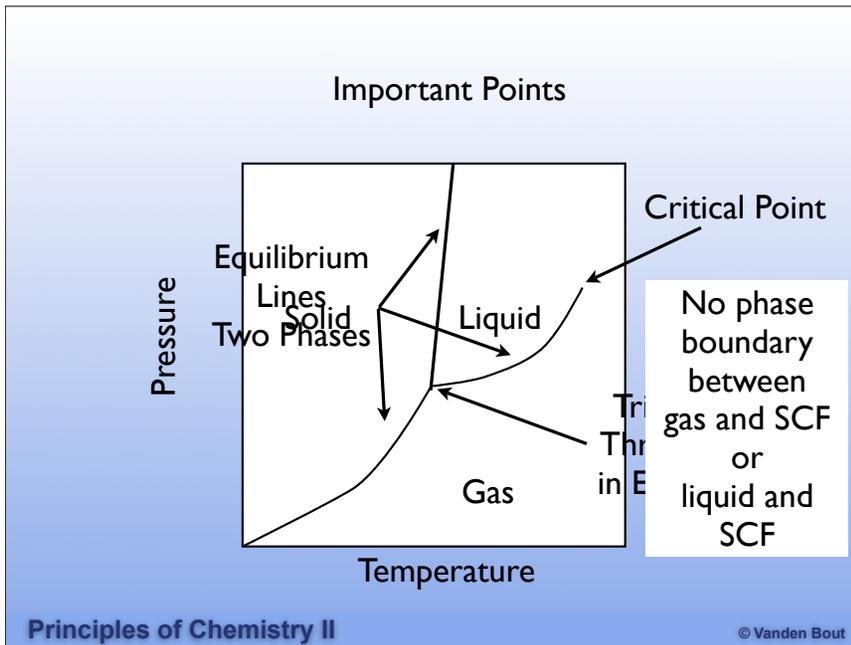
## Phase Diagrams

The diagram on the right shows  
different phases for a  
compound as a function of  
temperature and pressure

What is the phase labeled "A"?

- A. solid
- B. liquid
- C. gas
- D. no way to know





## Phase Diagram of Water

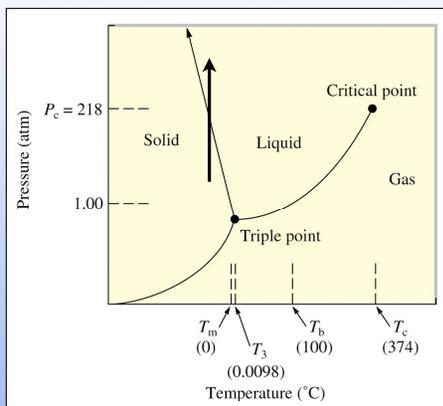
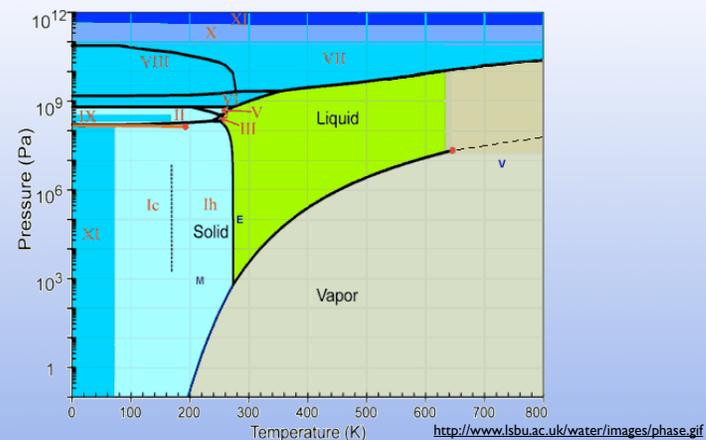


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At a constant temperature, increasing the pressure will cause ice to melt (it moves to the higher density phase which for water is a liquid)

## Phase Diagram of Water



Many different solid phases. At very high pressure the liquid will solidify

## Other Substances

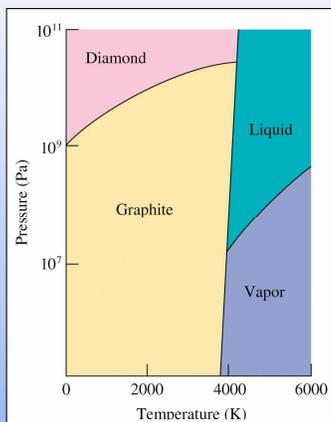
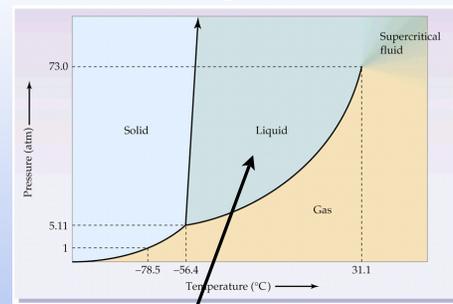


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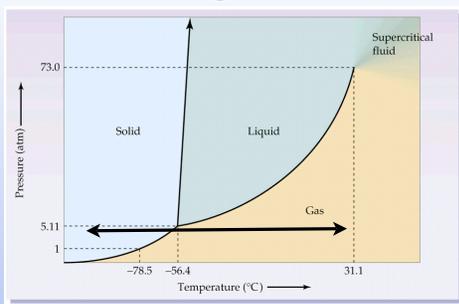
## Phase Diagram of CO<sub>2</sub>



What is the stable phase at 20 atm and 0°C?

- A. solid    B. liquid    C. gas    D. SCF

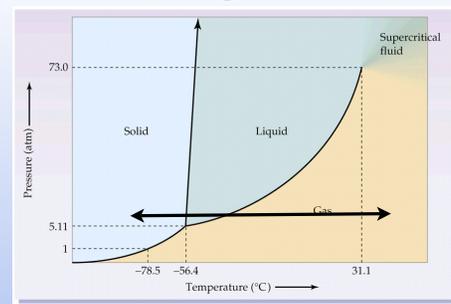
### Phase Diagram of CO<sub>2</sub>



If I start at  $-100^{\circ}\text{C}$  and 5 atm and increase the temperature to  $30^{\circ}\text{C}$ , how many phase transition occur?

- A. 1    B. 2    C. 3    D. 4

### Phase Diagram of CO<sub>2</sub>



No phase transition going for a liquid or a gas to a SCF

If I start at  $-100^{\circ}\text{C}$  and 7 atm and increase the temperature to  $35^{\circ}\text{C}$ , how many phase transition occur?

- A. 1    B. 2    C. 3    D. 4