The Kinetic Theory of Gas III:

- Z_I = collision frequency = number of collisions per molecule
- Z_{II} = collision rate = total number of collisions
- λ = mean free path = distance traveled between collisions

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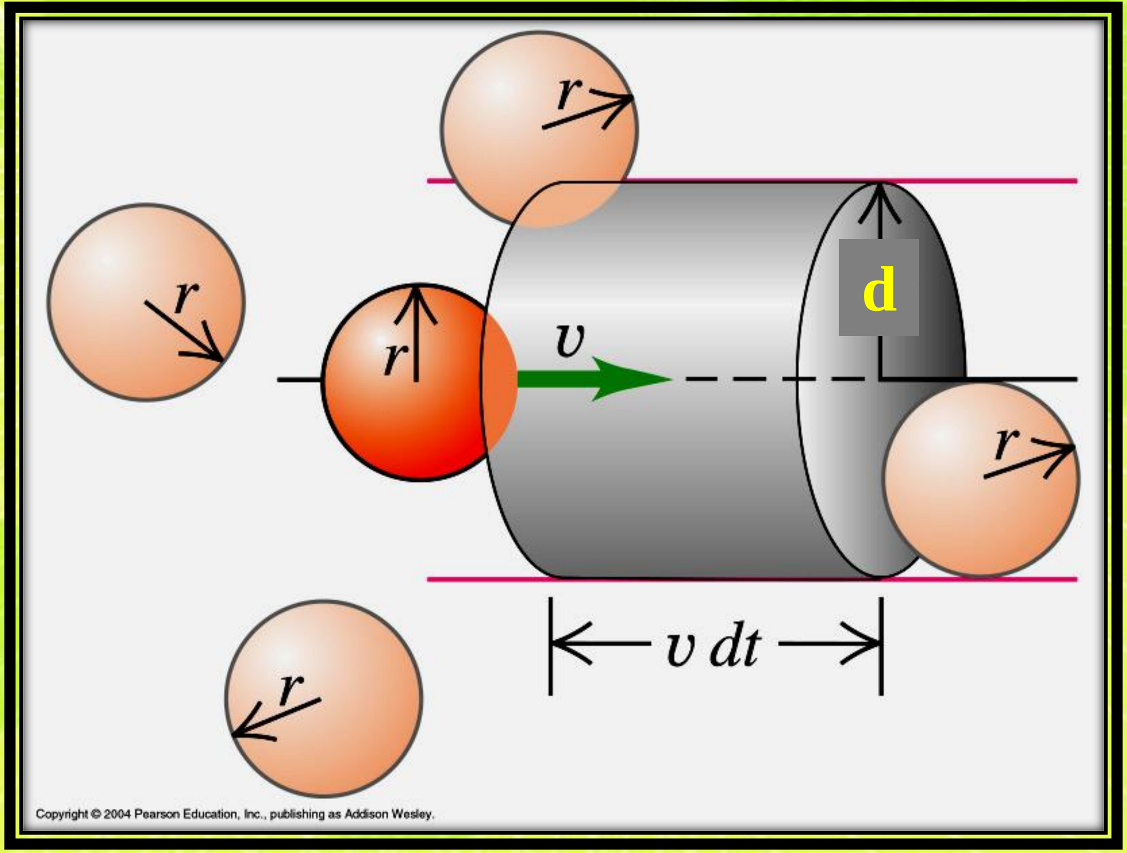
Collision amongst the molecules

- Collision shall occur when the centers of 2 molecules have distance d (interaction diameter), which is = d
- The Surface Area of Container is $\sigma = \pi d^2$
- The long of container (distance to be passed): $\ell = \upsilon dt$ (υ: average speed)
- Volume of the container (interaction volume) is $V = \sigma\ell$
- No. of collision:

$$\left(\frac{N}{V}\right)\sigma\ell$$



Collision Frequency (Z_I)

$$V = \sqrt{2} \cdot \pi \cdot d^2 \cdot v_{avg}$$

$$where: \; v_{relative} = \sqrt{2} \cdot v_{avg}$$

$$v_{avg} = \sqrt{\frac{8 \cdot k \cdot T}{\pi \cdot m}} = \sqrt{\frac{8 \cdot R \cdot T}{\pi \cdot M}}$$

$$v_{relative} = \sqrt{\frac{8RT}{\pi\mu}}$$

$$where \;\; \mu = \frac{m_A m_B}{m_A + m_B}$$

$$if \;\; m_A = m_B:$$

$$v_{relative} = \sqrt{\frac{8RT}{\pi} x \frac{2m_A}{m_A^{\;2}}}$$

Define: N* = N/V = molecules per unit volume

$$Z_I = (V) \cdot (N^*)$$

$$Z_I = \sqrt{2} \cdot \pi \cdot d^2 \cdot v_{avg} \cdot N^*$$

Collision Rate (Z_{II})

$$Z_{II} = Z_I \cdot N^* \cdot \left(\frac{1}{2}\right)$$

Double Counting Factor

$$Z_{II} = \frac{1}{\sqrt{2}} \cdot \pi \cdot d^2 \cdot v_{avg} \cdot (N^*)^2$$

$$N^* = \frac{N}{V} = ???$$

$$PV = nRT$$

$$PV = \frac{N}{N_{Avog}} RT$$

$$\frac{N}{N_{Avog} V} = \frac{P}{RT} = [A]$$

$$so \ \frac{N}{V} = \frac{PN_{Avog}}{RT} = \frac{P}{kT} = [A] N_{Avog}$$

Collision Rate (Z_{II})

$$Z_{II} = \frac{1}{\sqrt{2}} \cdot (N^*)^2 \cdot \pi \cdot d^2 \cdot v_{avg}$$

$$v_{avg} = \sqrt{\frac{8 \cdot k \cdot T}{\pi \cdot m}} = \sqrt{\frac{8 \cdot R \cdot T}{\pi \cdot M}}$$

For A-B collisions: μ_{AB} , υ_{AB}

Reduced Mass ≡> $\mu_{AB} = \frac{m_A \cdot m_B}{m_A + m_B}$

Relative Velocity ≡> $v_{relative(AB)} = \sqrt{\frac{8 \cdot k \cdot T}{\pi \cdot \mu_{AB}}}$

Collision Diameter

$$d_{AB} = \frac{d_A + d_B}{2}$$

Number per Unit Volume

$$N_A{}^* = \frac{N_A}{V}$$

$$N_B{}^* = \frac{N_B}{V}$$

Collision Rate (Z_{II}) of 2 different molecules

$$Z_{II(AA)} = \frac{1}{\sqrt{2}} \cdot (N_A{}^*)^2 \cdot \pi \cdot d_A{}^2 \cdot \left(\frac{8kT}{\pi \cdot m_A} \right)^{1/2}$$

$$Z_{II(AB)} = N_A{}^* \cdot N_B{}^* \cdot \pi \cdot d_{AB}{}^2 \cdot v_{avg(AB)}$$

$$Z_{II(AB)} = (N_{Avog})^2 . [A][B] . \pi \cdot d_{AB}{}^2 \cdot v_{avg(AB)}$$

$$Z_{II(AB)} = N_A{}^* \cdot N_B{}^* \cdot \pi \cdot d_{AB}{}^2 \cdot \left(\frac{8kT}{\pi \cdot \mu_{AB}} \right)^{1/2}$$

$$remember \quad [A]N_{Avog} = \frac{N}{V} = \frac{PN_{Avog}}{RT} = \frac{P}{kT}$$

Mean Free Path (λ)

$$\lambda = \frac{\text{distance traveled per unit time}}{\text{no molecules it collides with in unit time}} = \frac{v_{avg}}{Z_I}$$

$$\lambda = \frac{1}{\sqrt{2}\cdot\pi\cdot d^2\cdot N_A[A]} = \frac{V}{\sqrt{2}\cdot\pi\cdot d^2\cdot N}$$

The mean free path is independent of temperature

The mean time between collisions **is** temperature dependent

Kinetic-Molecular-Theory Gas Properties - Collision Parameters @ 25 °C and 1 atm

Species	Collision diameter		Mean free path	Collision Frequency	Collision Rate
	d / 10^{-10} m	d / Å	λ / 10^{-8} m	Z_I / 10^{9} s^{-1}	Z_{II} / 10^{34} m^{-3} s^{-1}
H_2	2.73	2.73	12.4	14.3	17.6
He	2.18	2.18	19.1	6.6	8.1
N_2	3.74	3.74	6.56	7.2	8.9
O_2	3.57	3.57	7.16	6.2	7.6
Ar	3.62	3.62	6.99	5.7	7.0
CO_2	4.56	4.56	4.41	8.6	10.6
HI	5.56	5.56	2.96	7.5	10.6