



# Summary of Gas Laws

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- Boyle's Law ( $T$  and  $n$  constant)

$$p_1 \times V_1 = p_2 \times V_2$$

- Charles' Law ( $p$  and  $n$  constant)

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

- Combined Gas Law ( $n$  constant)

$$\frac{p_1 V_1}{T_1} = \frac{p_2 V_2}{T_2}$$



# Ideal Gas Equation

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$$pV = nRT$$



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# Ideal Gas Equation - Example

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- 2.31 g of some gas has the volume of 0.706 L at 2.5 atm and room temperature (25°C). Determine the molar mass of this gas.



# Standard Molar Volume

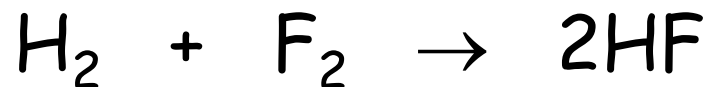
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- The **standard molar volume** of an ideal gas is equal to 22.414 liters per mole at standard temperature and pressure
- Standard temperature and pressure (STP)  
 $T = 273.15 \text{ K} = 0^\circ\text{C} = 32 \text{ F}$   
 $p = 760 \text{ torr} = 1 \text{ atm} = 101,325 \text{ Pa}$
- 1 mole of an ideal gas occupies 22.414 L volume ONLY at standard temperature and pressure
- This knowledge can be used for analysis of chemical reactions involving gases



# Gases in Chemical Reactions

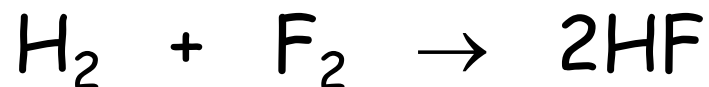
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# of moles:    1 mole    1 mole    2 moles

Volume @ STP: 22.4 L    22.4 L    (2×22.4) L

- The volumes of gases participating in chemical reactions are proportional to the stoichiometric coefficients
- We can operate with volumes in the same way as we operate with moles:



Volume:            1 L            1 L            2 L



# Example 1

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- What volume of HF will be produced by the reaction between 2.35 L of  $H_2$  and 4.10 L of  $F_2$ ?



## Example 2

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- What volume of  $C_5H_{12}$  was burned if 35.0 L of carbon dioxide was produced? What volume of oxygen was consumed in this reaction?



## Example 3

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- What volume of hydrogen will be produced in the reaction of 3 g of zinc with the excess of dilute hydrochloric acid, if the reaction is carried out at room temperature ( $25^{\circ}\text{C}$ ) and standard atmospheric pressure (1 atm)?



# Dalton's Law

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- Mixture of gases:  $A, B, C, \dots$
- Partial pressure - pressure that a gas would exert if it alone were contained in the volume occupied by the mixture of gases
- Let's assume that we know the number of moles of each gas present in the mixture:



# Dalton's Law - Example

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- Calculate the partial pressures and the total pressure of the mixture of 0.25 mol of  $H_2$  and 0.75 mol of  $N_2$  if at  $25^\circ C$  it occupies the volume of 12 L.



# Mole Fraction

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- Mixture of gases: A, B, C, ...
- Mole fraction of gas A:

$$X_A = \frac{n_A}{n_A + n_B + n_C + \dots} = \frac{n_A}{n_{\text{tot}}}$$



# Mole Fraction

- Mixture of gases: A, B, C, ...
- Mole fraction of gas A:

$$X_A = \frac{n_A}{n_A + n_B + n_C + \dots} = \frac{n_A}{n_{\text{tot}}}$$

$$X_A = \frac{p_A}{p_A + p_B + p_C + \dots} = \frac{p_A}{p_{\text{tot}}}$$



# Dalton's Law - Example

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- Into a 5.00 L container at 18°C are placed 2.00 g H<sub>2</sub>, 44.0 g CO<sub>2</sub>, and 16.0 g O<sub>2</sub>. Calculate the total pressure in the container, the partial pressure and the mole fraction of each gas.

# CHAPTER 13

- Liquids and Solids





# Gases vs. Liquids & Solids

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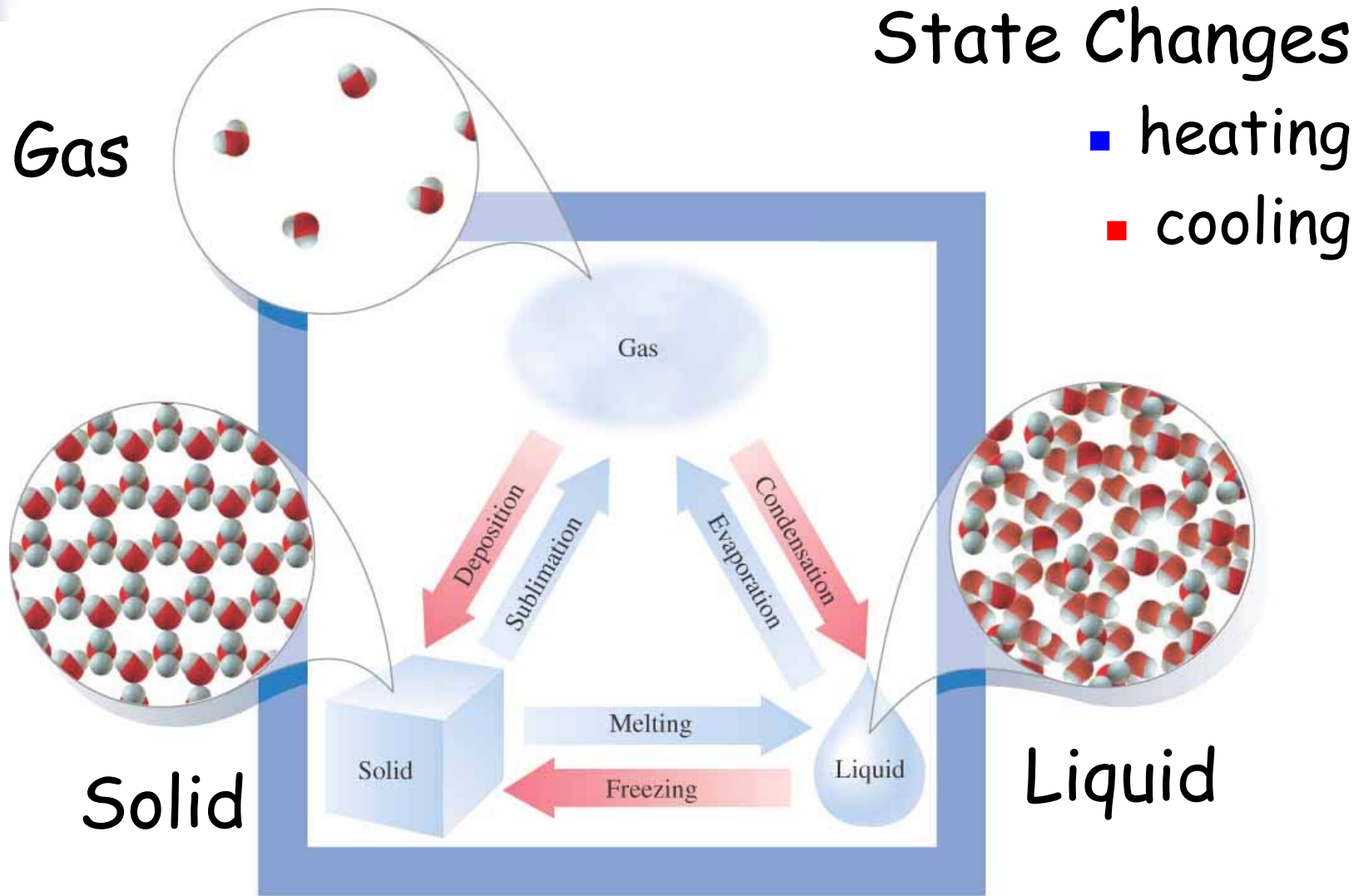
## Gases

- Weak interactions between molecules
- Molecules move rapidly
- Fast diffusion rates
- Low densities
- Easy to compress

## Liquids & Solids

- Strong interactions between molecules
- Molecules move slowly
- Slow diffusion rates
- High densities
- Hard to compress

# States of Matter





# Evaporation & Condensation

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- In every sample of liquid there is some fraction of molecules that possess enough kinetic energy to break away into a gas phase
- This process is called **evaporation**
- Therefore, some part of a liquid substance is always present in form of vapor (gas phase) over the surface of the liquid
- Gas phase molecules can strike the liquid surface and be captured there
- This process is the reverse of evaporation and it is called **condensation**



# Evaporation & Condensation

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- We should distinguish two situations:
  - A liquid in an open container

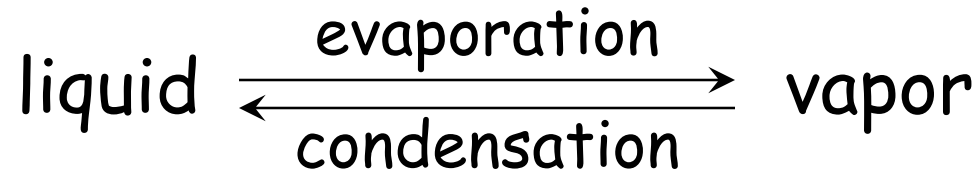
Gas phase molecules are free to move away from the liquid and eventually the liquid can evaporate completely (to dryness)
  - A liquid in a closed container

The motion of gas phase molecules is restricted by the walls of the container and there is always an equilibrium between the liquid and its vapor phase



# Vapor Pressure

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- As the temperature is raised, the fraction of molecules that can break away into the gas phase grows and vapor pressure increases
- The partial pressure of vapor molecules above the surface of a liquid at equilibrium at a given temperature is the **vapor pressure (vp)** of the liquid at that temperature
- Vapor pressures of liquids always increase as temperature increases



# Boiling

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- If a liquid is heated to sufficiently high temperature, its vapor pressure can become equal to the applied (atmospheric) pressure
- Gas phase in the form of bubbles is formed within the volume of the liquid and the bubbles rise to the surface and burst releasing the vapor into the air
- This process is called **boiling**
- The boiling point of a liquid is increased at higher atmospheric pressures and decreased at lower atmospheric pressures



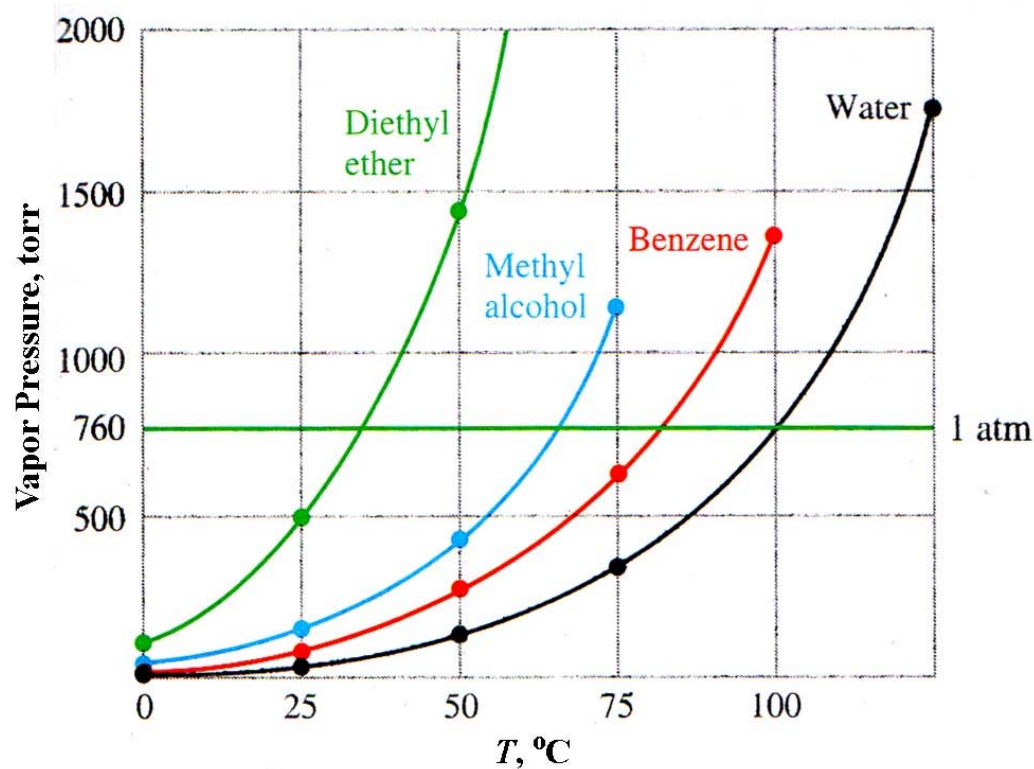
# Boiling vs. Evaporation

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- Boiling and evaporation are essentially different processes:
  - Boiling occurs only at certain temperature
  - Evaporation takes place at all temperatures as long as the liquid phase persists  
(for evaporation to take place the vapor pressure does not have to be the same as the atmospheric pressure)
- The knowledge of vapor pressure curves can be used to predict the boiling points of liquids at different pressures and to compare the attractive intermolecular forces acting in liquid phases

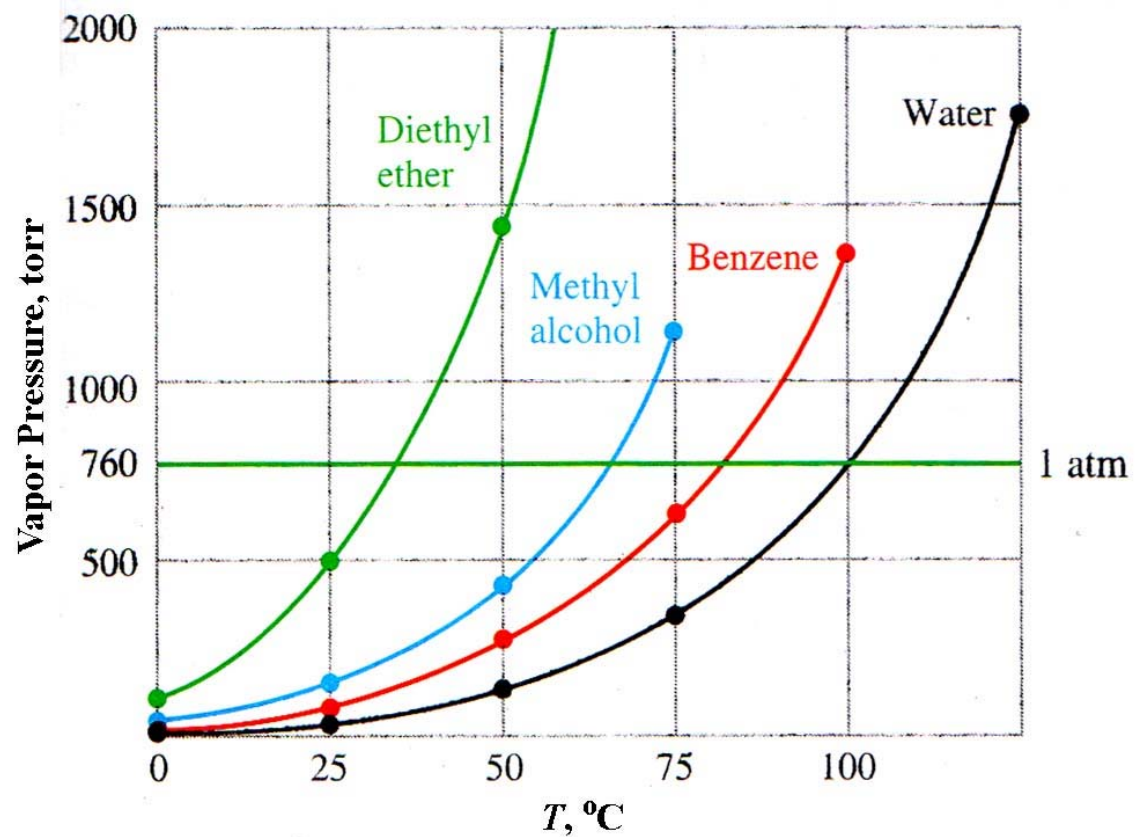
# Example 1

- Compare the boiling points of four liquids at normal atmospheric pressure, at 500 torr, and at 1000 torr. In which liquid attractive forces acting between molecules are the strongest?



## Example 2

- At normal atmospheric pressure and  $75^{\circ}\text{C}$ , which of the four compounds will exist in the liquid state? Explain your answer.





# Assignments & Reminders

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- Read Sections 12-1 through 12-13
- Read Sections 13-1, 13-6, 13-7, and 13-8
- Homework #8 is due by 9 p.m. on Monday
- Review Sessions for the Final Exam:
  - Wednesday @ 5:00-7:00 p.m. in 105 HELD
  - Thursday @ 5:30-7:30 p.m. in 105 HELD
  - Sunday @ 5:15-8:00 p.m. in 100 HELD