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**FEDERAL UNIVERSITY OF TECHNOLOGY MINNA
SECOND SEMESTER
PHYSIC 123 HANDOUT**

**DIGITALLY PREPARED BY:
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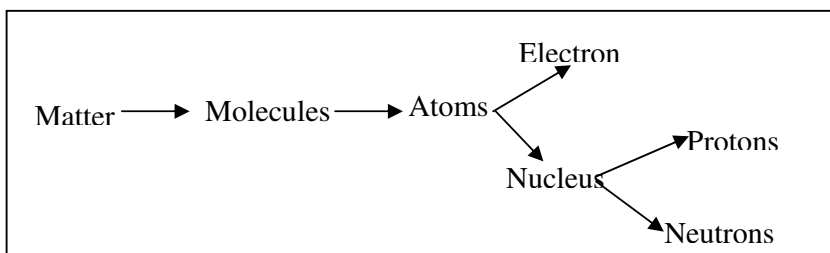
**TYPIST/DIGITALLY FORMULATED BY:
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PROPERTIES OF MATTER

Structure of matter



A simple diagrammatical description of matter is shown above.

Matter:

THIS is anything that has mass and occupies space. The force of attraction on the electron leads to nucleus weakening when the electron are further apart it gets to a point where they move under the influence of nucleus.

Electron:

This is the outer skin of matter, when electron are charged i.e. rubbed one's palm together, heat is generated. Matter is electrically stable due to its equilibrium (Same positive and negative charged particles)

Solid:

Intermolecular forces exist in solid since they are closely packed. **The intermolecular force is high and this makes solid very difficult to break.** As a result of the strong intermolecular force of solid, it gives the solids a definite shape and the molecules are arranged in a repeated regular pattern known as lattice.

Solid can vibrate at a fixed position transforming energy from points to point.

The molecules of solid vibrate in their mean position therefore; there is restriction in the movement of solid particles

Liquid:

In a liquid the molecules are arranged in this order NB: the force of attraction between the molecules is therefore weak compared to those of solids.

Gas:

The molecules in a gas are scattered.

NB: the force of attraction is very weak so it becomes infinitesimal (it appears as if it doesn't exist). Energy in gas is transfer from molecules to molecules.

NB:

- Liquid boil
- Solid melts
- Gas condense

Remember that $Q = Mc\theta + ML$ (During change of state i.e. when liquid changes to gas or solid to liquid)

Differences between boiling and evaporation

Boiling	Evaporation
It increases in internal energy	It causes cooling
It occurs in the entire container	It occurs at the surface
It occurs at definite temperature	It occurs at varying temperature

Remember that S. V P = Saturated Vapour Pressure

$$Q = Mct$$

$$Q = Ct$$

$$Q = ML$$

$$Q = mgh = \frac{1}{2} mv^2 = IVt$$

EFFECT OF HEAT

1. It causes increase in temperature (occurs in solid, liquid and gas)
2. Melting (it involves change in temperature, is applicable to solid only)
3. NB: When there is change in state the temperature is constant
4. It causes change in state (It is applicable to liquid)
5. It causes temporary madness
6. It causes thermal agitation in molecules
7. it causes expansion
8. it causes boiling

SATURATED VAPOR PRESSURE

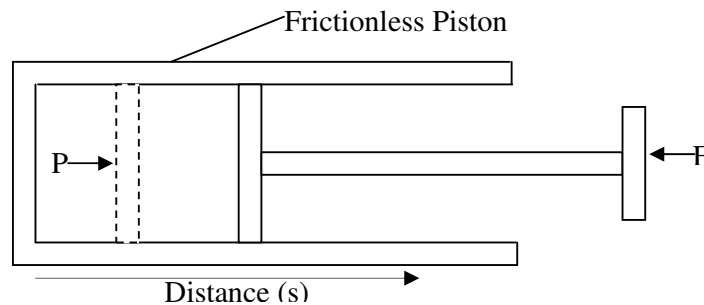
This is a pressure/degree of how hot or cold a body is. It is also the parameter that determines the direction of heat flow when two bodies are in thermal contact

Note that when three bodies are in contact, they are said to be in thermionic equilibrium.

ZENOTH'S LAW

For instance, when $A = B = C$. The temperature of the three bodies when they are equal is said to be constant.

Zenoth's law states **if the temperature of three bodies after separation remains the same they are said to be in thermodynamic equilibrium**



Consider a mass of gas enclosed in a cylinder by frictionless piston of cross sectional area (A) which is in equilibrium under the action of an external force (F), acting to the left and a force view to be pressure (P) of a gas acting on the right as shown on the diagram.

$$F = P_A$$

$$\int_{Final}^{Initial} dw = P.dv$$

$$W = P(V_2 - V_1) \text{ where } V_2 > V_1$$

$$W = PdV$$

NB: dV = change in pressure so that

$P.dV$ = Pressure \times Change in Volume (dV)

So Work done (W) = $P.dV$

From the first law of thermodynamics,

$$dq = du + dw$$

Hence

$$dq = du + PdV \quad - \quad - \quad - \quad 2$$

Remember that $PV = RT$ (Gas law)

Hence,

$$V = \frac{RT}{P}$$

HEAT CHANGE

Principle of heat capacity of gas

Molar heat capacity at constant volume (C_v) is the heat required to produce a rise in temperature in one mole of a gas when volume is kept constant.

Molar Heat Capacity at Constant Pressure (C_p): This is the heat required to produce a unite rise in temperature in one mole of gas when the pressure remains constant.

From equation (2) above, $dq = du + Pdv$

NB

dq = change in quantity of heat

du = change in internal energy

PdV = change in external energy

$dq = \text{No. of moles} \times C_p \times \text{Change in Temperature}$

$$\text{i.e. } dq = nC_p dt \quad - \quad - \quad - \quad 3$$

GAS LAW

NB: Pressure, Volume and Temperature are known as macroscopic .properties of matter

Remember from ideal gas law; $PV = RT$

Also remember that an ideal gas is a gas in which its volume is negligible compare with the volume of the container

A real gas is a gas that deviates from Raull's Law (Remember the Raul's Law?)

From Boyle's law $PV = K$

Charles Law $V/T = K$

From Pressure Law $P/T = K$ (remember all of that? Great)

Now show that $\frac{PV}{T} = K$ NB: $K = \text{constant}$

Therefore, $PV = KT$

QUESTIONS

1. A cylinder contains oxygen at the temperature of 20°C and a pressure of 15atm in a volume of 100L . A piston is lowered into the cylinder decreasing the volume occupied by the gas to 80L and raising the temperature to 25°C . Assuming oxygen behaves like an ideal gas under this condition, what is the pressure?

Solution

From the question;

$$\frac{P_1V_1}{P_2V_2} = \frac{T_1}{T_2} \quad \text{NB: } P_1 = 15\text{atm}, P_2 = ? V_1 = 100\text{L } V_2 = 80\text{L } T_1 = 30 + 27$$

$$T_2 = 25 + 273 = 293$$

Hence

$$\frac{15 \times 100}{P_2 \times 80} = \frac{293}{298}$$

Solving for P_2 , therefore $P_2 = 19.1\text{atm}$

QUESTION:

Calculate C_p and C_v of oxygen if their ratio is 1.40 and the density of oxygen is 1.43kgm^{-3} at STP, the pressure at $1\text{atm} = 1.01 \times 10^5$ and the molar mass of oxygen = 32×10^{-3}

Solution

From equation; $C_p : C_v = 1.40$ - - 1

NB: Density of O = 1.43kgm^{-3} , Pressure = $1.01 \times 10^5\text{Nm}^{-2}$ and molar mass O = 32×10^{-3}

But from the formulas state above; $R = C_p - C_v$ - 2

So, from equation (1) $C_p = 1.40C_v$ - - 3

Substitute the value of C_p in equation (2); $R = C_p - C_v$

Hence, $0.8205 = 0.40C_v$

Therefore, $C_v = 2.05$

Substitute the value of C_v in equation (3); $C_p = 1.40C_v$

Therefore $C_p = 1.40(2.05) = 2.87$

NB: Check that $\frac{C_p}{C_v} = \frac{2.87}{2.05} = 1.40$ correct!

QUESTION

The Pressure of a constant volume gas thermometer is 1500N/m^2 at 28°C . What will be the temperature of the gas when the pressure increases by $\frac{1}{3}\text{atm}$?

Solution

From the equation

$$P_1 / P_2 = T_1 / T_2$$

NB: $P_1 = 1500\text{N/m}^2$, $P_2 = \frac{1}{3} \times 1500 = 500 + 1500 = 2000\text{N/m}^2$

$$T_1 = 28 + 273 = 301\text{K} \text{ and } T_2 = ?$$

Hence,

$$301 / 200 = 301 / T_2$$

Therefore, $T_2 = 401.3\text{K}$

KINETIC THEORY OF MATTER

Kinetic theory of matter shows the comparison of how macroscopic properties of gas are related to the microscopic properties of a gas.

Examples of microscopic properties of gas are:

- speed
- mass

NB: Macroscopic Properties of gas are

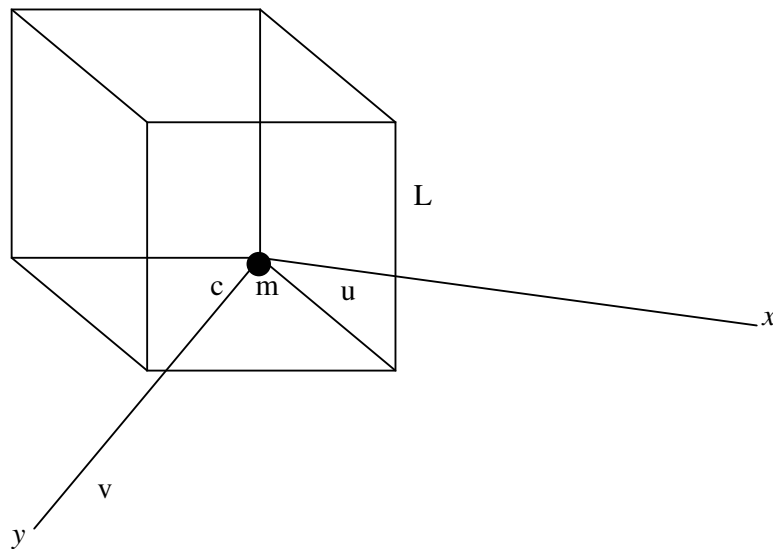
- Pressure
- Volume
- Temperature

ASSUMPTION OF KINETIC THEORY OF MATTER

1. The volume of the molecules is negligible compared to the volume of the container

NB: In ideal gas, the volume of the molecule of a gas is negligible compared to the containers while in real gas both the volume of the gas and the container are considered

2. The molecules of the gas moves in random motion, still obeying Newton's law of motion
3. The intermolecular force of attraction between the gas molecules is negligible
4. The molecules are the solid



5. The collision between the molecules of a gas and the wall of the container is perfectly elastic

Suppose a gas in a cubical box has a side L contains molecules each of mass (m)

Consider with one molecule moving with velocity (c) as shown in diagram above. We can resolve that (c) in three components (u, v, w) in x, y and z axis respectively

NB: A cubic box is used because it has three dimensional surfaces and matter has three states.

The molecules has momentum (Mu) to the right and on striking the wall of the container it rebounds with a momentum hence; change in momentum = 2Mu - - - (1)

If the molecules traveled to the wall of the container and rebound back with u again without striking any molecule on its way, it covers a ,distance 2L i.e. in time 2L/u i.e.

t = 2L/u

$$\text{NB: } \frac{dP}{dT} = \frac{d(Mu)}{dT} = \frac{m(v-u)}{dT} = \frac{mdV}{dT} = Ma = F$$

Hence,

$$F = \frac{dP}{dT} = \frac{2Mu}{\left(\frac{2L}{u}\right)} = \frac{Mu^2}{L}$$

$$F = \frac{Mu^2}{L} \quad - \quad - \quad - \quad - \quad (2)$$

Similarly,

$$F_x = \frac{M}{L} (u_1^2 + u_2^2 + u_3^2 + \dots u_n^2) \quad - \quad - \quad (3)$$

Where $u_1, u_2, u_3 \dots u_n$ are the different “Ox” components of the velocities of the molecules of (1, 2, 3, ...n)

Since the gas molecule exerts pressure on the container

Hence $P = F / A$

$$\rho P = \frac{M}{L^2} (u_1^2 + u_2^2 + u_3^2 + \dots u_n^2) \quad - \quad - \quad (4)$$

If \bar{u}^2 represents the mean value of the square of all the velocities components in the

$$\text{Ox direction then } \bar{u}^2 = \frac{(u_1^2 + u_2^2 + u_3^2 + \dots + u_n^2)}{N} \quad (5)$$

From equation No. (5)

$$\bar{u}^2 = u_1^2 + u_2^2 + u_3^2 + \dots + u_n^2 \quad (6)$$

From equation (4)

$$P = \frac{Nm\bar{u}^2}{L^2} \quad (7)$$

NB: Resolving “c” the velocity into three dimensional surfaces, hence

$$C^2 = u^2 + v^2 + w^2 \quad (8)$$

The Mean Square Value of the velocity (C^2) can be given as

$$\bar{C}^2 = \bar{u}^2 + \bar{v}^2 + \bar{w}^2 \quad (9)$$

Since N (number of molecules) is large and the molecules moves randomly the

mean square velocity \bar{C}^2 are equal. Hence

$$\bar{C}^2 = 3\bar{u}^2 \quad (10)$$

From equation (10)

$$u^2 = \frac{\bar{C}^2}{3} \quad (11)$$

Substituting equation (11) into (7) we obtain

$$P = \frac{Nm\bar{C}^2}{3L^2} \quad (12)$$

NB: $L^3 = \text{Volume (V)}$

Therefore,

$$P = \frac{Nm\bar{C}^2}{3V} \quad (13)$$

$$\boxed{PV = \frac{1}{3}Nm\bar{C}^2} \quad (14)$$

Also remember that density d is given by the relationship

$$d = \frac{\text{No.ofMass}}{\text{Volume}} \quad (\text{i.e}) \quad d = m/V$$

Therefore, by substituting this into equation (13) we have that

$$3P = dC^2$$

Therefore,

$$P = \frac{Nm\bar{C}^2}{3V} = \frac{d\bar{C}^2}{3}$$

where d is the density of the molecules and C is root mean square velocity

Observe from equation (14) above that

Macroscopic property = Microscopic property

- Molecules of a gas in the container they move
- Molecules of gas collide with the wall of the container and rebounds
- It obeys the law of motion (molecule of a gas)
- The molecules of gas move in the same direction have different momentum
- i.e. $P = MV$

TEMPERATURE IN KINETIC THEORY

Recall that

$$PV = \frac{1}{3} Nm\bar{C}^2 \quad - \quad - \quad - \quad (1)$$

$$PV = \frac{1}{3} N_A m\bar{C}^2 \quad - \quad - \quad - \quad (2)$$

Where N_A = Avogadro's number

$$PV = \frac{2}{3} N_A \left(\frac{1}{2} m\bar{C}^2 \right) \quad - \quad - \quad (3)$$

You should know that equation (2) and (3) are both equal. (Can you figure out why?)

Recall also that,

$$PV = RT \quad - \quad - \quad - \quad (4) \quad (\text{from General gas law})$$

So that,

$$PV = \frac{2}{3} N_A \left(\frac{1}{2} m\bar{C}^2 \right) = RT \quad - \quad - \quad (5)$$

Hence

$$\frac{1}{2} m \bar{C}^2 = \frac{3}{2} \frac{R}{N_A} T \quad - \quad - \quad - \quad - \quad (6)$$

(Try rearrange equation (5) and confirm to yourself that equation (6) is perfectly correct)

NB: $\frac{1}{2} m \bar{C}^2$ is known as kinetic energy or translational motion

So we can see that $R \propto N_A$

The ratio $R : N_A = \text{Boatman's constant} = k$

By introducing this constant to equation (6) therefore,

$$\frac{1}{2} m \bar{C}^2 = \frac{3}{2} k T \quad - \quad - \quad - \quad - \quad (7)$$

$$\text{K. E} = \frac{1}{2} m \bar{C}^2 = \frac{3}{2} k T$$

Therefore equation (7) explains the kinetic theory of temperature.

DEDUCTION FROM KINETIC THEORY OF MATTER

1. It is used to determine Avogadro's law

$$\text{From } PV = \frac{1}{3} Nm \bar{C}^2$$

$$P_1 V_1 = \frac{1}{3} N_1 m_1 \bar{C}_1^2$$

$$P_2 V_2 = \frac{1}{3} N_2 m_2 \bar{C}_2^2$$

Hence,

$$P_1 V_1 = P_2 V_2$$

$$\frac{1}{3} N_1 m_1 \bar{C}_1^2 = \frac{1}{3} N_2 m_2 \bar{C}_2^2$$

If the pressure, volume and temperature are the same, then $P_1 = P_2$, $V_1 = V_2$

$$\frac{1}{3} N_1 m_1 \bar{C}_1^2 = \frac{1}{3} N_2 m_2 \bar{C}_2^2 \quad (\text{i.e. } P_1 V_1 = P_2 V_2)$$

Hence, equal volume of ideal gas existing under the same condition of temperature, pressure contains equal number of molecules. This statement is known as **Avogadro's Law**

2. It determines Dalton's law of partial pressure.

The kinetic theory attributes gas pressure to bombardment of the walls of the containing vessels by molecules. In a mixture of ideal gasses we might therefore expect the total pressure to be the sum due to individual gas i.e.

$$P_1V_1 \rightarrow P_2V_2 \rightarrow PV; y_1 + y_2 = y$$

3. It determines graham's law of diffusion

Diffusion is the movement of gas molecules in air from one place to another



Ratio of diffusion of Gas 1

Ratio of diffusion of Gas 2

$$= \sqrt{\frac{\bar{C}_1^2}{\bar{C}_2^2}}$$

NB: $\sqrt{\bar{C}^2}$ is the mean square velocity (C_{rms})

$$P = 1$$

$$\frac{\bar{C}_1^2}{\bar{C}_2^2} = \frac{d_1}{d_2}$$

Rate of diffusion of Gas 1

Rate of diffusion of Gas 2

$$= \frac{\sqrt{d_1}}{\sqrt{d_2}}$$

Therefore, the rate of diffusion of gas is inversely proportional to the square root of its density

QUESTION

Calculate the root mean square speed of the molecules of hydrogen at (a) 273K (b) 373K

Density of hydrogen at s.t.p = $9.0 \times 10^{-2} \text{ kg/m}^3$

1atm = $1.01 \times 10^5 \text{ N/m}^2$

Solution

From equation above

$$P = \frac{d\bar{C}^2}{3}$$

Where P = pressure, \bar{C}^2 = mean square velocity and d = density

$$3P = dC^2 \quad \text{NB: } C_{\text{rms}} = \sqrt{C}$$

$$\text{But } P = 1\text{atm} = 1.9 \times 10^5 \text{Nm}^{-2} \text{ (convert 1atm to N/m}^2\text{)}$$

$$P = RT/V$$

Therefore

$$1.9 \times 10^5 = \frac{0.8205 \times 273}{V} \quad (\text{NB: } R = 0.8205)$$

$$\text{so solving the above therefore } V = 2.196 \times 10^{-3} \text{m}^3$$

$$3 \left(\frac{0.8205 \times 273}{2.2 \times 10^{-3}} \right) = 9 \times 10^5 \bar{C}^2$$

$$\text{NB: } P = \frac{d\bar{C}^2}{3} \text{ so that } 3P = dC^2$$

Solving the equation above for C, confirm for yourself that $\bar{C}^2 = 18.4 \times 10^2 \text{m/s}^2$.

Now, (b) since mean square speed of hydrogen is known, therefore the root mean square speed of 373K can be calculate

Let C_r represents root mean square of hydrogen at 373K and C represents root mean square speed of hydrogen at stp. Therefore

$$\frac{C_r}{C} = \sqrt{\frac{373}{273}} \quad \text{Where } C = 1.840 \times 10^3 \text{m/s}$$

Once again, confirm for yourself that $C_r = 2.150 \times 10^3 \text{m/s}$

QUESTION

From the following speed below

0.5, 2.5, 1.6, 2.75, 3.2, 0.72

Compute

- (i) Average speed (mean speed value) (\bar{C})
- (ii) Mean Speed square (\bar{C}^2)
- (iii) Root Mean Square (C_{rms})

Solution

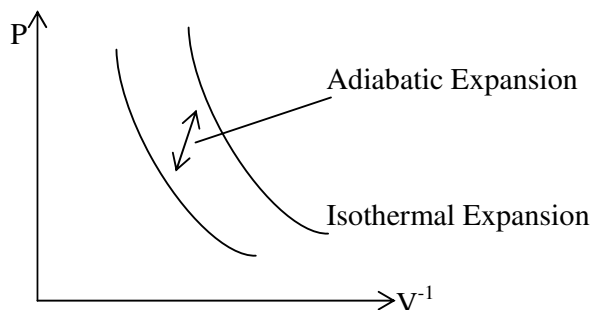
$$(i) \quad \text{Mean speed value } \bar{C} = \frac{0.5 + 2.5 + 1.6 + 2.75 + 3.2 + 0.72}{6} = 1.88 \text{m/s}$$

$$(ii) \quad \text{Mean Speed Square } (\bar{C}^2) = \frac{(0.5)^2 + (2.5)^2 + (1.6)^2 + (2.75)^2 + (3.2)^2 + (0.72)^2}{6} = 4.56 \text{m}^2/\text{s}^2$$

(iii) Root Mean Square Speed (C_{rms}) = $\sqrt{\bar{C}^2} = \sqrt{4.56} = 2.1 \text{ m/s}$

NB: This example shows clearly how to compute \bar{C}^2 , \bar{C} and C_{rms}

ADIABATIC EXPANSION



An adiabatic system is an isolated system in which no heat leaves the system or enters the system

NB: $dq = du + PdV$

When $dq = 0$, then

$0 = du + PdV$

$du = -PdV$

When there is increase in thermal energy by the system it means work is been done on the system. But when there is decrease in thermal energy of the system, it means work is been done by the system.

EXAMPLES OF ADIABATIC PROCESS

- i. Expansion of steel in the cylinder of steel engine
- ii. Expansion of hot gases in an internal combustion engine
- iii. Compression of air in a diesel engine/in air compressor

NB: To do something adiabatically is to do something quickly for example, in a calorimeter, in other to avoid heat loss or heat gain by the solution in the calorimeter. The calorimeter is lagged with cotton wool or silk.

REPRESSIBLE ISOTHERMAL EXPANSION

$dW = PdV$ - - - - (i)

recall also that

$PV = RT$ - - - - (ii)

From equation (ii) we have that

$$P = \frac{RT}{V} \quad - \quad - \quad - \quad - \quad (iii)$$

Substitute (iii) in (i) therefore we have that

$$dW = \frac{RT}{V} dV \quad - \quad - \quad - \quad - \quad (iv)$$

Dividing through by C_v (NB: $\gamma = \frac{C_p}{C_v}$) then

$$\frac{dVC_p}{V} \times \frac{1}{C_v} + \frac{dVC_v}{P} \times \frac{1}{C_v} = 0$$

(Because $du + PdV = 0$)

$$\frac{dV}{V} \times \frac{C_p}{C_v} + \frac{dV}{P} = 0$$

$$\boxed{\frac{dV}{V} \gamma + \frac{dV}{P} = 0} \quad (NB: \gamma = \frac{C_p}{C_v})$$

Similarly,

$$\boxed{\frac{dP}{P} + \gamma \frac{dV}{V} = 0}$$

Furthermore,

$$\ln P + \gamma \ln V = 0$$

$$\ln PV^\gamma = 0$$

$$\boxed{\ln P_1 V_1^\gamma = \ln P_2 V_2^\gamma}$$

This equation is for adiabatic process at constant temperature

$$P_1 V_1 = P_2 V_2 \quad - \quad - \quad - \quad - \quad (i)$$

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2} \quad - \quad - \quad - \quad - \quad (ii)$$

NB: $PV = RT$

Dividing equation (i) by (ii)

$$T_1 V_1^{\gamma-1} = T_2 V_2^{\gamma-1}$$

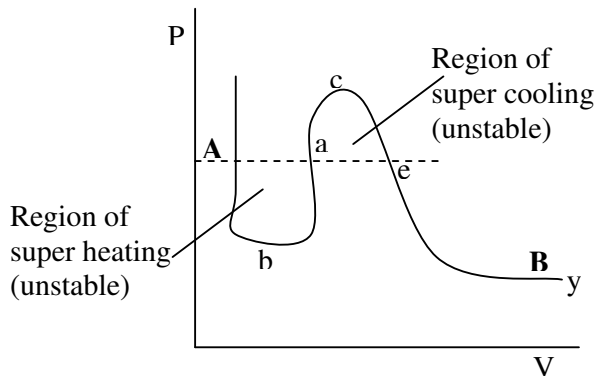
($TV^{\gamma-1} = \text{constant}$)

Similarly,

$$\frac{P_1^{\gamma-1}}{T_1^\gamma} = \frac{P_2^{\gamma-1}}{T_2^\gamma}$$

($\frac{P^{\gamma-1}}{T^\gamma}$ is constant)

REAL GAS; VAN DER WAAL EQUATION



$$\left(P + \frac{a}{V^2}\right)(V - b) = RT$$

$$\left(\frac{a}{V^2}\right) \text{ This is the value that is not negligible}$$

Lets consider a typical isotherm x , A, b, a, c, e, y above consider the behaviour at “a”, suppose we started with a homogeneous phase along the phase, the slope dP/dV is positive. This means that a small increase in volume is accompanied by increase in pressure, hence there is a spontaneous expansion towards C, that also implies that a small decrease in volume will lead to a spontaneous contraction towards “b”

$$dW = RT \cdot \ln V \implies W = RT \ln\left(\frac{V_2}{V_1}\right) \implies W = RT \ln\left(\frac{P_1}{P_2}\right) \quad - \quad - \quad 5$$

NB: we use $\frac{V_2}{V_1}$ and $\frac{P_1}{P_2}$ because $P_1 V_1 = P_2 V_2$.

In reversible adiabatic process, we move the piston extremely slowly from an ideal gas, an adiabatic expansion gives a temperature drop while the ratio $\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{\gamma-1}$

$$\text{NB } \gamma = \frac{C_p}{C_v}$$

But for a real gas, the temperature drop is greater because of the energy expended in overcoming the intermolecular forces of attraction from $dq = du + dW$

NB: $dW = PdV$

Hence, $dq = du + PdV - \quad - \quad - \quad - \quad - \quad (i)$

When $dq = 0$ then,

$$PV + \frac{a}{V} - Pb - ab = RT \quad - \quad - \quad 3$$

$$P + V \left(\frac{dP}{dV} \right)_T - \frac{a}{v} - b \left(\frac{dP}{dV} \right)_T + \frac{2ab}{V^2} = 0 \quad - \quad - \quad 4$$

$$\left(\frac{dP}{dV} \right)_T = 0$$

$$P = \frac{a}{V^2} - \frac{2ab}{V^3} \quad - \quad - \quad - \quad - \quad 5$$

$$\frac{dP}{dV} = -\frac{2a}{V^3} + \frac{6ab}{V^4} = 0$$

$$V_c = 3b, \quad P_c = \frac{a}{27b^2}$$

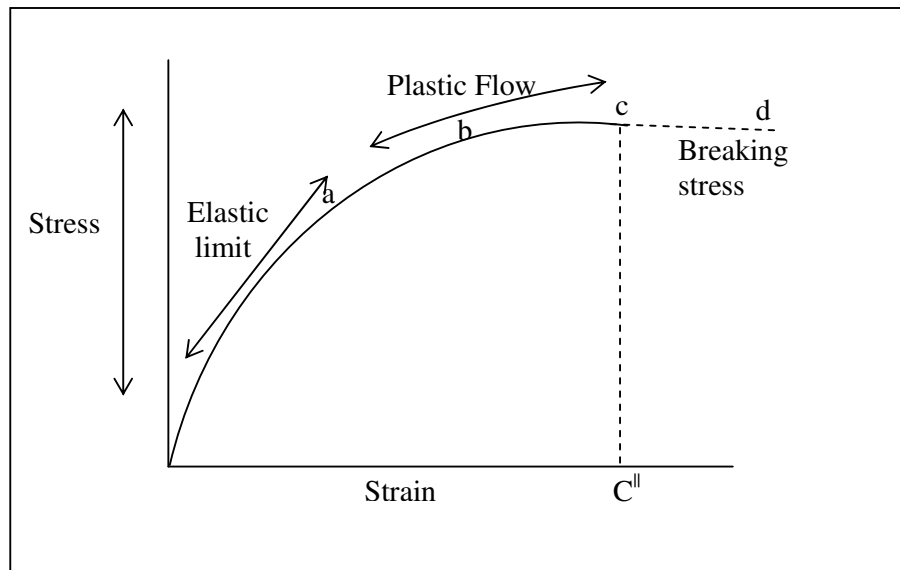
$$T_c = \frac{8a}{27Rb}$$

for a single gas; $\frac{RT_c}{P_c V_c} \quad - \quad - \quad (\text{critical coefficient})$

Coefficient lies between 3 – 3.5

UNIT TWO

ELASTICITY



C'' -----> Plastic Definition

At yield point a stretched material can still return to its original shape but it does not obey Hooke's law

At point d, small increase in stress will bring large increase in strain

NB:

Tensile stress = F/A

Tensile Strain = e/L

Tensile stress $F/A \propto$ tensile strain e/L

Therefore,

$$\frac{F}{A} \propto \frac{e}{L}$$

$$\frac{F}{A} = K \frac{e}{L}$$

K = elastic modulus measures of how difficult it is for a material to be deformed.

TYPES OF MODULUS

1. Young Modulus (E)
2. Shear Modulus (\mathcal{E})
3. Bulk modulus (B)

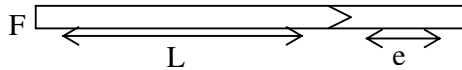
Young Modulus = $T_{\text{stress}} \propto T_{\text{strain}}$

$$\text{Young Modulus} = \frac{T_{\text{stress}}}{T_{\text{strain}}}$$

$$\frac{\frac{F}{A}}{\frac{e}{L}} = E$$

$$\frac{T_s}{T_s} = E$$

From the diagram below we have



($mgh = Fs = fh = P.E$)

NB: s is distance covered while h is the height

Hence,

$$W = \frac{1}{2} Fe$$

NB:

$$\frac{\frac{1}{2} Fe}{AL} = \frac{1}{2} \left(\frac{F}{A} \times \frac{e}{L} \right) = \frac{1}{2} \left(\frac{T_{\text{stress}}}{T_{\text{strain}}} \right)$$

When stress is applied to a material we have dW/W

While strain applied to a material is e/L

Hence,

$$\frac{dW}{W} \propto \frac{e}{L} = -\phi \frac{e}{L}$$

$$-\phi = \text{poison ratio} = \frac{dW/W}{e/L} = \frac{dW}{W} \times \frac{L}{e}$$

Example:

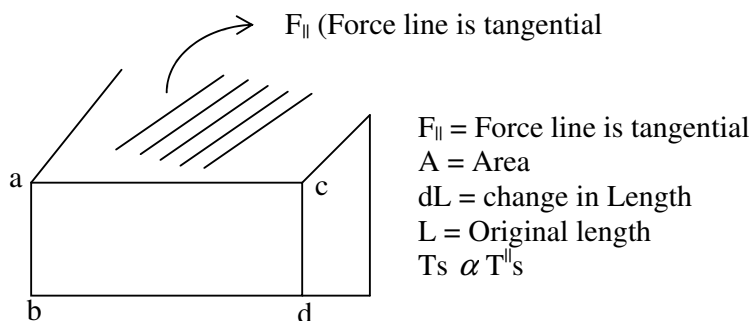
A material 4m long and 2cm^2 in cross section stretched 2mm, when a mass of 20Kg is placed at the lower end. Find E (Young Modulus)

Recall that $E = \frac{F/A}{e/L} = \frac{F}{A} \times \frac{L}{e}$

Hence,

$$E = \frac{200 \times 9.8}{2 \times 10^{-4}} \times \frac{4}{2 \times 10^{-3}} = 1960 \times 10^7 \text{Nm}^{-2}$$

SHEAR MODULUS



Share Modulus for a particular material is 50Pa. with which a shear force of 10N is applied to the lower surface of the material that is 5cm on each end. Find the shear stress

(2) How far will the surface be displaced **NB: material under consideration is cube.**

Solution

(Please follow the solving to this example in your lecture. No working was provided to this problem as at the time of typing this note)

EXAMPLE

Two parallel and opposite forces each 4000N are applied tangentially to the upper and lower phases of a cubical metal box which is 25cm on the side

Find the angle of shear and the displacement of the upper surface relative to the lower surface shear modulus ($G = 80\text{gPa.}$)

EXAMPLE

Compute the volume change of a solid copper cube 10mm on each edge when subjected to pressure of 5mPa, the bulk modulus of copper is 1000mPa

EXAMPLE

For a matter or a student bombarded by pressure on every side

NB for question (1)

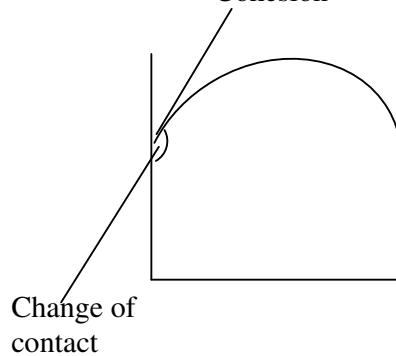
$$B = dPV / V^y$$

$$V^y B = dPV$$

$$V^y = dPV / B$$

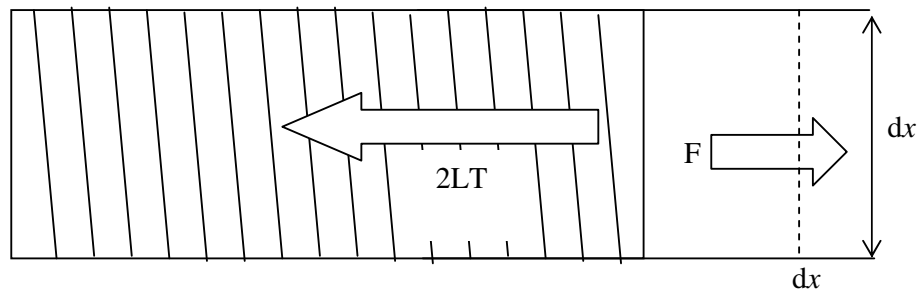
Where $B = 1000\text{mPa}$, $dP = 5\text{mPa}$, $V = 10\text{mm} = 10^{-6}\text{m}^3$ $V^y = ?$

$$V^y = 5 \times 10^{-6} / 10^3 = 5 \times 10^{-9}\text{m}^3$$



- The force of cohesion is greater than the force of adhesion e.g. mercury.
- Change of contact is above 90°
- The molecule of cohesion does not wet glass
- It has a convex shape
- Its resultant tends towards the right

SURFACE TENSION



Remember that surface tension is the force acting parallel per unit length at the surface of a liquid. Also you should know that surface tension is the elastic tendency of liquids which makes them enquire the least surface area possible.

$$\text{Surface tension} = \gamma = \frac{F}{2L}$$

unit is N/m

Work done

HYDROSTATIC

Pressure

Buoyancy is the ability to float

Pressure $P = \frac{F}{A} = \rho gh$ (unit N/m²)

Where ρ = density g = acceleration and h = height

NB: for any object to float, weight = upthrust

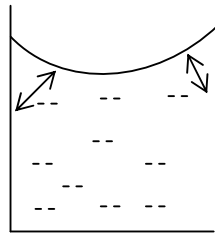
ARCHIMEDES PRINCIPLE

Surface tension: when the surface of a liquid acts as an elastic surface skin as pressure is applied, the force acting per unit length is perpendicular to the surface where the force acts.

NB: Surface tension = $\gamma = \frac{F}{2L}$

ADHESION: This involves the molecules of different substances. Where there is presence of attractive forces.

COHESION: This involves the forces acting between the same molecules.



NB: The force of adhesion is

- greater than the force of cohesion e.g. in water
- The angle of contact is less than 90°
- it causes wetting of glass
- It has a concave shape
- Resultant force tends towards the left.

EXAMPLE:

The excess pressure “P” within a bubble of a radius 0.1mm in water. Take surface tension $T = 72.7 \times 10^{-3}$ (A bubble of “A” within liquid that has liquid A surface = $2T/r$) where $T = 72.7 \times 10^{-3}$, $r = 0.1/1000 = 10^{-4}$

$$\text{Therefore } P = \frac{2T}{r} = \frac{2 \times 72.7 \times 10^{-3}}{1 \times 10^{-4}} = 1454 \text{ N/m}$$

CAPILLARITY

The narrower the capillary tube, the faster the movement of the liquid above the tube, while the wider the capillary tube the slower the movement of the liquid above the capillary tube.

PRACTICE QUESTIONS

1. A body weighs 0.20N in air, 0.12N when fully immersed in water and 0.25 N when ‘fully ‘immersed in liquid. Calculate (i) It lost weight (ii) it relative density
2. An object of density 10g/cm^3 weight 100g when suspended with a string from a spring balance, it is then put into a liquid of density 0.5gcm^3 until $\frac{3}{4}$ of its volume in water is immersed in the liquid.
3. Differentiate between cohesive and adhesive forces. Draw a diagram where applicable
4. If adhesive forces are greater than cohesive forces, what happens to the liquid in capillary tube?
5. Differentiate between surface energy and surface tension
6. If a surface is wetted by water, what will be the angle of contact?
7. Determine the volume of 200g of liquid for which its relative density is 1.60; relative density of water to be 1000kg/m^3

NB: Relative density of substance = RD

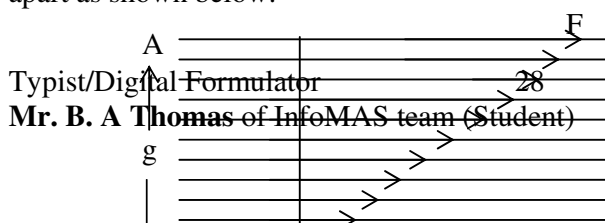
<You may refer to your Secondary school not for help>

VISCOSITY AND COEFFICIENT OF VISCOSITY

Viscosity is the inherent property of all fluids and may be called the internal friction offered by a fluid to the flow. For water in a beaker, when stirred and left to itself. The motion subside after sometimes which can happen only in the presence of a resisting force acting on the liquid. The temporary resistance offered by fluids to the shearing stress is called viscosity. Viscosity is that property of fluid due to which they opposes relative motion between its adjacent layers.

Liquid like water, kerosene etc. which flows readily are said to be mobile, while liquid such as tar, pitch which do not flow readily are said to be viscous. Liquids like honey, engine oil are said to be more viscous than tar.

Consider a liquid contained in between two plate A and B, a small distance apart as shown below.



If the liquid is assumed to be divided into diffinty. Thin parallel horizontal layer and the upper plate are polished with a small force (F) in the direction indicated. By doing so, we applied a tangential force or tangential stress ‘on the liquid and as a result we find the topmost layer of the liquid moving with a constant velocity after initial acceleration produced become zero.

The next layer also moves with a constant velocity but its velocity is slightly less than the velocity of the upper layer. The velocity of the layer next to it is also constant and it is still smallest. In fact, all the layers moves but the velocity keep decreasing towards B and the velocity of the layer in contact with B is zero. The liquid may be regarded as a pile of tin sheet placed one above the other just as a pile of playing cards. Each layers of the liquid like each card drags with the next lower layer. As it happen when one card moves over the surface of the other, it moves is opposed by the force of friction.

Similarly, due to sliding of one area over the other, forces are called into action within the liquid which resist the motion of layers. This force is called vicious and the property of the liquid is called viscosity.

Consider a layer AB of a liquid moving with a velocity (V) ant a parallel layer (CA) at a distance (DS) from it moving with a velocity of (V + DV). As shown in the figure 2 above. Then DV/DS is known as velocity gradient. This difference of velocity is caused by force acting parallel to the upper layer in the direction of the layer. In the absence of this force the relative motion between the two layer cease after some time.

Newton force and viscous force acting tangential on a layer of the fluid is directly proportional to

1. Velocity gradient (DV/DS) in a direction perpendicular to the layer

2. The surface area of the lay

$$F \propto - \frac{DV}{DS} \text{ And}$$

$$F \propto A$$

So,

$$F \propto - \frac{DV}{DS} \cdot A$$

Therefore,

$$F = - \int A \frac{DV}{DS} \quad - \quad - \quad - \quad - \quad (i)$$

This is called Newton's law of viscous flows in straight line motion. The symbol \int is a constant and it depends upon the nature and temperature of the liquid. The -ve sign indicates that air is a backward dragging force. i.e. force acts in a direction opposite to the one in which the layer moves.

Now if $A = 1$, $DV/DS = 1$, then

$$F = \int (\text{coefficient of viscosity})$$

Hence, the \int coefficient of viscosity of a liquid may be defined as the tangential force per unit area which resist the flow of two parallel layer having unit velocity gradient perpendicular to the streamline flow. The unit in which the coefficient of viscosity is expressed is called POISEM system. The coefficient of viscosity of a liquid is equal to the tangential force per unit area that is required to maintain unit relative velocity between its two layer unit distances

STREAMLINE AND TURBULENT

A streamline flow is that in which all particles of the liquid moves in an orderly pattern and the part of every particles is the same as that of the liquid as a whole. When a liquid flows steadily such that each particle passing a certain point flows exactly the same path and has the same velocity as its preceding particles, the flow is called streamline flow. In such a flow the velocity of every point within the liquid remains constant both in magnitude and direction the flow remains streamline so long as the velocity is not large and remain the load in a certain velocity is called critical velocity beyond which the flow becomes turbulent and is hardly regular. The velocity at which the laminar or streamline flow changes into turbulent is known as critical velocity

REYNOLDS NUMBER

Reynolds studies the motion of fluid in detail and observed that the critical velocity (V_c) of a fluid is related to the density of the liquid, its coefficient of viscosity and radius of the two by the following relation

$$V_c = \frac{Kn}{\rho r} \quad - \quad - \quad - \quad (ii)$$

K is constant known as Reynolds number. On the basis of series of experiment, Reynolds concluded that the constant K which is the combination of four factors determines whether the flow is streamline or turbulent that is, Reynolds number determines the nature of the flow of liquid through a fluid on the basis of the experiment, it is observed that for a tube of 1cm, flow is laminar if K is 2000 and in general when K is less than about 2000, the flow is laminar, where as above 3000, the flow is turbulent. In the transition region between 200 to 3000, the flow is unstable and may change from one type to another.

POISEUILLE EQUATION FOR THE FLUID OF LIQUID THROUGH A TUBE

When a liquid is flowing under a constant pressure between the end of a capillary, the tube of radius (A) and length (m) it is assumed that;

The flow of liquid is parallel to the axis of the tube everywhere and to the streamline.

The flow of liquid is steadily i.e. there is no acceleration of the liquid at any point.

The velocity of the liquid layer in contact with the wall is zero and increases regularly and continuously towards the interior becoming maximum along the axis of the tube.

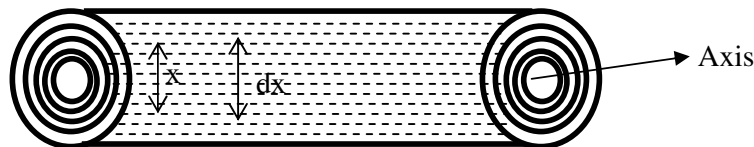


Fig. 3

Consider a cylinder layer of liquid to coaxial to the tube and radius shown in fig above. The surface area of the lay above is $2\pi r l$ and the velocity of the flow is the same at all points and since the velocity of flows increase as we move towards the axis of the cylinder from the wall of the cylinder, the liquid outside these imaginary cylindrical shape layer which will be moving slower than the inside of it. And hence, will exert a backward tangential force on the inner faster moving liquid. The viscous force or retarding force according to Newton's law of viscosity is given by

$$F = - \int A \frac{DV}{Dx}$$

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$$F = -\int 2\pi x \frac{DV}{Dx}$$

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THE TYPIST HAS BEEN THE VERY PROLIFIC TYPIST, ADDICTED TO TYPING LIKE WINE (MR. B. A. THOMAS OF COMPUTER SCIENCE DEPARTMENT FUTMINNA) THANK YOU VERY MUCH FOR GIVEN YOUR SUPPORT.

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