# SOLIDS, LIQUIDS, AND GASES

(BUT MOSTLY GASES)

Ch 10, 11, 12, 13

## Particle Representations

- Draw 10 molecules for each:
  - Solid
  - Liquid
  - Gas

## Particle Representations

- Draw 10 molecules for each:
  - Solid—molecules held tightly together, wiggle slightly
  - Liquid
  - Gas

## Particle Representations

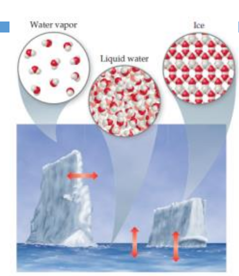
- Draw 10 molecules for each:
  - Solid—molecules held tightly together, wiggle slightly
  - Liquid—molecules packed closely, move rapidly, can slide
  - Gas

## Particle Representations

- Draw 10 molecules for each:
  - Solid—molecules held tightly together, wiggle slightly
  - Liquid—molecules packed closely, move rapidly, can slide
  - Gas—molecules far apart, move at high speeds, collide with each other and walls of container

## Particle Representations

- Volume per mole of solids and liquids are similar



## Solids, 12.2

7

- Crystalline—repeating pattern
- Amorphous—no order

Obsidian (typically $KAlSi_3O_8$), an amorphous solid

Iron pyrite ($FeS_2$), a crystalline solid

## Solids, 12.2

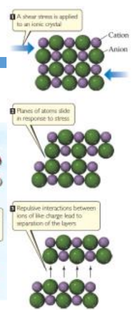
8

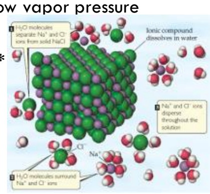
- Properties determined by types and strengths of IMFs
- Stronger IMFs → higher boiling points and vapor pressures
  - Also melting points, but more subtly

## Ionic Solids, 12.5

9

- Strong IMF interactions between ions
  - High MP, high BP, low vapor pressure
  - Brittle
  - Conduct electricity*

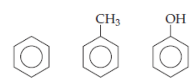


## Molecular Solids, 12.6

10

- IMFs?
- Low MP, BP
- Don't conduct electricity

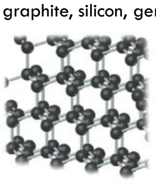


| | Benzene | Toluene | Phenol |
|---|---|---|---|
| Melting point (°C) | 5 | –95 | 43 |
| Boiling point (°C) | 80 | 111 | 182 |

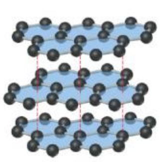
## Covalent-Network Solids, 12.7

11

- Atoms covalently bonded in 3D network
- Diamond, graphite, silicon, germanium, quartz ($SiO_2$)



(a) Diamond



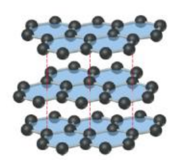
(b) Graphite

## Covalent-Network Solids, 12.7

12

- Nonmetals
- High MP
- Rigid
- Hard
- Why is graphite soft?

(a) Diamond

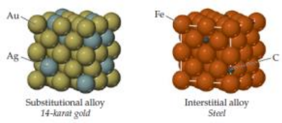


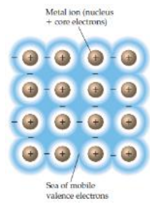
(b) Graphite

## Metallic solids, 12.4

13

- Sea of electrons
- Conduct heat and electricity
- Malleable and ductile
- Interstitial vs substitutional alloys

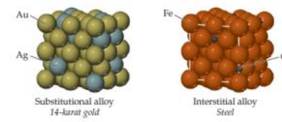



## Metallic solids, 12.4

14

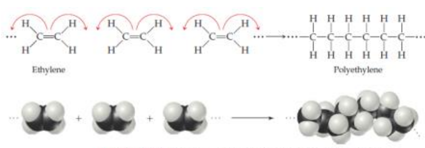
- Interstitial alloys
  - Rigid
  - Harder, stronger
  - Less malleable/ductile
- Substitutional alloys




## Polymeric solids, 12.8

15

- Monomers joined together

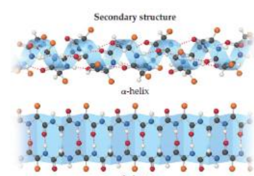



▲ FIGURE 12.35 The polymerization of ethylene monomers to make the polymer polyethylene.

## Biomolecules/biopolymers, 24.6

16

- Noncovalent interactions (IMFs) between two different molecules OR between different areas of same molecule




## Liquids, 11.3

17

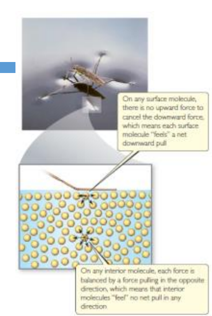
- Particles are in close contact
- Moving and colliding
- How do IMFs influence arrangement and movement of particles?
  - Viscosity
  - Surface tension

## Liquids, 11.3

18

SAE 40
higher number
higher viscosity
slower pouring

SAE 10
lower number
lower viscosity
faster pouring



## Gases, 10.1

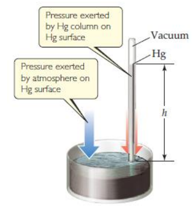
19

- Collisions and spacing between molecules depend on temperature, pressure, volume
- Can compress
- Vapor—a substance that is solid or liquid under ordinary conditions (water vapor)

## Gases and Pressure, 10.2

20

- Units: kPa, psi, atm, mm Hg, torr, etc
- 1 atm = 760 mmHg = 760 torr
- Gas pressure caused by molecule collisions (container, each other, etc)
- Atmospheric pressure caused by gravity, atmosphere presses down on surface
- Barometer (right)




## Gas pressure practice 1

21

Perform the following calculations:

1. 657 mmHg to atm
2. 830 torr to atm
3. 1.50 atm to mmHg

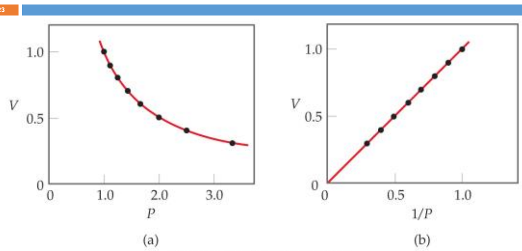
## Combined Gas Law*, 10.3

22

- Combined gas law: $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$
- *Not on AP equation and constant sheet*
- K = ˚C + 273.15

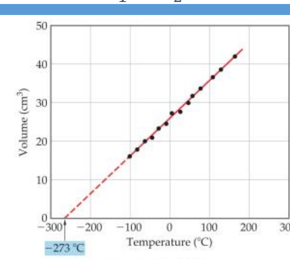
## Boyle's law $P_1V_1=P_2V_2$, T is constant

23




## Charles's law $\frac{V_1}{T_1} = \frac{V_2}{T_2}$, P is constant

24



## Gay-Lussac law $\frac{P_1}{T_1} = \frac{P_2}{T_2}$, V is constant

25

- What would a graph look like?

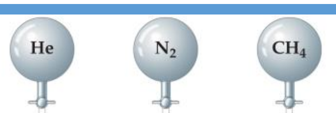
## Avogadro's law

26

- Constant T, P
- The volume of a gas is directly proportional to the number of moles (n)
- What would a graph look like?
- Equal V of different gases contain the same number of molecules (1 mol = 22.4 L at STP)

## Avogadro's law

27




| | He | $N_2$ | $CH_4$ |
|---|---|---|---|
| Volume | 22.4 L | 22.4 L | 22.4 L |
| Pressure | 1 atm | 1 atm | 1 atm |
| Temperature | 0 °C | 0 °C | 0 °C |
| Mass of gas | 4.00 g | 28.0 g | 16.0 g |
| Number of gas molecules | $6.02 \times 10^{23}$ | $6.02 \times 10^{23}$ | $6.02 \times 10^{23}$ |



## Combined gas law practice 2

28

1. If a 1.23 L sample of gas at 53.0 torr is put under pressure up to a value of 240. torr at a constant pressure, what is the new volume?
2. A gas has a volume of 0.572 L at 35°C an 1.00 atm pressure. What is the temperature inside a container where this gas has a volume of 0.535 L at 1.00 atm?
3. A gas at 25 °C in a closed container has its pressure raised from 150. atm to 160. atm. What is the final temperature of the gas?

## Combined gas law practice 3

29

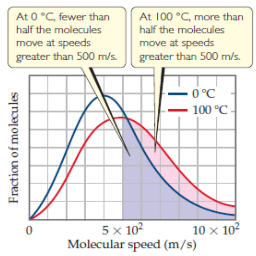
- 20.5 L of nitrogen at 25°C and 742 torr are compressed to 9.8 atm at constant temperature. What is the new volume?
- What would the final volume be if 247 mL of gas at 22°C is heated to 98°C , if the pressure is held constant?
- At what temperature would a gas at 40.5 atm at 23.4°C have at a pressure of 81.9 atm at constant volume?
- A sample of gas has a volume of 4.18 L at 29°C and 732 torr. What would its volume be at 24.8°C and 756 torr?

## Kinetic molecular theory, 10.7

30

- Ideal gases:
  - Have no attractive/repulsive forces
  - Have negligible volume
  - Molecules are in constant, rapid, random, straight-line motion
  - Kinetic energy is proportional to the temperature
    - Any two gases at same T have same KE
    - KE = ½ m $v^2$

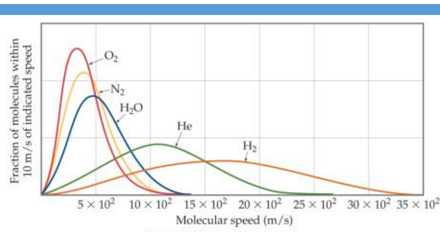
## Distribution of molecular speed, 10.7




## Molecular speed

- A sample each of xenon gas and helium gas have the same temperature. Which gas molecules have the fastest speed?
- KE = ½ m $v^2$

## Molecular speeds at 25°C




## Ideal gases vs real gases

- Real gases:
  - Have IMFs
  - Particles have volumes
- Real gases behave ideally when:
  - Low P
  - High T
  - Low mass

## Ideal Gas Law, 10.4

- Ideal gas law: P V = n R T
- R = 8.314 J $mol^{-1}$ $K^{-1}$; 0.08296 L atm $mol^{-1}$ $K^{-1}$; 62.36 L torr $mol^{-1}$ $K^{-1}$
- K = °C + 273.15

## Graphical representations

- Sketch graphs of the relationships between P, V, T, n

## Ideal gas law practice 4

37

1. A sample of gas in a 500.0 mL flask has a pressure of 1.2 atm and a temperature of 25 °C. How many moles of the gas are in the flask?

- 0.025 mol

## Ideal gas law practice 4

38

2. A sample of aluminum chloride weighing 0.100 g was vaporized at 350.°C and 1.00 atm pressure to produce 19.3 mL of vapor. Calculate the molar mass of aluminum chloride.

- 265 g $mol^{-1}$

## Ideal gas law sample problem 4

39

3. What is the density of carbon dioxide at 0.985 atm and 50.0°C?

## Partial pressures, 10.6

40

- In a gaseous mixture, each component exerts a pressure (partial pressure)
- The sum of all the partial pressures = total pressure
- $P_T = P_1 + P_2 + P_3 + \ldots$
- $P_1 = X_1 P_T$
- Mole fraction $X_1 = n_1/n_T$

## Partial pressure practice 5

41

1. The atmospheric pressure at DIA on 12/2 at 10:20 pm was 624 torr. If air is 78% nitrogen and 21% oxygen,
   a. Determine the partial pressures of nitrogen and oxygen.
   b. If a sample of air contains 10.0 moles of molecules, what is the mole fraction of nitrogen? Oxygen?

## Partial pressure practice 5

42

2. A mixture of gases contains 4.46 moles Ne, 0.74 moles Ar, and 2.15 moles Xe. Calculate the partial pressure of each gas if the total pressure is 2.00 atm.

- $P_{Ne}$ = 1.21 atm
- $P_{Ar}$ = 0.20 atm
- $P_{Xe}$ = 0.585 atm

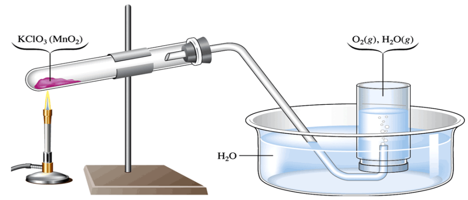
## Partial pressure practice 5

43

3. The partial pressure of nitrogen in air is 590 torr and the partial pressure of oxygen in air is 160 torr. What is the total pressure of the air?
4. A sample of oxygen is collected over water at 26˚C and 760 mmHg. The vapor pressure of water at 26˚C is 25 mmHg. The total volume of gas is 0.500 L. How many moles of oxygen were collected?

## Collecting gas over water

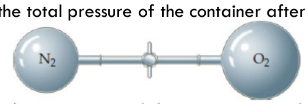
44




## Partial pressure practice 6

45

- What happens when the valve is opened?
- Determine the total pressure of the container after the gases mix.




| | |
|---|---|
| 1.0 L | 1.5 L |
| 3.0 atm | 1.5 atm |
| 25˚C | 25˚C |

## Effusion and diffusion

46

- Effusion—gas passing through small hole into vacuum
- Diffusion—gas molecules spreading through a volume
- Lighter molecules move faster than heavier molecules

- Which will effuse faster, $H_2$ or $CH_4$?
- Which will diffuse faster, $H_2$ or $CH_4$?