International Journal of Science and Healthcare Research
Vol.1; Issue: 4; Oct.-Dec. 2016
Website: www.gkpublication.in/ijshr
Review Article *ISSN: 2455-7587*

Diffusivity: A Review on Research and Studies with Insight into Affecting Parameters

Sunil Jayant Kulkarni

Datta Meghe College of Engineering, Airoli, Navi Mumbai, Maharashtra, India.

Received: 02/10/2016 | Revised: 24/10/2016 | Accepted: 24/10/2016

ABSTRACT

Diffusivity is number of moles transferred per unit area per unit time per unit concentration gradient. The molar flux in molecular diffusion is divided into two parts. One is due to bulk motion and other is due relative speed of particle or molecule. Diffusion plays major role in applications such as drying, catalysis and many other chemical engineering applications. Diffusion through solid is classified as diffusion through porous solid, diffusion through polymers and surface diffusion. Depending on size of molecule, porous diffusion is classified as Fickian, Knudsen diffusion and transient diffusion. Various investigators have carried out studies on diffusivity and its affecting parameters. Current review summarizes research and studies on diffusivity and its affecting parameters.

Key words: Temperature, pressure, moisture diffusivity, coefficients, mechanisms.

INTRODUCTION

In chemical engineering molecular diffusion is very basic and important phenomenon. Concentration difference is driving force for it. Important unit operations related to mass transfer includes gas absorption, distillation, drying and extraction. [1-4] nowadays modified and combined processes and unit operations such as leaching, extractive distillation, reactive extraction, reactive absorption and membrane bioreactors are being used for more effective separation and for intensifying processes. [5-10]

Studies on mass transfer coefficient are also reported. The mass transfer near the boundary layer is many times due to diffusion. Diffusion can be eddy or turbulent or molecular diffusion. Eddy diffusivity is defined for turbulent diffusion. Many times combined mass and heat transfer occurs, when considerable temperature change occurs along with mass transfer. The studies on boundary layer are important for proper understanding of momentum, heat and mass transfer near the boundaries. [11,12] Also effect on viscosity of various parameters is important. [13-15] Investigations are reported on effect of various parameters on diffusivity in various applications. Current review gives an insight into studies and research on diffusivity and its affecting parameters.

RESEARCH AND STUDIES ON DIFFUSIVITY IN VARIOUS APPLICATIONS WITH INSIGHT INTO ITS AFFECTING PARAMETERS

Azizi and Peyghambarzadeh investigated mass transfer diffusivity in convective drying process for effect of temperature history. [16] In a batch dryer, they carried out studies on convective hot air drying of potato slabs and the effects of drying air temperature and slab thickness. They varied temperature level from 50 to 80^{O}C. The slab thickness was varied from 0.5 to 1.5 cm. They observed that effective moisture diffusivity can be increased by increasing slab thickness and drying temperature. According to them, considerable time is required to reach the final temperature. So the assumption of constant moisture diffusivity during drying time may not to be valid. Due to this diffusion model doesn't predict the convective drying kinetics as well as the isothermal drying system. Kim carried out extensive studies and found that the theoretical foundation of thermal diffusion is still Einstein's random walk. [17] Heterogeneity of a random walk under a temperature gradient needs to be added. According to these studies, the steady state of a diffusion process is decided by particle speed and not by the diffusivity.

Nakashima carried out investigation on effects of temperature and clay fraction on self-diffusion of H_2O in stevensite gel. [18] They used pulsed-gradient spin-echo (PGSE) proton nuclear magnetic resonance (NMR) for measurement of self-diffusion coefficients of water molecules in Na-stevensite gel. They observed that effects of boundary layers were negligible. Also they found that the solid distribution was spatially random. Duda studied molecular diffusion in polymeric solids. [19] According to him molecular diffusion in polymeric systems is affected by factors such as temperature, concentration, polymer molecular weight and polymer morphology. They reviewed recent advances which can serve as precursors for the development of basic theories to describe diffusion through polymer composites. They concentrated their studies on diffusion of low molecular weight solvents. According to them, properties of a homogeneous sample of the polymer may not be same as the bulk properties of the polymer in a composite. Mukherjee et.al carried out an investigation on viscosity and diffusion coefficients of a glassy binary mixture. [20] They carried out a large number of simulations of a glassy binary mixture. The emphasis of their studies was on temperature and pressure dependence. They observed that pressure has weaker effect on the dynamic properties. They found that upto a certain pressure, viscosity and diffusion coefficients vary exponentially with pressure. Also they found that viscosity and diffusion show super-Arrhenius dependence.

Zheng et.al investigated the temperature effects on the hydrogen permeation behaviours. [21] They carried out pipeline steel studies in 1MPa H_2S environment. They applied high-temperature and high-pressure electrochemical measurement techniques, scanning electron microscopy and X-ray diffraction for studying the effects of the corrosion product films formed on the surface of L360NCS pipeline steel at different temperatures. They identified three stages in hydrogen fermentation namely rising stage, declining stage and steady stage. They observed that with rise in temperature, the peak values of hydrogen permeation curves increased. Fernandez et.al investigated polystyrene latex spheres for temperature dependence of the diffusion coefficient. [22] In their investigation, they carried out extensive measurements on the diffusion of carboxylate-modified polystyrene latex spheres. They found that observed data showed a second order fit. Rarely did it indicate third order fit. Charest et.al carried out an investigation on the effects of pressure and gravity on sooting characteristics and flame. [23] They solved the unmodified and fully-coupled equations governing reactive, compressible, gaseous mixtures. They used an acetylene-based, semi-empirical model. In their investigation, they observed that pressure and gravity significantly influence the flames. Their effect on buoyancy and reaction rates causes this influence. Valikova and Nazarov presented a new approach for pressure influence on diffusion. [24] Their approach allowed calculation of the temperature- and pressure dependences of impurity diffusion coefficient taking into account correlation effects. In their work, they estimated the copper impurity diffusion coefficient versus temperature and pressure. Also they determined volumes for copper impurity diffusion in iron.

Bobde et.al carried out investigation on effect of various parameters on liquid diffusion. [25] They conducted experimental runs with various concentrations at various temperatures and time. They carried out experiments with porous pot and used it for determining diffusion coefficient. They observed that concentration, time, and temperature have significant effect on the diffusion coefficient. Flaconneche et.al carried out an investigation on permeability, diffusion and solubility of gases in polyethylene, polyamide and poly vinylidene fluoride. [26] They used the time lag method on a specific permeation cell. For this purpose, they showed that permeability, diffusion and solubility depend on temperature. According to their studies, diffusion was directly related to the gases molecule size. Yuan carried out research on high temperature coating for thermal and mechanical behaviours. [27] They discussed two important issues in case of high temperature coatings. These issues were thermal property related to oxidation/corrosion behavior and microstructure stability, and mechanical properties. Creep and fatigue were two most important properties. They used diffusion model. This model also accounted for the influence of surface oxidation, coating-substrate interdiffusion and diffusion blocking effect caused by internal voids and oxides. In their investigations, they observed that the thickening rate of the diffusion coatings was controlled by the inward diffusion of aluminium. They also observed that the fatigue limit of specimens with thin coating (50 μm) was not much affected by precracking of the coating prior to the fatigue test.

Kaptan used the decay rates of radicals in the temperature range for determining the diffusion coefficient of oxygen into polymeric spheres. [28] They used electronic spin technique. They used the phenomenon of diffusion of oxygen in poly (methyl methacrylate) (PMMA). In their investigation, they observed that the decay rates of radicals with oxygen permeation increased with temperatures. Wu studied oxygen diffusion through. [29] They used titanium (Ti) alloys in their experiments. They investigated the energetic and diffusion pathways for oxygen in 14 other hexagonal closed-packed (HCP) elements. They explained the fact that Ti alloy properties are very sensitive to oxygen content. They studied the atomistic mechanism of oxygen diffusion in titanium. Their studies also included the effect of substitutional solutes on oxygen diffusivity. Abbaszadeh investigated effect of air velocity and temperature on energy and effective moisture diffusivity for Russian olive. [30] They carried out thin layer drying of Russian olive in their investigation. They evaluated effective moisture diffusivity, activation energy and energy consumption. They found that effective moisture diffusivity increased with temperature. They also observed that drying of russian olive fruit only occurs in a course with falling rate. Also it was observed that increased air velocity in constant temperature decreased effective diffusivity. Maierova et.al examined the influence of variable thermal properties on the thermal state of a sub ducting slab. [31] They combined a kinematic slab model with models of thermal conductivity. They observed that variable thermal diffusivity results in a modest increase of negative buoyancy of the slab.

Lu and Siebenmorgen investigated moisture diffusivity of long-grain rice components. [32] They used the finite element method for modeling of moisture adsorption of long-grain rice. They conducted adsorption tests on white, brown, and rough rice. Their studies indicated that endosperm had considerably higher diffusivity values than the bran and hull. Also an Arrhenius-type function explained the diffusivity temperature-dependency for each rice component. Mukhopadhyaya et.al investigated the water absorption characteristic for building materials. [33] It was determined through water absorption test. In eastern white pine, they observed a clear surface temperature effect on water absorption coefficient. According to their investigations, Lower water absorption coefficient or liquid diffusivity values can be affected by surface temperature variation. A lower water absorption coefficient or liquid diffusivity value doesn’t have significant effect of surface temperature variation.

For mass transfer flow through an inclined plate, Akter et.al investigated chemical reaction and thermal diffusion effects. [34] They studied effect of chemical reaction and thermal diffusion on boundary layer mass transfer flow. According to the studies, these two phenomenon's have significant effect on the boundary layer fluid flows through an inclined plate. Arya et.al carried out an investigation on the diffusion of molecules in AlPO4-5 pores. [35] Their studies indicated the presence of a low-temperature surface barrier for diffusion. According to them, pore exit barrier tends to diminish as temperature and loading increase. They also observed that exit effects become significant when the size of the sorbate molecule becomes equal to the pore size.

CONCLUSION

The molar flux in molecular diffusion is divided into two parts. One is due to bulk motion and other is due relative speed of particle or molecule. Diffusion plays major role in applications such as drying, catalysis and many other chemical engineering applications. Various investigators have carried out studies on diffusivity and its affecting parameters. Current review summarizes research and studies on diffusivity and its affecting parameters. Temperature and pressure affects the diffusivity significantly.

REFERENCES

1. Treybal R.E. "Mass Transfer Operations" McGraw Hill 3rd Edition, 1992, 565-645.
2. Sunil Jayant Kulkarni, "Advancements, research and challenges in reactive adsorption: a review", International Journal of Research, 2015, 2(1), 310-313.
3. Sunil Jayant Kulkarni, "A review on research and advancements in extractive distillation", International Journal of Research, 2015, 2(1), 306-309.
4. Sunil Jayant Kulkarni, "Solar distillation: a review", International Journal of Research (IJR), 2014, 1(11), 1171-1176.
5. Sunil J. Kulkarni, Ajaygiri K. Goswami, "Applications and Advancements in Treatment of Waste Water by Membrane Technology- A Review", International Journal Of Engineering Sciences & Research Technology, 2014, 3(9), 446-449.
6. Bahareh Asadollahi Esfahani, Banafsheh Asadollahi Esfahani, Mina Shams Koupaei, Seyyedeh, Zahra Ghasemi, "Industrial waste water treatment by membrane systems", Indian Journal of Fundamental and Applied Life Sciences, 2014, 4(1), 1168-1177.
7. Sunil J. Kulkarni, Pallavi M. Kherde, "A review on advanced membrane separation methods for water treatment", Int. J Res Rev., 2015, 2(8), 513-517.
8. Sunil J. Kulkarni, "A review on studies and research on various aspects of leaching", Int J Res Rev., 2015, 2(9), 579-583.
9. David Laird, Pierce Fleming, Baiqun Wang, Robert Horton, Douglas Karlen, "Biochar impact on nutrient leaching from a midwestern agricultural soil", Geoderma, 2010, 158, 436-442.
10. Dechen Chezom, Kinley Chimi, Sangay Choden, Tashi Wangmo And Dr Shashi Kumar Gupta, "Comparative study of different leaching procedures", International Journal Of Engineering Research And General Science, 2013, 1(2), 1-5.
11. Xiangfeng Bo, Bo Liu, Pengcheng Zhao, Zhiyuan Cao, "Experimental investigation of boundary layer characteristics on blade surface under different inlet flow conditions", Energy And Power Engineering, 2010, 2, 313-319.
12. Gryning, S-E., Batchvarova, E., & Floors, R. " A study on the effect of nudging on long-term boundary layer profiles of wind and weibull distribution parameters in a rural coastal area", Journal Of Applied Meteorology And Climatology, 2013, 52(5), 1-6. Doi: 10.1175 /Jamc-D-12-0319.1
13. Mostafa Bakhoday Paskyabi A,N, Ilkerfer A, Alastaird.Jenkins, "Surface

gravity wave effects on the upper ocean boundary layer: modification of a one-dimensional vertical mixing model", 2012, Continental Shelf Research, 38, 63–78.

14. Sunil Jayant Kulkarni, "Studies and research on effect of temperature on viscosity of fluids: a review", International Journal of Engineering Management and Life Sciences (IJEMLS), 2016, 1(2), 33-36.
15. Sunil J. Kulkarni, Ajay K. Goswami, "Research on application of hydrotropy:a review", Int. J Sci Eng Tech Res., 2014, 3(10), 2617-2619.
16. S. Azizi And S.M. Peyghambarzadeh, "Effect of temperature history on mass transfer diffusivity in convective drying process", World Applied Sciences Journal, 2010, 10(10), 1216-1224.
17. Yong-Jung Kim, "Einstein's random walk and thermal diffusion", Department Of Mathematical Sciences, Kaist, 291 Daehak-Ro, Yuseong-Gu, Daejeon 305-701,Korea, (Yongkim@Kaist.Edu), 2013, 1-9.
18. Y. Nakashima, "Self-diffusion of H_2O in stevensite gel:effects of temperature and clay fraction", Clay Minerals, 2002, 37, 83-91.
19. J. L. Duda, "Molecular diffusion in polymeric systems", Pure & Appl. Chem., 1985, 57(11), 1681-1690.
20. Arnab Mukherjee, Sarika Bhattacharyya, And Biman Bagchi, "Pressure and temperature dependence of viscosity and diffusion coefficients of a glassy binary mixture, solid state and structural chemistry unit", J. Chem. Phys. , 2002, 116, 4577-4580.
21. Shuqi Zheng, Chengshuang Zhou, Pengyan Wang, Changfeng Chen, And Liqiang Chen, "Effects of the temperature on the hydrogen permeation behaviours of l360ncs pipeline steel in 1 mpa H_2S environments", Int. J. Electrochem. Sci., 2013, 8, 2880-2891.
22. Alina C. Fernandez And George D. J. Phillies, "Temperature dependence of the diffusion coefficient of polystyrene latex spheres", Biopolymers, 1983, 22, 593-595.
23. Marc R.J. Charest, Clinton P.T. Groth And Omer L. Gulder, "Effects of pressure and gravity in laminar coflow ethylene diffusion flames", 49th AIAA Aerospace Sciences Meeting Including The New Horizons Forum And Aerospace Exposition, January 2011, Orlando, Florida, 4-7.
24. Irina Valikova, Andrei Nazarov, "Simulation of pressure- and temperature dependence of impurity diffusion in BCC metals", The Open-Access Journal For The Basic Principles Of Diffusion Theory, Experiment And Application, 2009, 11(53), 1-2.
25. Mr.K.M. Bobde, Ms. M.C.Likhar, Mr.M.V. Shivramwar, "Effect of concentration, temperature, time on liquid-liquid diffusion", International Journal For Advance Research In Engineering And Technology, 2013, 1, 72-74.
26. B. Flaconnèche, J. Martin And M.H. Klopffer, "Permeability, diffusion and solubility of gases in polyethylene", Polyamide 11 And Poly (Vinylidene Fluoride), Oil & Gas Science And Technology – Rev., 2001, 53(3), 261-278.
27. Kang Yuan, "Thermal and mechanical behaviors of high temperature coatings", Linkoping Studies In Science And Technology Thesis No. 1569, Division Of Engineering Materials, Department Of Management And Engineering Linköping University, Linköping, sweden,Http://Www.Liu.Se, Linköping, February 2013, 581-583.
28. H. Yilmaz Kaptan, "ESR study on the effect of temperature on the diffusion of oxygen into PMMA And PVAC Polymers", Journal of Applied Polymer Science, 1999, 71, 1203–1207.
29. Henry Wu, "Oxygen diffusion through titanium and other HCP Metals", Dissertation Submitted In Partial Ful_Llment Of The Requirements for The Degree Of Doctor Of Philosophy In Materials Science And Engineering In The Graduate College Of The University Of Illinois At Urbana-Champaign, 2013, 1-87.
30. Abbaszadeh, Ahmad; Motevali, Ali; Ghobadian, Barat; Khoshtaghaza, Mohammad Hadi; Minaei, Saeid, "Effect of air velocity and temperature on energy and effective moisture

diffusivity for russian olive(elaeagnusan gastifolial l.) in thin-layer drying", Iran. J. Chem. Chem. Eng. Research Note, 2012, 31(1), 75-79.

31. P. Maierova T. Chust, G. Steinle-Neumann, O. Cadek And H. Cízkova, "The effect of variable thermal diffusivity on kinematic models of subduction", Journal Of Geophysical Research, 2012, 117(B07202), 1-14. Doi:10.1029/2011jb0 091 19.
32. R. Lu, T. J. Siebenmorgen, "Moisture diffusivity of long-grain rice components", Transactions Or The ASAE, American Society Of Agricultural Engineers 000 1-2151 /92/ 3506-, 1992, 1955-1962.
33. Mukhopadhyaya, P.; Kumaran, K.; Normandin, N.;Goudreau, P., "Effect of surface temperature on water absorption coefficient of building materials", Journal Of Thermal Envelope And Building Science, 2002, 26(2), 179-195.
34. Farjana Akter, Md. Manjiul Islam, Ariful Islam, Md. Shakhaoath Khan, Md. Saddam Hossain, "Chemical reaction and thermal diffusion effects on mass transfer flow through an inclined plate", Open Journal Of Fluid Dynamics, 2016, 6, 62-74. Http://Dx.Doi. Org/10.4236/ Ojfd.2016. 61006.
35. Gaurav Arya, Edward J. Maginn, And Hsueh-Chia Chang, "Effect of the surface energy barrier on sorbate diffusion in AlPO 4-5", J. Phys. Chem., 2001, 105, 2725-2735.

How to cite this article: Kulkarni SJ. Diffusivity: a review on research and studies with insight into affecting parameters. International Journal of Science & Healthcare Research. 2016; 1(4): 9-14.

******