A

Project Report

On

Experimental studies on measuring the Diffusion coefficient of various solids with varying geometries in air

Submitted by

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(Roll No.: 111CH0485)

In partial fulfillment of the requirements for the degree in

Bachelor of Technology in Chemical Engineering

Under the supervision of

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CERTIFICATE

This is to certify that the work contained in the thesis entitled "**Experimental study on Diffusion coefficient of various solids of varying geometries in air**", submitted by **Utkarsh (111ch0485)**, has been carried out under my supervision and this work has not been submitted elsewhere for a degree.

Date:

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I might want to extend my earnest on account of my companions and partners. Last however not the minimum, I wish to significantly recognize my guardians for their steady backing.

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ABSTRACT

Molecular diffusion is basic to mass transport and the essential system of this marvel and quantitative estimation of the same is discriminating to mass exchange operations viz. refining, assimilation/stripping, fluid extraction and so forth. In this piece of work, we consider the diffusion coefficient of diverse solids with distinctive geometry. It is an imperative thing to highlight that radiant substances locate an unfathomable use in different fields like in the generation of moth balls, in the decontamination of mixes, in the Frost free Freezer. In any case, suitably measured diffusivity information can without much of a stretch be utilized as a part of evaluating the mass exchange coefficients utilizing key ideas of different prescient hypotheses like (film, entrance, surface re-establishment and limit layer).In this work, solids of different geometries (both spherical as well as cylindrical) were chosen to measure the diffusivity. Naphthalene balls, Camphor balls, Iodine balls, Phthalic anhydride balls and caffeine balls were used to study the diffusion phenomenon. Moreover the Phthalic anhydride and caffeine balls were only present in the spherical form while Naphthalene, Camphor and Iodine balls were present in both spherical and cylindrical form. These solids carried different colours as Naphthalene and camphor balls were white in colour whereas Iodine appeared as bluish blackish solid, again caffeine balls were white and Phthalic anhydride appeared as dull white in colour.

Keywords: Diffusion, Diffusivity, Diffusion coefficient, spherical solids, cylindrical solids, etc

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LIST OF SYMBOLS

dxA/dz	Concentration gradient per unit length
D_{AB}	Diffusion constant.
J_{AZ}	Diffusional flux (mole/m^2.sec)
N_A	Molar flux of A.(Kmol/m^2 sec)
C	Total concentration of A and B in (moles/m^3)
Xa	Mole fraction of A.
ρa	Density of substance A (Kg/m^3)
R	Gas law constant = 8314 m^3pa/Kg mole-K
	= 82.057×10^{-3} m3-atm/Kg mole-K
	= 82.057 cm^3atm/Kg mole-K
T	Operating temperature (in ^oC or K)
M_A	Molecular weight of diffusing substance (in g/g mol)
M_B	Molecular weight of non-diffusing substance (in g/g mol)
P	Total pressure (in atm, Pa)
δ	Difference in height (in m or cm.)
P_{AS}	At surface, Partial pressure of the sample (atm)
$P_{A\infty}$	At the bulk, Partial pressure of the sample (atm)
Z	Distance in the direction of diffusion (in m or cm)
V	Molar volume, (cm^3/g mol)
M	Molecular weight, (g/g mol)
r_s	Radius of the sphere. (m or cm)

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CHAPTER - 1
INTRODUCTION

1.1 Background of the Research

Diffusion and convection, both can identify with Mass exchange. If, there is no external mechanical Disturbance then mass exchange happens on account of scattering part. Additionally, when there is a plainly visible exacerbation in the medium, which on the other hand amazingly affects the rate of mass exchange, it transforms into a convective transport. Along these lines, the stronger the stream field, making additionally mixing and turbulence in the medium, the higher is rate of mass exchange. The thought of nuclear dispersal is fundamental and is extensively used as a piece of variety of investigative and building applications. At whatever point there is transport of any gas/liquid/solid particles happen Through a stagnant zone depicted by a laminar stream organization, the noteworthiness of sub-nuclear Diffusion is all the more clear. In reality, when there is a turbulent development sets into the technique, there dependably remains a laminar zone close to as far as possible by and large influencing the stream segment. Transport in a penetrable medium is a customary situation where nuclear scattering happens. A typical delineation is the scattering of reactants and things in a porous driving force pellet. Other than normal pore scattering, Knudsen and surface scattering too accept a discriminating part in choosing the execution of an impulse. To be careful, examination of sub-nuclear scattering is the key reason to the examination of mass exchange generally speaking. Mass exchange is the reason of various manufactured and common strategies. Substance procedure incorporate compound vapor affirmation (CVD) of silane ($SiH4$) onto a silicon wafer (the doping of silicon wafer lead to the game plan of a silicon dainty film), the air dissemination of waste water provoking its filtration, the sterilization of metals and isotopes et cetera. The characteristic structures consolidate oxygenation of flow framework and the vehicle of particles across over layer inside the kidney et cetera. It is discriminating to highlight the way that any mechanical mass exchange operation incorporates multicomponent system; of course, suitable twofold structure data can be sufficiently used to gage the multi-part system.

Moreover, for any unit operation including more than a solitary stage (likewise, therefore region of an interphase), it is the close-by or general mass exchange coefficient which illuminates the mass exchange operation winning inside the system and can be suitably. measured in wetted divider area tests. Nevertheless, suitably measured diffusivity data can without a doubt be used as a piece of evaluating the mass exchange coefficients using essential thoughts of diverse farsighted theories like (film, invasion, surface energizing and breaking point layer).

1.1 Objective

In the presented project work, focus has been made upon to measure the diffusion coefficients of solids (in air) with varying geometries using a packed bed column. Naphthalene balls, Camphor balls and Iodine balls are selected for studying the diffusion phenomenon in spherical as well as in cylindrical geometry whereas Phthalic anhydride balls and caffeine balls are selected for studying the diffusion phenomenon in spherical geometry only. Comparing this factor for the substances will help us to understand the basic industrial or household uses of these solids and based on this we can compare the extent of utility of these materials.

CHAPTER 2
LITERATURE REVIEW

2.1 Principles of diffusion

Diffusion is the improvement of individual parts influenced by a physical help through a mixture. The most no doubt understood explanation behind diffusion is a fixation angle of the diffusing section. A fixation angle tends to move the portion to the part in such a direction as to adjust focuses and wreck the inclination. Right when the angle is kept up by continually supplying the diffusing part to the high focus end of the slope and evacuating it at the low-fixation end, there is a Steady-state flux of the diffusing portion. This is the typical for some mass trade operations.

A valid example, when you sprinkle an aroma in a room, the smell of the fragrance spread further and further and one can perceive the scent in other side. This is just the thought of the diffusion. The particles of the aroma when connects with air and structures a focus inclination and the sections of smell is tend to move from higher fixation to the lower focus and therefore the iotas of the scent is being spread and the scent of the scent can go further and further.

2.2 Theory of diffusion

Molecular diffusion is the Thermal development of liquid or gas particles at temperature above outright zero. The rate of this advancement is a component of temperature thickness of the liquid and the mass or size of the particle. The net flux of a particle from a territory of high obsession to one of lower center is clarified by Diffusion.

Sub-nuclear diffusion or sub-nuclear transport can be described as the exchange or advancement of individual particles through a liquid by method for the self-assertive individual improvement of atoms. Atomic diffusion is frequently depicted numerically utilizing Fick's laws of diffusion.

2.2.1 Fick’s law of diffusion

Fick’s law is only meant for binary diffusion and steady state flow. Fick's laws of Diffusion describe diffusion and can be used to solve for the diffusion coefficient, *D*. They were derived by Adolf Fick in the year 1855.

2.2.1.1 Fick’s first law of diffusion

Fick's first law relates the diffusive flux to the concentration field, by postulating that the flux goes from regions of high concentration to regions of low concentration, with a size that is corresponding to the concentration gradient. Here just molecules are moving entire main part of molecules is not in movement.

$$J_{AZ} = -CD_{AB}\left(\frac{dx_A}{dz}\right) \tag{2.1}$$

Where.

dx_A/dz is the concentration gradient per unit length

D_{AB} is the diffusion constant

J_{AZ} diffusional flux of unit (mole/m^2.sec)

C is the total concentration of A and B in (moles/m^3)

X_A mole fraction of A in concentration of A and B.

The direction which has the drop in concentration supports diffusion in that direction thus producing a negative sign.

2.2.1.2 Fick’s second law of diffusion

Fick's second law predicts how diffusion causes the fixation to change with time. Exactly when shaky state diffusion takes put in one heading in a strong or stagnant fluid, there exhibiting differential numerical articulation is called the next law of Fick.

$$\frac{dC_A}{dt} = D_{AB}\left(\frac{d^2C_A}{dx^2}\right) \tag{2.2}$$

CHAPTER 3

MATERIALS AND METHODS

3.1 Materials required

The solids required for conducting the whole set of experiments are:

Naphthalene (spherical) $C_{10}H_8$

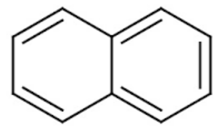
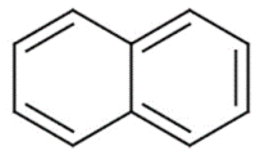


Fig 3.1

Naphthalene (cylindrical) $C_{10}H_8$



Camphor (spherical) $C_{10}H_{16}O$

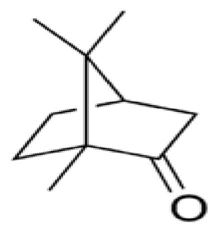
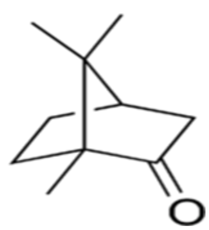


Fig 3.2

Camphor (cylindrical) $C_{10}H_{16}O$



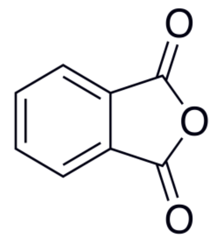
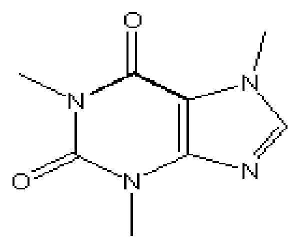
Iodine (spherical)	I_2	 Fig 3.3
Iodine (cylindrical)	I_2	
Phthalic anhydride (spherical)	$C_6H_4(CO)_2O$	 Fig 3.4
Caffeine (spherical)	$C_8H_{10}N_4O_2$	 Fig 3.5

Table 3.1: Materials required for the experiment

3.2 Spherical shaped solid's Diffusion

A case of spherical shape is taken. An evaporating drop is considered that has radius „r_s" at any instant„t". A thin spherical shell of inner radius „r" and thickness Δr is imagined around the drop. This is diffusion of a molecule which includes a binary system, A" through air B". Then,

Rate of input of A into the thin shell (at r = r) : $(4\pi r^2)N_{A,r}$

Rate of output of A from the thin shell (at r = r+ Δr) : $(4\pi r^2)N_{A,r+\Delta r}$

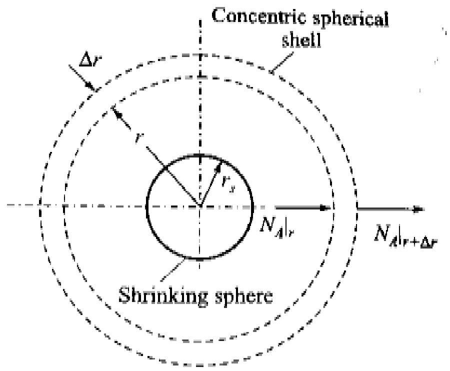


Fig 3.6 A sketch indicating shell balance for mass transfer from a sphere

The notation $|_r$ means that the quantity is evaluated at the position r

Accumulation rate = 0

Using the balance of steady state mass,

Input - output = accumulation

$$(4\pi r^2)N_{A,r} - (4\pi r^2)N_{A,r+\Delta r} = 0$$

Dividing both sides by Δr and taking the limit Δr¬0,

$$\lim_{\Delta r \to 0}\left(\frac{(4\pi r^2)\mathrm{NA,r} - (4\pi r^2)\mathrm{NA,r+\Delta r}}{\Delta r}\right) = 0$$

Implies that $$-\frac{d}{dr}(4\pi r^2 N_A) = 0$$

implies that $$4\pi r^2 N_A = \text{constant} = W \text{ (say)} \qquad (3.1)$$

Equation 3.1 is a very important result for steady state diffusion through a variable area and can be generalized as

$$(\text{Area})(\text{Flux}) = \text{Constant} \qquad (3.2)$$

In this case diffusion of molecule A takes place, but as air is not soluble in the molecule therefore it does not diffuse. So, the case clearly states the diffusion of A through non diffusing B. Since radial condition diffusion occurs, we get

$$N_A = (N_A + N_B)\frac{P_A}{P} - \frac{D_{AB}}{RT}\frac{dP_A}{dr}$$

Putting $N_B = 0$ and rearranging,

$$N_A = -\frac{D_{AB}P}{RT(P-P_A)}\frac{dP_A}{dr}. \tag{3.3}$$

From equation 3.1 and 3.3,

$$-\frac{dP_A}{P-P_A} = \frac{WRT}{4\pi D_{AB}P}\frac{dr}{r^2} \tag{3.4}$$

Equation 3.4 can be integrated from $r = r_s$ (i.e. the surface of the molecule) to $r = \infty$ (i.e. far away from the drop) where $P_A = P_{A\infty}$

Here P_{AS} corresponds to the vapour pressure of the molecule at the surface and $P_{A\infty}$ represents the partial pressure of the molecule in the bulk air.

$$-\int_{P_{As}}^{P_{A\infty}} \frac{dP_A}{P-P_A} = \frac{WRT}{4\pi D_{AB}P}\int_{r_s}^{\infty}\frac{dr}{r^2}$$

$$\Rightarrow \ln\frac{P-P_{A\infty}}{P-P_{As}} = \frac{WRT}{4\pi D_{AB}P}\frac{1}{r_s}$$

$$\Rightarrow W = \frac{4\pi D_{AB}P\,r_s}{RT}\ln\frac{P-P_{A\infty}}{P-P_{As}} \tag{3.5}$$

Since The continuous rate of molar mass transfer is W, rate of vaporization equals it at any point of time.

This equation relates the rate to the change in molecule.

$$W = -\frac{d}{dt}\left(\frac{4}{3}\pi r_s^3 \frac{\rho_A}{M_A}\right) = -4\pi \frac{\rho_A}{M_A} r_s^2 \frac{dr_s}{dt} \tag{3.6}$$

As the size of the molecule decreases with the passage of time, a negative sign has been considered.

$$-4\pi \frac{\rho_A}{M_A} r_s^2 \frac{dr_s}{dt} = \frac{4\pi D_{AB} P\, r_s}{RT} \ln \frac{P - P_{A\infty}}{P - P_{As}}$$

Here again we have made utilization of the „pseudo-steady state" suspicion, that the particle size changes so gradually that the diffusion of the substance through the encompassing air happens basically at steady state unsurpassed. The adjustment in the particle estimate over significant time of time can be dictated by coordinating the above comparison.

If at time t = 0, the radius of the molecule is r_{s0} and at time t it is r_s. Then,

$$-\int_{r_{s0}}^{r_s} r_s dr_s = \frac{D_{AB} P M_A}{RT\rho_A} \ln \frac{P - P_{A\infty}}{P - P_{As}} \int_0^t dt$$

$$\Rightarrow r_{s0}{}^2 - r_s{}^2 = \frac{2D_{AB} P M_A t}{RT\rho_A} \ln \frac{P - P_{A\infty}}{P - P_{As}} \tag{3.7}$$

Hence diffusivity of the molecule in the **spherical geometry** is calculated as

$$D_{AB} = \frac{RT\rho_A \left(r_{S0}^2 - r_S^2\right)}{2tPM_A \ln\left(\frac{P - P_{\infty}}{P - P_{AS}}\right)} \tag{3.8}$$

3.3 Cylindrical shaped solid's Diffusion

This is the case of diffusion through a variable area of A(diffusing) to B(non-diffusing). Taking the help of equation 3.2 and 3.3, we may write

$$(2\pi rL)N_A = (2\pi rL)\left(-\frac{D_{AB}P}{RT(P-P_A)}\right)\frac{dP_A}{dr} = W \ \text{(Constant)} \tag{3.9}$$

L= Cylinder's length.

From the axis of the cylinder, the distance of any point within any surrounding film is considered as r.

Molar rate of diffusion is denoted by W.

The variation of distance from radius of the cylinder (r_c) to the outer edge of the air-film ($r_c+\delta$) where

The thickness of the film is represented by δ

The cylindrical substance has its partial pressure values as

At $r = r_c$, $P_A = P_{As}$ (sublimation pressure)

At $r = r_c+\delta$, $P_A = 0$, as the substance in the bulk air doesn't have a molecule.

For the calculation of the rate of sublimation, we have to integrate the equation 3.9

$$-\int_{P_{AS}}^{0}\frac{dP_A}{P-P_A} = \frac{WRT}{2\pi D_{AB}PL}\int_{r_c}^{r_c+\delta}\frac{dr}{r}$$

$$\Rightarrow W = \frac{2\pi D_{AB}PL\ \ln\left(\frac{P}{P-P_{AS}}\right)}{RT\ln\left(1+\frac{\delta}{r_c}\right)} \tag{3.10}$$

For the calculation of the rate, we make the usual pseudo-steady state Approximation.

If at any time t the mass of the cylinder, Neglecting the losses at the end, the rate of sublimation is,

$$W = -\frac{d\left(^{m}/_{M_A}\right)}{dt} = -\frac{d}{dt}\left(\frac{\pi r_c^2 L \rho_A}{M_A}\right) = -2\pi L\left(\frac{\rho_A}{M_A}\right) r_c \frac{dr_c}{dt} \tag{3.11}$$

Molecular weight is represented by M_A.

From equations 3.10 and 3.11,

$$\frac{2\pi D_{AB} PL \ln\left(\frac{P}{P-P_{As}}\right)}{RT \ln\left(1+\frac{\delta}{r_c}\right)} = -2\pi L\left(\frac{\rho_A}{M_A}\right) r_c \frac{dr_c}{dt}$$

By integrating,

$$-\int_{r_c^1}^{r_c^2} r_c \ln\left(1+\frac{\delta}{r_c}\right) dr_c = \frac{D_{AB}P}{RT}\frac{M_A}{\rho_A}\ln\left(\frac{P}{P-P_{As}}\right)\int_o^t dt$$

$$\Rightarrow \frac{1}{2} r_{c1}^2 \ln\left(1+\frac{\delta}{r_{c1}}\right) - \frac{1}{2} r_{c2}^2 \ln\left(1+\frac{\delta}{r_{c2}}\right) + \frac{\delta}{2}\left[(r_{c1}-r_{c2}) - \delta \ln\left(\frac{r_{c1}+\delta}{r_{c2}+\delta}\right)\right]$$

$$= \frac{D_{AB}P}{RT}\frac{M_A}{\rho_A}\ln\left(\frac{P}{P-P_{As}}\right) t \tag{3.12}$$

Equation 3.12 is the desired equation for finding the diffusivity of **cylindrical geometries**.

3.4 Experimental setup

Fig 3.7 Experimental setup

- The equipment consists of a cylindrical glass tube of 45mm internal diameter and 240mm height.
- The column is fitted with a mesh near the base to hold the solid balls.
- The height of the packing may be around 15cm.
- Dry air is supplied from the bottom and the outlet from the packed bed passes through the wet gas meter (for the measurement of air flow rate).
- The experiment is conducted at ambient conditions at same flow rate.

3.5 Experimental Procedure

Fig 3.8 Front view of the packed bed

- The dimensions of the balls were determined using Vernier caliper before putting in the diffusing Cylinder.
- The Rota meter was provided with the flow rate of 30lpm after placing the balls inside the column.
- The experimental setup was left to run for 45 minutes and after finishing the dimensions of the ball was again measured using Vernier caliper.
- Three readings for each type of solid was taken to get an average value of the initial data and the final data.

CHAPTER 4

EXPERIMENTATION

4.1 Observation

Table 4.1: For spherical naphthalene, tested data are tabulated as under

S.NO	Before Diffusion, Diameter (cm)	After Diffusion Diameter (cm)
1.	1.90	1.89
2.	1.88	1.87
3.	1.86	1.855

Table 4.2: For cylindrical naphthalene, tested data are tabulated as under

S,NO	Before Diffusion, Diameter (cm)	After Diffusion, Diameter (cm)	Before Diffusion, Height (cm)	After Diffusion, Height (cm)
1.	0.49	0.443	0.85	0.823
2.	0.47	0.431	0.835	0.802
3.	0.478	0.442	0.84	0.808

Table 4.3: For spherical camphor, tested data are tabulated as under

S.NO	Before Diffusion, Diameter (cm)	After Diffusion Diameter (cm)
1.	1.90	1.88
2.	1.88	1.87
3.	1.86	1.845

Table 4.4: **For cylindrical camphor**, tested data are as under

S,NO	Before Diffusion, Diameter (cm)	After Diffusion, Diameter (cm)	Before Diffusion, Height (cm)	After Diffusion, Height (cm)
1.	1.0	0.88	0.9	0.85
2.	0.98	0.85	0.83	0.8
3.	1.0	0.9	0.91	0.85

Table 4.5: For spherical Iodine, tested data are tabulated as under

S.NO	Before Diffusion, Diameter (cm)	After Diffusion Diameter (cm)
1.	1.90	1.852
2.	1.892	1.847
3.	1.894	1.850

Table 4.6 For cylindrical Iodine, tested data are tabulated as under

S,NO	Before Diffusion, Diameter (cm)	After Diffusion, Diameter (cm)	Before Diffusion, Height (cm)	After Diffusion, Height (cm)
1.	1.0	0.948	0.9	0.836
2.	0.973	0.92	0.86	0.796
3.	0.986	0.932	0.88	0.816

Table 4.7: For spherical Phthalic anhydride, tested data are tabulated as under

S.NO	Before Diffusion, Diameter (cm)	After Diffusion Diameter (cm)
1.	1.90	1.893
2.	1.87	1.864
3.	1.882	1.88

Table 4.8: For spherical caffeine, tested data are tabulated as under

S.NO	Before Diffusion, Diameter (cm)	After Diffusion Diameter (cm)
1.	1.90	1.898
2.	1.884	1.883
3.	1.89	1.887

4.2 Calculation

4.2.1 For sphere shaped Naphthalene ball ($C_{10}H_8$)

Before Diffusion, weight of the Naphthalene bulk = 106.6 gm

After Diffusion, weight of the Naphthalene bulk = 105.916

Count of Naphthalene bulk = 33

Before Diffusion, average weight of the bulk = 3.23 gm

After Diffusion, average weight of the bulk = 3.21 gm

From the table 4.1 data for naphthalene ball:

Before diffusion, average radius = 0.94 cm

After Diffusion, average radius = 0.9367 cm

Time (t) = 45 minutes = (45×60) seconds =2700 seconds.

Density = 1.14 gm/cm^3 , M_A = 128

At surface (P_{AS}), partial pressure of the naphthalene ball = 1.145×10^{-4} atm

From equation 5.8 we can calculate D_{AB} value as,

$$D_{AB} = \frac{RT\rho_A \left(r_{S0}^2 - r_S^2\right)}{2tPM_A \ln\left\{\frac{P-P_\infty}{P-P_{AS}}\right\}}$$

$$= 2.292 \times 10^{-3} \text{ cm}^2/\text{s}$$

Hence, For sphere shaped naphthalene, D_{AB} = 2.292 x 10^{-3} cm^2/s

4.2.2 For cylinder shaped Naphthalene balls

Before Diffusion, weight of the bulk = 6.82 gm

After Diffusion, weight of the bulk= 6.31 gm

Count of the bulk = 11

Before Diffusion, average weight of one ball = 0.62 gm

After diffusion, average weight of one ball = 0.574 gm

From the table 4.2 data for naphthalene:

Before Diffusion, average radius of the bulk = 0.48 cm

After Diffusion, average radius of the bulk = 0.434 cm

Before Diffusion, average height of the bulk = 0.84 cm

After Diffusion, average height of the bulk = 0.812 cm

Thickness, δ = 0.038 cm

Time (t) = 45 minutes = (45×60) seconds =2700 seconds.

Density = 1.14 gm/cm^3 , MA = 128

At the surface (PS), Partial pressure of the sample = 1.145×10^{-4} atm

D_{AB} value can be calculated from the equation 5.12

$$D_{AB} = \frac{RT\rho_A}{PtM_A \ln\left(\frac{P}{P-P_{As}}\right)}\left[\frac{1}{2}r_{c1}^2 \ln\left(1+\frac{\delta}{r_{c1}}\right) - \frac{1}{2}r_{c2}^2 \ln\left(1+\frac{\delta}{r_{c2}}\right) + \frac{\delta}{2}\left[(r_{c1}-r_{c2}) - \delta \ln\left(\frac{r_{c1}+\delta}{r_{c2}+\delta}\right)\right]\right]$$

= 2.424×10^{-3} cm^2/s

Hence, For cylinder shaped naphthalene, D_{AB} = 2.424×10^{-3} cm^2/s

4.2.3 For sphere shaped camphor balls

Before Diffusion, weight of the bulk = 105.8 g

After Diffusion, weight of the bulk = 104.92 gm

Count of the bulk = 33

Before Diffusion, average weight of one ball = 3.206 gm

After diffusion, average weight of one ball = 3.179 gm

From the table 4.3 data for camphor ball:

Before Diffusion, average radius of the bulk = 0.94 cm

After Diffusion, average radius of the bulk = 0.9325 cm

Time (t) = 45 minutes = (45×60) seconds =2700 seconds.

Density = 0.99 gm/cm^3 , M_A = 152

At the surface (P_S), Partial pressure of the sample = 8.68 ×10^{-4} atm

From equation 5.8 we can calculate D_{AB} value as

$$D_{AB} = \frac{RT\rho_A \left(r_{S0}^2 - r_S^2\right)}{2tPM_A \ln\left\{\frac{P-P_\infty}{P-P_{AS}}\right\}}$$

$$= 2.324 \times 10^{-3} \text{ cm}^2/\text{s}$$

Hence, For sphere shaped camphor, D_{AB} = 2.324 x 10^{-3} cm^2/s

4.2.4 For cylinder shaped camphor balls

Before Diffusion, weight of the bulk = 6.8 gm

After Diffusion, weight of the bulk = 6.04 gm

Count of the bulk = 10

Before Diffusion, average weight of one ball = 0.68 gm

After diffusion, average weight of one ball = 0.604 gm

From the table 4.4 data for camphor:

Before Diffusion, average radius of the bulk = 0.496 cm

After Diffusion, average radius of the bulk = 0.442 cm

Before Diffusion, average height of the bulk = 0.88 cm

After Diffusion, average height of the bulk = 0.83 cm

Thickness, δ = 0.05 cm

Time (t) = 45 minutes = (45×60) seconds =2700 seconds.

Density = 0.99 gm/cm^3 , M_A = 152

At the surface (P_S), Partial pressure of the sample) = 8.68 $\times 10^{-4}$ atm

D_{AB} value can be calculated from the equation 5.12

$$D_{AB} = \frac{RT\rho_A}{PtM_A \ln\left(\frac{P}{P-P_{As}}\right)}\left[\frac{1}{2}r_{c1}^2 \ln\left(1+\frac{\delta}{r_{c1}}\right) - \frac{1}{2}r_{c2}^2 \ln\left(1+\frac{\delta}{r_{c2}}\right) + \frac{\delta}{2}\left[(r_{c1}-r_{c2}) - \delta \ln\left(\frac{r_{c1}+\delta}{r_{c2}+\delta}\right)\right]\right]$$

= 2.6 x 10^{-3} cm^2/s

Hence, For cylinder shaped camphor, D_{AB} = 2.6 x 10^{-3} cm^2/s

4.2.5 For sphere shaped Iodine balls

Before Diffusion, weight of the bulk = 140.542 gm

After Diffusion, weight of the bulk = 130.554 gm

Count of the bulk = 1

Before Diffusion, average weight of one ball = 140.542 gm

After diffusion, average weight of one ball = 130.554 gm

From the table 4.5 data for Iodine ball:

Before Diffusion, average radius of the bulk = 1.895 cm

After Diffusion, average radius of the bulk = 1.849 cm

Time (t) = 45 minutes = (45×60) seconds =2700 seconds.

Density = 4.933 gm/cm^3 , M_A = 253

At the surface (P_S), Partial pressure of the sample) = 7.58 x 10^{-2} atm

From equation 5.8 we can calculate D_{AB} value as

$$D_{AB} = \frac{RT\rho_A\left(r_{S0}^2 - r_S^2\right)}{2tPM_A \ln\left\{\frac{P-P_\infty}{P-P_{AS}}\right\}}$$

$$= 5.3 \times 10^{-2}\ cm^2/s$$

Hence, For sphere shaped Iodine, D_{AB} = 5.3 x 10^{-2} cm^2/s

4.2.6 For cylinder shaped Iodine balls

Before Diffusion, weight of the bulk = 130.743 gm

After Diffusion, weight of the bulk = 109.66 gm

Count of the bulk = 10

Before Diffusion, average weight of one ball = 13.074 gm

After diffusion, average weight of one ball = 10.966 gm

From the table 4.6 data for Iodine:

Before Diffusion, average radius of the bulk = 0.986 cm

After Diffusion, average radius of the bulk = 0.933 cm

Before Diffusion, average height of the bulk = 0.880 cm

After Diffusion, average height of the bulk = 0.816 cm

Thickness, δ = 0.064 cm

Time (t) = 45 minutes = (45×60) seconds =2700 seconds.

Density = 4.933 gm/cm^3 , M_A = 253

At the surface (Ps), Partial pressure of the sample) = 7.58 x 10^{-2} atm

D_{AB} value can be calculated from the equation 5.12

$$D_{AB} = \frac{RT\rho_A}{PtM_A \ln\left(\frac{P}{P-P_{As}}\right)}\left[\frac{1}{2}r_{c1}^2 \ln\left(1+\frac{\delta}{r_{c1}}\right) - \frac{1}{2}r_{c2}^2 \ln\left(1+\frac{\delta}{r_{c2}}\right) + \frac{\delta}{2}\left[(r_{c1}-r_{c2}) - \delta \ln\left(\frac{r_{c1}+\delta}{r_{c2}+\delta}\right)\right]\right]$$

= 6.1 x 10^{-2} cm^2/s

Hence, For cylinder shaped Iodine, D_{AB} = 6.1 x 10^{-2} cm^2/s

4.2.7 For sphere shaped Phthalic anhydride balls

Before Diffusion, weight of the bulk = 128.506 gm

After Diffusion, weight of the bulk = 128.302 gm

Count of the bulk = 3

Before Diffusion, average weight of one ball = 42.835 gm

After diffusion, average weight of one ball = 42.767 gm

From the table 4.7 data for Pthalic anhydride ball:

Before Diffusion, average radius of the bulk = 1.884 cm

After Diffusion, average radius of the bulk = 1.883 cm

Time (t) = 45 minutes = (45×60) seconds =2700 seconds.

Density = 1.53 gm/cm^3 , M_A = 148

At the surface (P_S), Partial pressure of the sample) = 3.64 ×10^{-4} atm

From equation 5.8 we can calculate D_{AB} value as

$$D_{AB} = \frac{RT\rho_A \left(r_{S0}^2 - r_S^2\right)}{2tPM_A \ \ln\left\{\frac{P-P_\infty}{P-P_{AS}}\right\}}$$

$$= 3.57 \times 10^{-4} \text{ cm}^2/\text{s}$$

Hence, For sphere shaped phthalic anhydride, D_{AB} = 3.57 x 10^{-4} cm^2/s

4.2.8 For sphere shaped Caffeine balls

Before Diffusion, weight of the bulk = 104.465 gm

After Diffusion, weight of the bulk = 104.415 gm

Count of the bulk = 3

Before Diffusion, average weight of one ball = 34.822 gm

After diffusion, average weight of one ball = 34.805 gm

From the table 4.8 data for caffeine ball:

Before Diffusion, average radius of the bulk = 1.891 cm

After Diffusion, average radius of the bulk = 1.8907 cm

Time (t) = 45 minutes = (45×60) seconds =2700 seconds.

Density = 1.23 gm/cm^3 , M_A = 194

At the surface (P_S), Partial pressure of the sample) = 3.23×10^{-4} atm

From equation 5.8 we can calculate D_{AB} value as

$$D_{AB} = \frac{RT\rho_A \left(r_{S0}^2 - r_S^2\right)}{2tPM_A \ \ln\left\{\frac{P-P\infty}{P-P_{AS}}\right\}}$$

$$= 2.91 \times 10^{-5} \ cm^2/s$$

Hence, For sphere shaped caffeine, D_{AB} = 2.91×10^{-5} cm^2/s

4.3 Result

The results obtained from the above experiments have been tabulated as under:

Table 5.1: Result table

S.NO	Name of the sample	Calculated value of D_{AB} (cm^2/s)
1.	Sphere shaped Naphthalene	2.292×10^{-3}
2.	Cylinder shaped Naphthalene	2.424×10^{-3}
3.	Sphere shaped Camphor	2.324×10^{-3}
4.	Cylinder shaped Camphor	2.6×10^{-3}
5.	Sphere shaped Iodine	5.3×10^{-2}
6.	Cylinder shaped Iodine	6.1×10^{-2}
7.	Sphere shaped Phthalic anhydride	3.57×10^{-4}
8.	Sphere shaped Caffeine	2.91×10^{-5}

CHAPTER 5

CONCLUSION AND FUTURE SCOPE

5.1 Conclusion

This project work presents the following conclusions:

(a) It is found that in case of solids with different geometry the diffusivity differs in various manners.

(b) Moreover, when the diffusivity of sphere shaped solids is compared to the diffusivity of cylinder shaped solids, the diffusivity of cylinder shaped solids of the same material was "greater" than the diffusivity of sphere shaped solids of the same material.

(c) This implies that it requires more time for sphere shaped solids to diffuse than for the cylinder shaped solids to diffuse.

5.2 Future scope

The present work can be extended to carry out further research in the following areas:

- This study can especially be valuable in prepared sustenance bundling commercial ventures for controlled appraisal of dispersion of supplements, smell and so forth for keeping up worldwide principles (feel and in addition nourishment astute).
- Studies on Diffusion can be extended to heterogeneous gas solid catalytic reactions (especially for catalysts with different shapes) to get a better understanding of further mechanism.
- This study can also be useful in determining the use of experimented solids in various fields like in production of Mothballs, purification of other compounds, in Dye sublimation, in alchemy etc.

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