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BSK1133 PHYSICAL CHEMISTRY

CHAPTER 1
KINETIC THEORY OF GASES
(PART B)

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Description

Aims

- To understand the derivation of an ideal gas equation by using theory of kinetic
- To understand the Boltzman relationship of gases

Description

Expected Outcomes

- ❖ Able to understand the kinetic molecular theory of gases and how an ideal gas equation derived using that theory
- ❖ Able to understand the Boltzman relationship of gases

References

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1.5 Derivation of Ideal Gas using Theory of Molecular Kinetic

Assumptions based on derivation

- composed of molecules which are separate and tiny particles
- gas molecules have kinetic energy ($KE = \frac{1}{2} mv^2$) which are in rapid, constant and straight line motion. (which means)
- the collisions between molecules are completely <u>elastic</u> where there is no exchange of energy
- there is no attraction or repulsion between gas molecules.
- Each molecule exhibits different velocity.

Detail explanation on the assumptions and derivation

- Consider a room which has a cube shape with six surfaces. The pressure on each of the surfaces is the same.
- Imagine that there are a single gas molecule in the room. Force will be exerted when that gas molecule strikes the walls of the room.
- Physicists consider a **force** to have been exerted when **there is a change in the momentum of a particle.**
- **Momentum (p)** = **mass** of the particle **(m)** X the **velocity (u)** of the particle.

- If the particle collide to the room surfaces with **perfect elastic collision (u)**, then, the particle will rebound in the exact opposite direction with exactly same **momentum (-u)**.

- The change in velocity can be determined by:

  u = velocity before - velocity after

  u = u - (-u) = 2u

- **Momentum : p = m x u = m(2u) = 2mu**

- The momentum (force) exerted is consistent in all surfaces of the room.

- Thus, we can conclude that the particle must travel a distance of 2d before it strikes the same surface again.

- However, the times of the particle strikes the same surface will depend on how fast it travels, u, and the distance between each event:

- Rate the particle strikes the room surface $= \dfrac{u}{2d}$

- Thus, the force exerted by a particle = 2 mu x $\dfrac{u}{2d}$

- Force exerted to the wall of the room $= \dfrac{mu^2}{d}$

- In a space, there must consist a lots of gas particles that freely filled the space. Considering the number of particles in this space as N.
- How many of these particles will be striking the surface of interest?

$$\frac{1}{3}N$$

- The total force exerted on this surface can now be determined:
- Total Force = $\frac{1}{3}N \text{ x } \frac{mu^2}{d}$

- Since we know the pressure equation is: $P = \dfrac{F}{A}$

- And the force calculated for a single particle $= \dfrac{1}{3} N \times \dfrac{mu^2}{d}$

- The surface area of the room (assuming it a cube shape):

$$A = d^2$$

- The pressure can now be determined:

$$P = \frac{1}{3} N \frac{mu^2}{d^3}$$

$$P = \frac{1}{3} N \frac{mu^2}{V} \quad (\text{where } d^3 = V)$$

- Rearrange this equation to obtain:

$$PV = \frac{1}{3} N m u^2$$

- Recall that KE = ½ mu^2

- PV = (½ mu^2)($\frac{2}{3}N$)

- PV = (KE)($\frac{2}{3}N$)

1.6 Boltzman Constant Relationship

Boltzmann Relationship

- The Boltzmann relationship between kinetic energy and temperature is:

$$KE = \frac{3}{2} kT$$

- Boltzman constant, k is R/N_A

- $k = 1.38064852(79)\times10^{-23}$ J/K

Replace KE with this term:

$$PV = \left(\frac{3}{2}kT\right)\left(\frac{2}{3}N\right)$$

or $PV = NkT$

N = number of particles

N / N_A (Avogadro's number) = n (number of mol).

K (Boltzman constant) / N_A = R (the gas constant)

Simplifying the equation will finally form:

PV = nRT *an ideal gas equation*

Conclusion

- The ideal gas equation is derived based on the theory of molecular kinetic of the gas.

- Temperature play a significant role to the kinetic of the gas molecules which can be seen in Boltzman relationship.

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