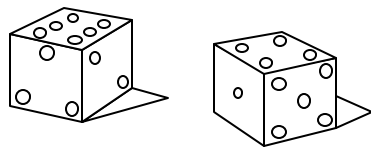


## Particle Motion in the Gaseous State

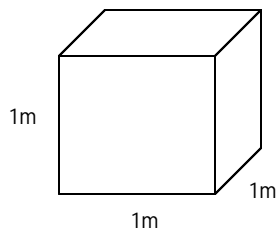


What type of particles can we have in the gaseous state?

- Atoms such as He or Rn – easily treated as spherical particles
- Molecules such as CO<sub>2</sub> or C<sub>4</sub>H<sub>10</sub>

We want to consider these particles and their behavior without reaction occurring.

If we have a 1 m<sup>3</sup> box of a gas at 25°C and 1 atm, how many particles of gas are in the box?



Number of particles = ?

Number of particles

moles      Avogadro's number      PV = nRT

1 m<sup>3</sup> = 1000 L

$$= nN_A = (PV/RT) N_A$$


$$= [1.0 \text{ atm} \times 1000 \text{ L} / (0.0821 \text{ L}\cdot\text{atm}/\text{mole}\cdot\text{K} \times 298\text{K})] \times 6.02 \times 10^{23} \text{ particles/mole}$$

$$= 2.5 \times 10^{25} \text{ particles}$$

Do the particles take up space in the box?

How much of the volume of the box is occupied by the volume of the atoms?

For argon atom  $r_{vdw} = 181 \text{ pm} = 1.81 \times 10^{-10} \text{ m}$

  $V_{\text{atom}} = (4/3)(\pi)r^3 = 2.5 \times 10^{-29} \text{ m}^3$

total volume occupied =  
volume of atom x number of atoms  
=  $2.5 \times 10^{-29} \text{ m}^3/\text{atom} \times 2.5 \times 10^{25} \text{ atoms}$

=  $6.2 \times 10^{-4} \text{ m}^3$  (0.062%) or 621 cm<sup>3</sup>

For an IDEAL GAS, we assume:

Atoms or molecules occupy essentially no space in the container.

Atoms or molecules do not interact with each other.

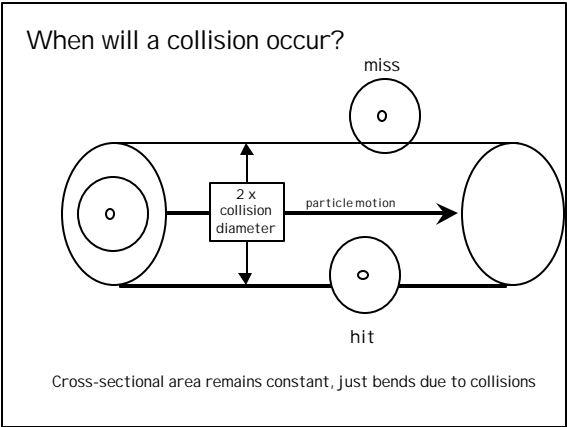
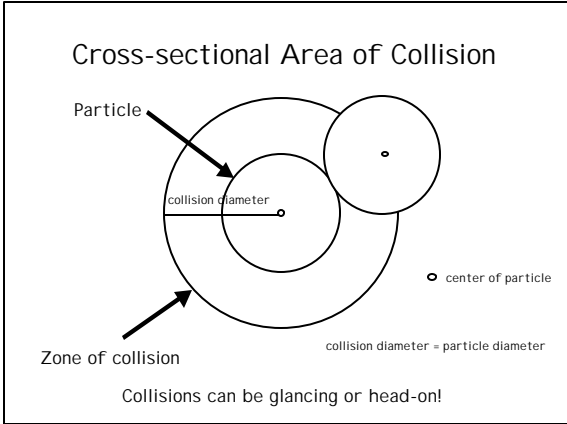
psst... not bad at room conditions!!

How would you describe how the particles in the box are behaving?

Are they static?

Are they in random rapid motion?

Are there collisions between particles?



Some collision properties of gases - for one cubic meter of gas at 25°C and 1 atm

gas	MM, g/mole	average		collision frequency		overall collision rate x 10 <sup>12</sup> , m <sup>3</sup> -sec
		velocity, m/sec	collision diameter, pm	per molecule, 10 <sup>9</sup> /sec		
H <sub>2</sub>	2	1776	273	125	14.1	17.4
He	4	1256	218	193	6.5	7.9
N <sub>2</sub>	28	475	374	66	7.1	8.7
O <sub>2</sub>	32	444	357	72	6.1	7.4
Ar	40	397	362	70	5.6	6.8
CO <sub>2</sub>	44	379	456	44	8.5	10.3
HI	128	222	556	30	7.4	10.3

**Mean free path**- average distance a particle travels between collisions

How does average velocity vary with molar mass?  
As MM increases, velocity decreases

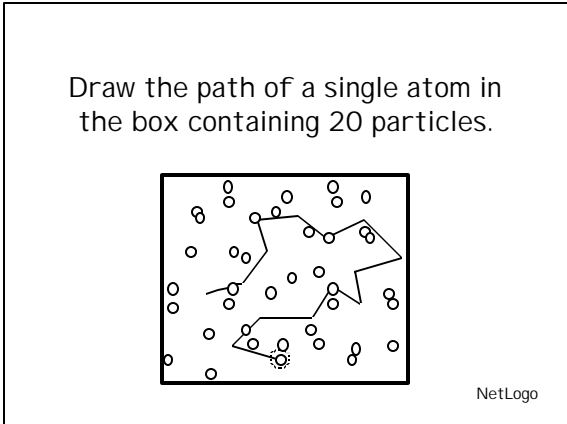
How does the collision diameter vary with molar mass?  
As MM increases, collision diameter increases

How does the mean free path vary with molar mass?  
As MM increases, mean free path decreases

How do the collision frequency and overall collision rate vary?  
Both do not vary by much

### Summary

- particles in rapid (~1000 mph for N<sub>2</sub> and O<sub>2</sub> at 25°C) and random motion
- a very large number of collisions of particles occurs
- larger atoms/molecules (higher MM) travel slower; however, have greater collision diameters
- increasing the number of particles, increases the collision rate



### Questions

Why is the particle motion in a gas chaotic?

Oxygen gas will dissolve in water. The mean free path of dissolved oxygen is less than gaseous oxygen. Why?

How does an increase in temperature influence the collection of particles?

For a chemical reaction to occur in the gaseous state, some things to think about:

- Are collisions required?
- Do all collisions lead to reaction?
- Does the orientation of a molecule in a collision make a difference?