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Experimental Investigations on Diffusion of Nano-Additive Volatile Liquids in Gas

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Abstract: Depletion of conventional fuel resources due to increasing demand of energy requires environmental concern. It is the driving force to search the ways for saving the fuel and development of the alternative fuels. This may be done by increasing the efficiency of the engine or by reducing the consumption by fuel saving. With the objective of minimizing the fuel loss due to its volatile nature for fuels like petrol, methanol etc. present work has been undertaken. In the present work diffusion coefficient of the different volatile liquids have been calculated initially by a simple experiment and study about the effect of temperature variation on diffusivity has also reported. Then an attempt has been made to synthesize the Nano-additives to control the volatility of liquids. Present work is also extended to find out the effect of increase in Nano-additive concentration on the liquid diffusivity.

Keywords: Petrol, Methanol, Thermostatic water bath, Alumina Nano-powder, Diffusivity, optimization and cost analysis.

I. INTRODUCTION

Due to increasing population and changing lifestyle energy demand is continuously increasing. Most of the energy resource used today is oil, coal, and natural gas, to full fill the world energy demand. Present work has been undertaken. In the present work diffusion coefficient of the different volatile liquids have been calculated initially by a simple experiment and study about the effect of temperature variation on diffusivity has also reported. Diffusion is the movement of an individual component through a mixture due to some physical driving force. It occurs all mass transfer operation in at least one phase or often both the phases. Diffusion can be two types, molecular and eddy depending on the phase conditions. The transfer through stagnant layers, is known as “molecular diffusion” and this is a slow process. Diffusion can be two types, molecular and eddy diffusion depending on the phase condition. The transfer through the stagnant layers, is known as “molecular diffusion” while the one taking place in fluid phases by physical mixing and by the Eddies of turbulent flow is termed as “eddy diffusion. Although diffusion occurs because of statistical effects, when modelling diffusion, we normally use continuous partial differential equations to describe the statistical process to the observed macroscopic phenomenon of “diffusion down to concentration gradient” was elucidated by Albert Einstein. There, he considered the related phenomenon of Brownian motion. The PDEs used to model diffusion problems might include Fick’s laws, the convection-diffusion equation, or more complex method for concentrated mixture, like Maxwell-Stefan diffusion. In case of molecular diffusion, since the mass transfer occurs from a region of high concentration to one of lower concentration, the flux is proportional to the concentration gradient.

$$J_a \ \alpha \ \frac{\partial Ca}{\partial Z} \quad \textbf{or} \quad J_a = -\,\mathrm{Dab}\frac{\partial Ca}{\partial Z}$$

Where J_a is the molar flux of component a. And Dab is the proportionality constant, called the molecular diffusivity or diffusion coefficient of molecule a in b. Diffusivity is defined as the ratio of flux to its concentration gradient and its unit is m^2/s. It provides the diffusive mobility of a constituent and is a function of the temperature, pressure, nature and concentration of the other constituents. Since the diffusive mobility is a function of the number of collisions, diffusivity increases with decrease in pressure because number of collisions is less at lower pressure. However, in case of a liquid the effect of pressure is negligible. Again, random thermal movement of molecules increases with increases in temperature, so diffusivity increases with increases in temperature. Then an attempt has been made to synthesize the Nano-additives to control the volatility of liquids. Present work is also extended to find out the effect of increase in Nano-additive concentration on the liquid diffusivity. Temperature is a major factor which affect diffusion. Temperature dependence of the diffusion co-efficient is expressed as:

$$D = Do \exp\left(-\frac{Q}{RT}\right)$$

Where, Do is exponential factor and Q is the Activation energy for diffusion.

Nanoparticles are particles between 1 and 100 Nano-meters (nm) in size. In nanotechnology, a particle is defined as a small object that behaves as a whole unit with respect to its transport and properties.

Basically there are three methods for the preparation of nanoparticles:

Physical method.

Chemical method.

Biological method.

A. Nanoparticle is Catalyst in Diffusion Process

Nanoparticles are of great scientific interest as they are, in effect, a bridge between bulk materials and atomic or molecular structures. A bulk material should have constant physical properties regardless of its size, but at the Nano-scale size-dependent properties are often observed. Thus, the properties of materials change as their size approaches the nanoscale and as the percentage of the surface in relation to the percentage of the volume of a material becomes significant. For bulk materials larger than one micrometer (or micron), the percentage of the surface is insignificant in relation to the volume in the bulk of the material. The interesting and sometimes unexpected properties of nanoparticles are therefore largely due to the large surface area of the material, which dominates the contributions made by the small bulk of the material. Suspensions of nanoparticles are possible since the interaction of the particle surface with the solvent is strong enough to overcome density differences, which otherwise usually result in a material either sinking or floating in a liquid. Diffusion plays an important role in mass transport processes. In binary systems, mass transfer processes have been studied extensively using both experiments and molecular simulations. From a practical point of view, systems consisting more than two components are more interesting. However, experimental and simulation data on transport diffusion for such systems are scarce. Therefore, a more detailed knowledge on mass transfer in multi component systems is required. The presence of multiple components in a system introduces difficulties in studying diffusion in experiments. Investigating the concentration dependence of diffusion coefficients seriously increases the required experimental effort. The practical application of diffusion with added nanoparticles requires transitioning from well controlled experimental settings to highly variable "real-life" conditions. Understanding the resulting changes in the behavior and stability of nanoparticles in this and therefore of paramount importance. In the present work diffusion coefficient of the different volatile liquids have been calculated initially by a simple experiment and study about the effect of temperature variation on diffusivity has also reported. Then an attempt has been made to synthesize the Nano-additives to control the volatility of liquids.

II. LITERATURE REVIEW

Amit Sharma et al. [1] Combustion synthesis technique for synthesis of Aluminium oxide using urea as fuel and Aluminium Nitrate as an oxidizer is found to be easy & economical route & is able to produce Nano phase alumina powder. In present experiment urea is found to have outstanding potential towards solution combustion. T. Graham [2], Discussed about the liquid diffusion applied to analysis. The property of volatility, possessed in various degrees by so many substances, affords invaluable means of separation, as is seen in the ever-recurring processes of evaporation and distillation. J Chromatogr A [3], Discussed about that the determination of diffusion coefficients by gas chromatography. Brahm D. Prasher, Yi Hua Ma [4], those are study about the Liquid diffusion in micro porous alumina pellets. The effect of the ratio of the molecular solute diameter to the pore diameter and adsorption equilibrium on the liquid phase effective diffusivity for different hydrocarbon solutes was studied in two alumina pellets. José P.Pinheiro, Rute Domingos, Rocio Lopez, Kevin Wilkinson [5], discussed about a methodology, based on a labile metal ion probe using stripping chronopotentiometry at scanned deposition potential (SSCP), is presented for the determination of the diffusion coefficients of nanoparticles and humic matter.

III.EXPERIMENTAL SETUP AND METHODOLOGY

Preparation of nanoparticle as discussed in section 1.12 is somewhat a complicated process involving three different methods categorized as physical, chemical and biological methods. The process by which our experiment for the preparation of nanoparticle is done by combustion method. This method is mainly used for the formation of oxides from nitrates.

1) Object/Equipment used if this process are:
2) Muffle furnace
3) Mortar and pestle
4) Copper nitrate, Aluminum nitrate, urea

5) Crucible
6) Pyrometer
7) Weighing machine

Fig.1 Schematic diagram of experimental setup for Nano-particle.

Properties of chemical used

Property	Aluminium nitrate	Urea
Formula	$Al(NO_3)_3$	CH_4N_2O
Molar mass	212.996 gm/mole	60.06 gm/mole
Melting point	72.8^0C	133^0C
Density	$1.72gm/cm^3$	$1.32gm/cm^3$

A. Preparation of Nano-Fluid

Two-step method is used for preparing Nano-fluids. In this method nanoparticle is mixed with the base fluid and mixed with the help of high speed magnetic stirrer, high shear mixing and ultrasonic agitation. The stability of Nano-fluid is a big concern as when nanoparticle is mixed with base fluid it settle down. So to get better results ultrasonic agitation is used. By using magnetic stirrer or high shear mixing if the stability of Nano-fluid remains constant for 2 3 min then it can be used as a fuel for laboratory purpose because in combustion chamber all parts are movable there will not arise any concern of stability as nanoparticle in Nano-fluid will also be in motion. To get better results surfactants can be used so that they tie up the molecule of nanoparticle and base fuel but use of surfactant at high temperature application is a big concern. So surfactant was not used in this project only by high shearing method Nano-fluid was made. Due to the difficulty in preparing stable Nano-fluids by two-step method, several advanced techniques are developed to produce Nano-fluids, including one-step method. Two-step method is the most economic method to produce Nano-fluids in large scale, because Nano-powder synthesis techniques have already been scaled up to industrial production levels. Due to the high surface area and surface activity, nanoparticles have the tendency to aggregate.

Figure **:** Magnetic stirrer

In case of non - availability of diffusivity value, we are the same can be determined by the using of simple experiment devised by Stefan. For the purpose, the liquid should be fairly volatile. The different volatile liquid is taken in a different –different small diameter test tube and is allowed to diffuse to atmosphere by holding it inside a thermostatic bath. And by this thermostatic bath to maintaining the temperature is constant at the whole experiments. In case of non-availability of diffusive value, we are using the same can be determined in the laboratory experiment devised by stefan. For the purpose of liquid should be fairly volatile. We are using the different volatile liquid are methanol, petrol, diesel, turpentine. And its property as: methanol:- molecular weight of the methanol = 32.04 gm/mol. As shown in fig. And it's density is equal to 792 kg/m3. The level of the liquid at the start of the experiment and after an appreciable time interval are accurately noted. The water bath temperature is set at the desired level and to wait the bath attains the set temperature The test tube is filled with petrol to within 2 centimeter of the top of the test tube.
The initial diffusion height of the liquid in the test tube from the top is noted down.

Then the diffusivity (D_{ab}) is calculated corresponding to its bath temperature. The diffusional flux or the diffusivity for the process is,

$$D_{ab} = \frac{P_{bm} R T \rho_L}{2 M_L \theta P_T (Pa1 - Pa2)} ({Z_2}^2 - {Z_1}^2)$$

Where,

ρ_L = Density of liquid

M_L = Molecular weight of the liquid

= Time of diffusion

$Z_2 - Z_1$ = Fall in the liquid level in the test tube.

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Fig : Experimental setup for measurement of diffusivity.

IV. RESULT AND DISCUSSION

Table 1: outcome of diffusivity at temp. variation.

SL. No.	Temp. at ºc (X)	Petrol (Y)	Methanol (Y)
01.	40	8	0.47
02.	50	18.3	0.7
03.	60	27.1	0.831

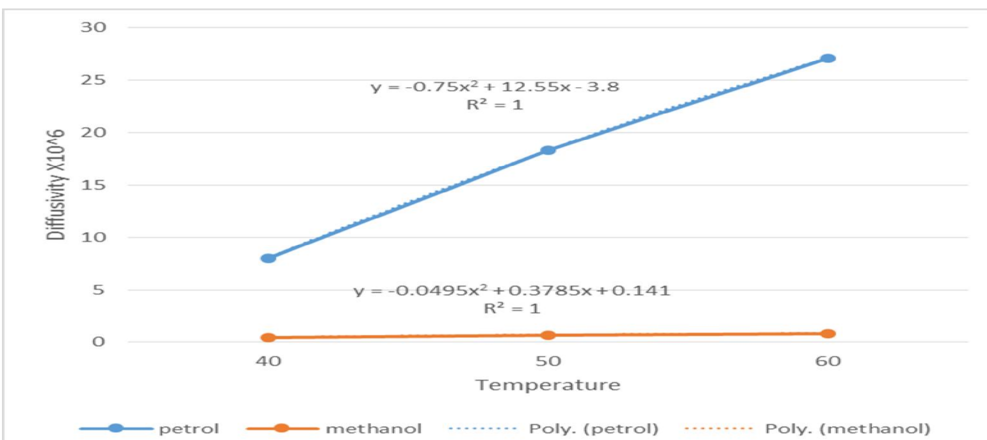

Fig.1: Outcome of Diffusivity at temp. variation.

It can be calculate from the above experiments that the value of diffusivity for different volatile liquids is obtained and is approximated to the original value, from the analysis of fig. 6.1 It is evident that the diffusivity increases with increase in temperature.

Table 6.2: Diffusivity (in m2/sec)x10ˆ6 at Temperature = 40ºc.

SL. No.	Liquids with Nano-additive (gm/70ml) (X)	Petrol (Y)	Methanol (Y)
01.	0.0	8.0	0.47
02.	0.1	5.41	0.33
03.	0.2	2.2	0.273
04.	0.3	1.75	0.216

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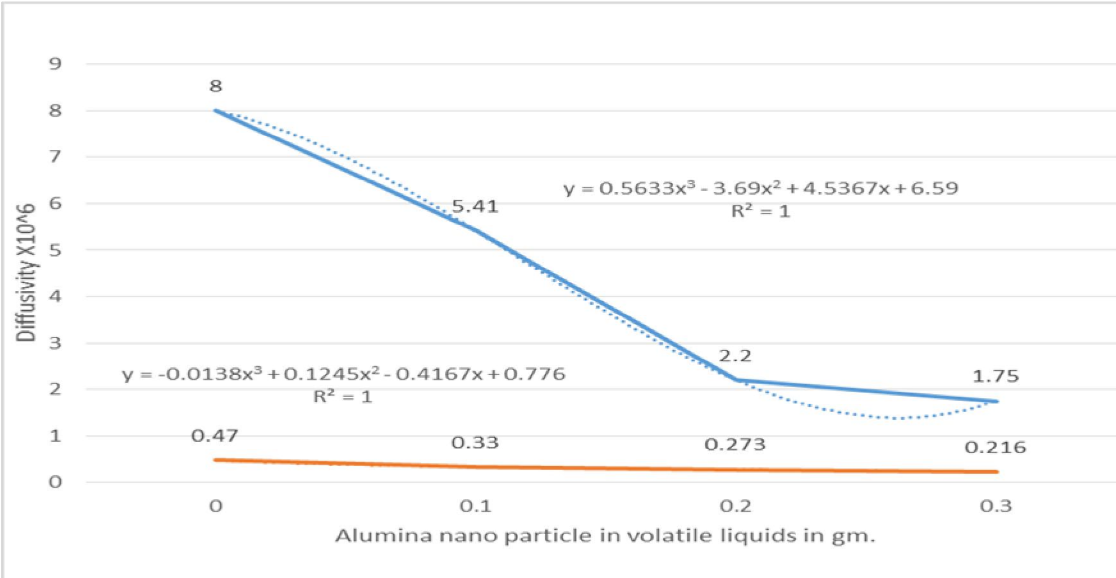

Fig. 2: Diffusivity (in m2/sec)x10ˆ6 At Temperature = 40ºc.

Table 3: Diffusivity (in m2/sec)x10ˆ6 at Temperature = 50ºc.

SL. No.	Liquids with Nano-additive (gm/70ml) (X)	Petrol (Y)	Methanol (Y)
01.	0.0	18.3	0.7
02.	0.1	10.55	0.603
03.	0.2	3.35	0.366
04.	0.3	3.01	0.360

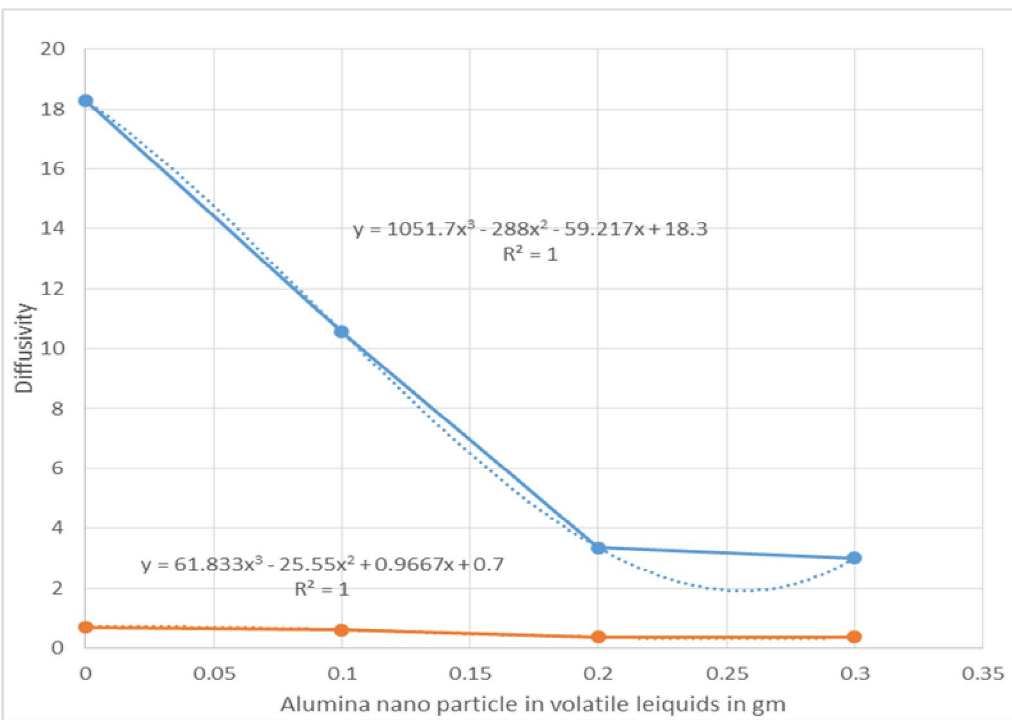

Fig. 3: Diffusivity (in m2/sec)x10ˆ6 at Temperature = 50ºc.

Table 4: Diffusivity (in m2/sec)x10ˆ6 at Temperature = 60ºc.

SL. No.	Liquids with Nano-additive (gm/70ml) (X)	Petrol (Y)	Methanol (Y)
01.	0.0	27.1	0.831
02.	0.1	18.3	0.501
03.	0.2	7.51	0.396
04.	0.3	7.37	0.355

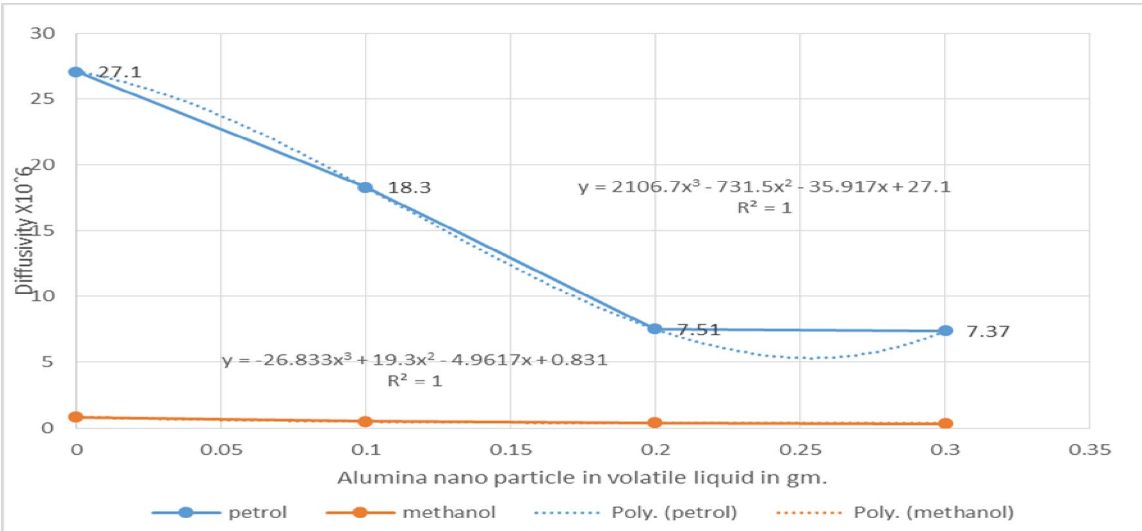

Fig. 4: Diffusivity (in m2/sec)x10ˆ6 at Temperature = 60ºc.

Fig. 6.2, 6.3, and 6.4 reveals that for initially addition of aluminum oxide Nano-particle decrease the diffusivity of petrol shortly up to the value of 3.62gm/ltr. then further addition of Nano-particle do not affect much on the diffusion rate.

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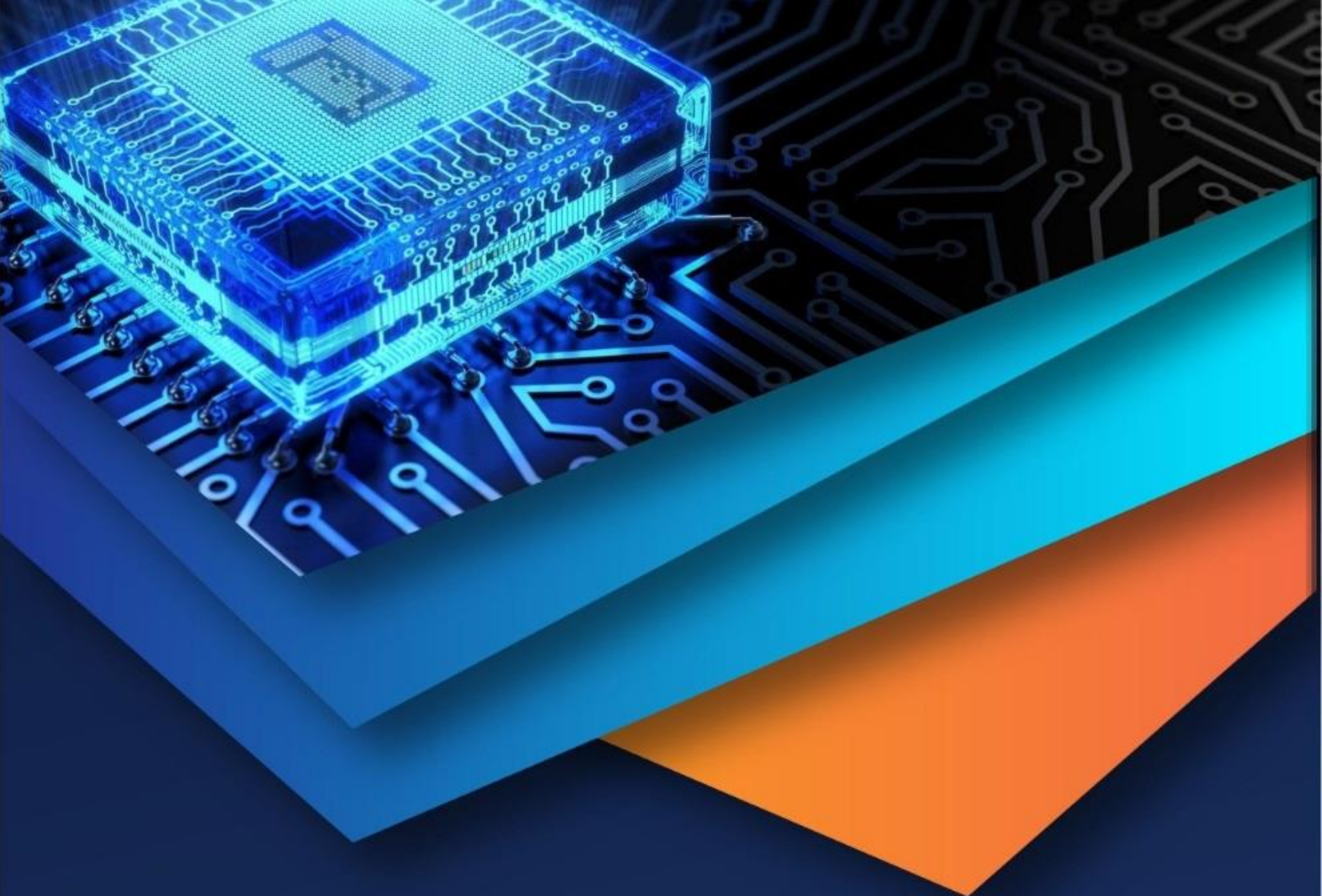

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