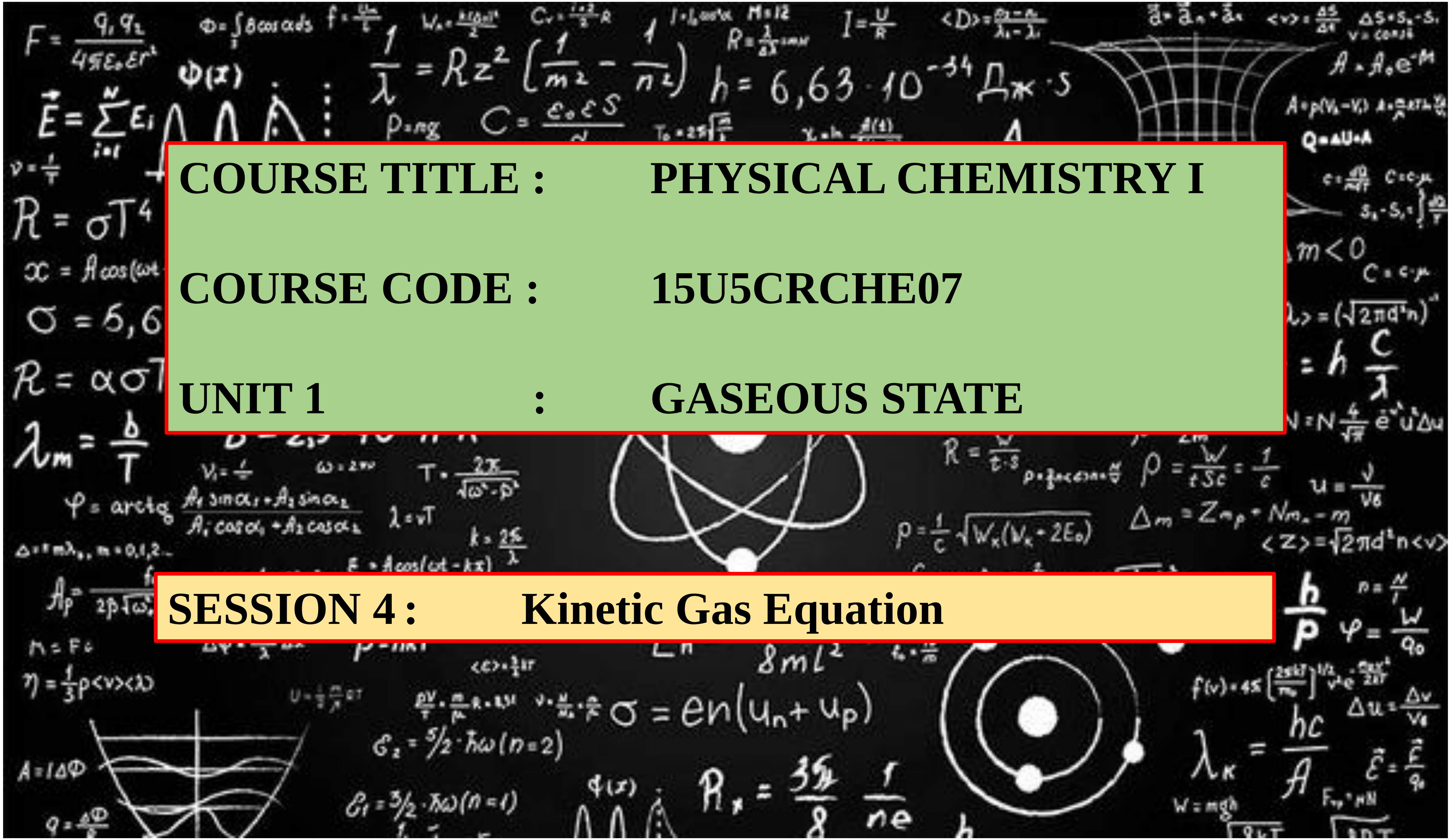


COURSE TITLE : PHYSICAL CHEMISTRY I

COURSE CODE : 15U5CRCHE07

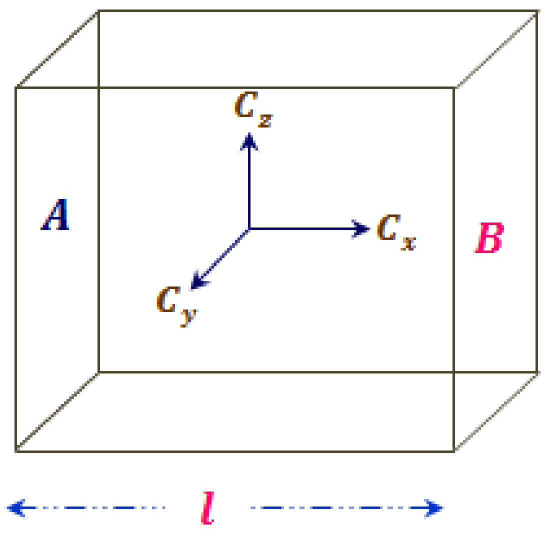
UNIT 1 : GASEOUS STATE

SESSION 4 : Kinetic Gas Equation

PRESSURE OF AN IDEAL GAS – THE KINETIC GAS EQUATION

The pressure of a gas is due to the elastic collisions of the gas molecules on the walls of the container

Consider N molecules of a gas - each of mass ‘m’, enclosed within a cube of edge length ‘l’.



Consider a single molecule with mass ‘m’ and velocity ‘c’.

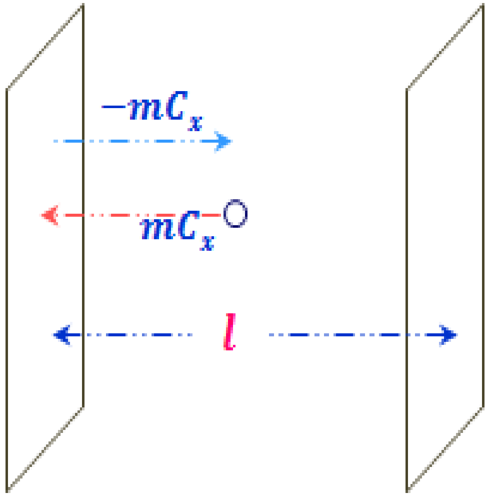
The velocity is resolved into three components cx, cy and cz along the x, y and z axes

$$c^2 = c_x^{\ 2} + c_y^{\ 2} + c_z^{\ 2}$$

Consider the motion in the x-direction towards face A of the cube.
The molecule will strike the face A with momentum mc_x.

it will rebound with a momentum $-mc_x$

Change in momentum = $mc_x - (-mc_x) = 2mc_x$



Velocity of the molecule is c_x m/s.

The distance travelled by the molecule in 1 second = c_x

The distance travelled by the molecule for colliding with face A = $2l$

Number of collisions on face A by the molecule in 1 second = $\frac{c_x}{2l}$

Change in momentum of a molecule per second = $2mc_x \times \frac{c_x}{2l} = \frac{mc_x^{2}}{l}$

Total change in momentum per second due to the impact on the two opposite faces along x-axis = $\frac{2mc_x^{2}}{l}$

The total change in momentum per molecule per second = $\frac{2mc_x^{2}}{l} + \frac{2mc_y^{2}}{l} + \frac{2mc_z^{2}}{l}$

$= \frac{2mc^{2}}{l}$

Let the individual velocities of molecules 1 to N be respectively c_1, c_2, c_3 ………… to c_N.

The total change in momentum per second of N molecules $= \frac{2mc_1^{\ 2}}{l} + \frac{2mc_2^{\ 2}}{l} + \ldots\ldots\ldots\ldots + \frac{2mc_N^{\ 2}}{l}$

$$= \frac{2m}{l}\left(c_1^{\ 2} + c_2^{\ 2} + \ldots\ldots\ldots\ldots c_N^{\ 2}\right)$$

$$= \frac{2mN}{l}\left(\frac{c_1^{\ 2} + c_2^{\ 2} + \ldots\ldots\ldots\ldots c_N^{\ 2}}{N}\right)$$

$$= \frac{2mNu^2}{l}$$

$u^2 = \left(\frac{c_1^{\ 2} + c_2^{\ 2} + \ldots\ldots\ldots\ldots c_N^{\ 2}}{N}\right)$ is Mean Square Velocity

u is known as the **Root Mean Square** (RMS) Velocity

The total change in momentum per second is equivalent to the force, f.

$$f = \frac{2mNu^2}{l}$$

$$P = \frac{force}{area} = \frac{f}{A}$$

$$P = \frac{force}{area} = \frac{2mNu^2}{l \times A}$$

$$A = 6l^2$$

$$P = \frac{2mNu^2}{l \times 6l^2} = \frac{mNu^2}{3l^3}$$

$$V = l^3$$

$$P = \frac{1}{3V} mNu^2$$

$$PV = \frac{1}{3} mNu^2$$

Kinetic Gas Equation