The Effect of Mixing Ratio on Thermal Diffusion Factor by The Separation of Liquid Binary Mixture

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Abstract:

Thermal diffusion factor (α_T) were calculated through the separation of ethanol-water mixtures using thermal diffusion column, for four different ethanol concentrations (80%, 70%, 60% and 50%) and it was found this factor (α_T) changes smoothly as ethanol concentration decrease .

تأثير نسبةِ الخَلْط على عاملِ الإنتشارِ الحراريِ بواسطة فصل خَلِيْطِ سائلِ ثنائيِ

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ملخص البحث :

في هذا البحث تمت دراسة تأثير درجة الحرارة على جهد الانهيار الكهربائي في مجموعة من السوائل الهايدروكاربونية المشبعة والتي تتضمن n-hexane, n-heptane, n-octane تحت تأثير المجال الكهربائي الغير المنتظم والناتج من استخدام منظومة الأقطاب الكهربائية إبرة– صفيحة. حيث وجد انه في مدى درجة حرارة الغرفة لا يوجد تأثير كبير لتغير درجة الحرارة على قيمة المجال اللازم للانهيار الكهربائي مقارنة بدرجات أعلى من هذا المدى, كذلك فقد كان لعدد ذرات الكربون في السائل العازل تأثيرا على جهد الانهيار حيث وجد إن زيادة عدد ذرات الكربون يؤدي إلى زيادة هذا الجهد كنتيجة حتمية لزيادة لزوجة المادة العازلة.

Introduction:

Thermal diffusion phenomena can be used to separate fluids and nuclear isotopes of materials when the material is influenced by a temperature gradient.

In such a case, the lighter component tends to move towards the hot side while the heavier component moves towards the cold side (Rijab 2000). Ordinary diffusion processes work against this effect and when an equivalent state is reached, a net separation effect is established. This separation effect is usually described in terms of a parameter called the thermal diffusion factor α_T which is given by:-

$$\alpha_T = \frac{\ln(q)}{\ln(T_1 / T_2)} \qquad \text{-------- (1)}$$

Where q is the separation factor and equal to

$$q = \frac{(C_1 / C_2)Top}{(C_1 / C_2)Bottom}$$

C_1 and C_2 are the concentrations of the components of the mixture, and T_1 and T_2 being the hot and the cold ends of the temperature gradient respectively.

The parameter α_T is theoretically related to the force constant of the particular potential force function being used to describe the interactive force that is acting between the molecules and thus considered as an important transport parameter thus α_T measurements can give understanding of molecular force (Azooz and Noory, 1994).

Thermal diffusion column is one of the main types of thermal diffusion equipment used to study the molecular interaction.

It is basically consists of two coaxial cylindrical tubes with a small annular spacing between them. The inner tube is usually heated from the inside by an electric wire heater and thus forms the hot surface, while the outer tube is surrounded by a cooling jacket thus, forming the cold surface. The mixture kept within the annular space between the two tubes.

Theoretical Part:

The large temperature gradient acts to create convection currents with the overall equilibrium effect on molecular components being separated, with the lighter one concentrating at the top, while the heavy component concentrating sat the bottom. This type of equipment has the advantage of producing large separation effects which are fairly easy to detect. Nevertheless it suffers from the disadvantage that the thermal diffusion factor α_T can only be obtained from the relation (AL-Faydhi,1998) :-

$Ln(q)= \alpha_T F_s (r_c, r_h, L, T)$ -------- (2)

where F_s is the calibration factor function, which depends on the geometrical dimensions of the column including the hot tube radius r_h, the cold tube radius r_c, and the Length of the column L in addition to its

$$T = \frac{T_C + T_h}{2}$$

dependence on the mean temperature T across the annular spacing, where

Although, F_S has been calculated mathematically for some Thermal Diffusion Columns (T.D.Cs) (Youssef and Youssef, 1989). These calculations are model dependent. It was demonstrated that experimental calibration using fluids with known α_T can give better results (Acharyya, 1987) thus any data measured using this apparatus could be used to predict behaviour of other mixtures . Several authors studied thermal diffusion factor through separation of liquids, Leppla and Wiegand (1999) performed measurements of the transport coefficients ST (Soret coefficient), D (mutual diffusion coefficient) and D_T (thermal diffusion coefficient) on the three binary organic liquid mixtures 1,2,3,4-tetrahydronaphthalene–n–dodecane, 1,2,3,4-tetrahydronaphthalene–isobutylbenzene and isobutylbenzene–n–dodecane with the weight fraction c ¼ 0:5 at T ¼ 298:15K by means of Thermal-Diffusion-Forced Rayleigh Scattering (TDFRS) for benchmarking purposes where some parameters extracted from previously experiments.

Experimental work:

The thermal diffusion column used in this work consists of two cylindrical tubes with diameters 1.27 and 3.175 cm and the inner spacing between them is 1.6 cm and a spiral tube for cooling the whole system as in fig.(1) the length of the column was (63) cm. Most of the researches of the thermal diffusion columns used a heating wire for heating the inner tube (Kobayashi N., 2001, Ecenarro O., 1989, etc.) while in this work we used a different technique which is to let a heated water to flow inside the heating tube making heat exchange with the outer tube (the cooled tube) and leaves the whole column to a boiler for heating and thus completing the circulation. A rotary pump was connected to the reservoir for the circulation purposes of the cooled water. To test the system a mixture of Ethanol and distilled water was used and the thermal diffusion factor (α_T) was determined experimentally after the saturation period approved. The hot temperature was set as (75°C) and the cold temperature set as (17 °C). A different set of mixing ratio were taken to analyze the effect of the mixing ratio on the separation process .The sets were (50, 60, 70 and 80%) for water.

The density is used here as a good indicator to investigate the separation processes (Ecenarro et al , 1991)

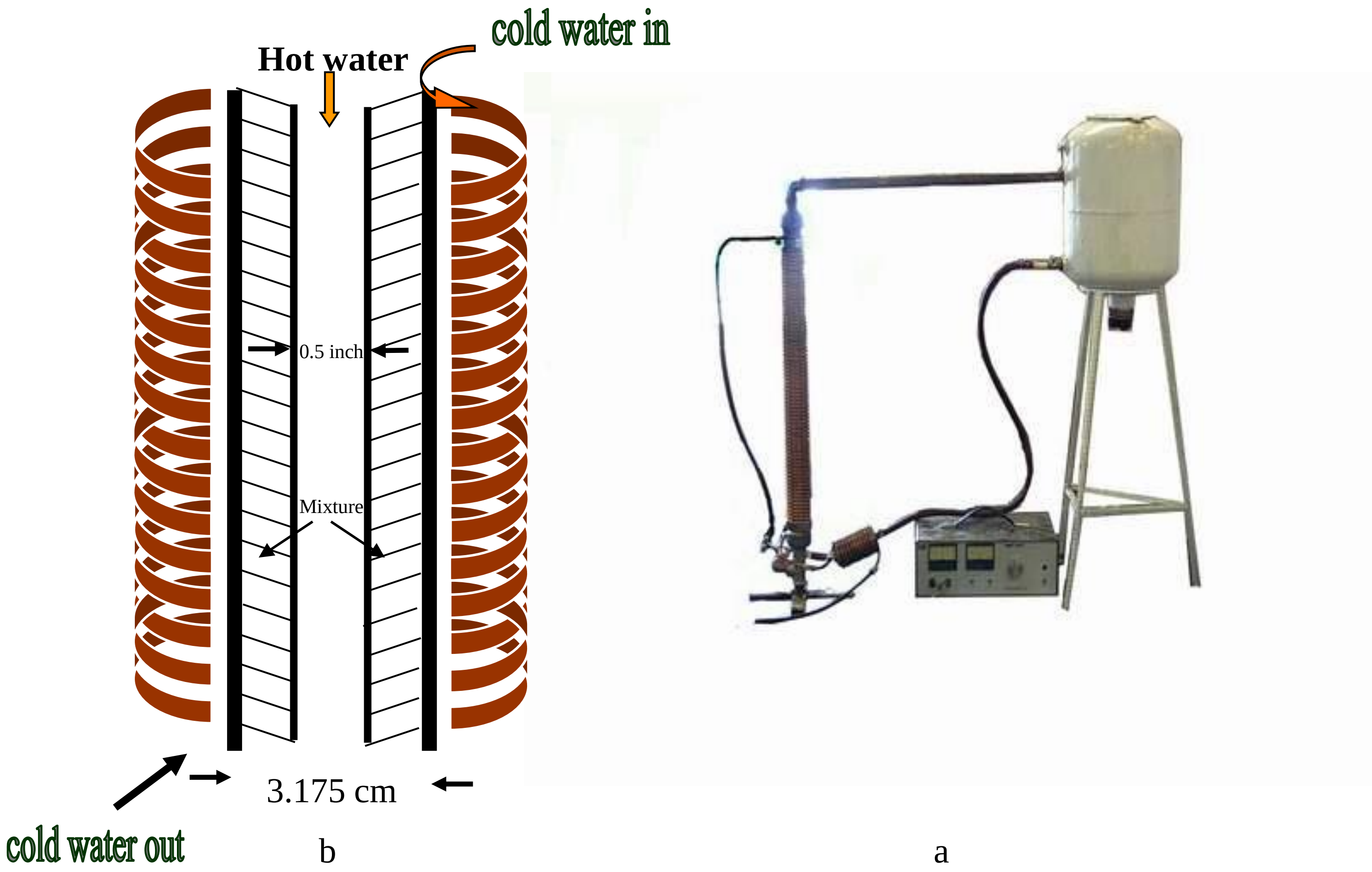

Fig. (1): **a. Experimental Apparatus**

b. Schematic diagram of the T.D.C.

This method makes use of the fact that different molecular velocities cause lighter molecules to concentrate in hotter regions when a temperature gradient exists. The separation factor is determined by the ratio of the mass difference and the total masses, so it is larger for light elements. In general the separation factor is small (around 1.01), so many cascade stages are needed. Although the equipment required is simple, the power requirement (for heat) is extremely large, although this can be reduced if waste heat is available from other industrial processes.

The Results and discussions

After the steady state is reached by controlling the temperature at the top and the bottom of the column using thermometers the densities at both the top and bottom of the column were driven. The results of 50% mixture ratio is shown in fig.(2). The same thing applied for the 60%, 70% and 80% mixture ratio in figs.(3), (4) and (5) respectively. The thermal diffusion factor (α_T) were calculated using equation (1) for all cases of mixture concentration. Figure (6) illustrate the values of the thermal diffusion factor (α_T) versus the time for the different previously mentioned mixing ratios of Ethanol –Distillated water.

Conclusions

Thermal diffusion factor (α_T) represents one of the transport physical properties which is strongly related to the force constants. These force constants affect on the parameters of any molecules according to their models .Thus, understanding the behavior of thermal diffusion factor (α_T) provides a unique opportunity to address some of the questions about local structure effect and its influence on dynamics in the molecule. Thermal diffusion factor (α_T) were calculated through the separation of ethanol-water mixtures, for four different ethanol concentration and it was found that (α_T) changes smoothly as ethanol concentration decrease .

That means that all the factors of the thermal diffusion leading to the separation processes become more effective at low rate of mixing ratio. Also it is clear that the effect of thermal diffusion on density take place (figs. 2,3,4,and 5) and that the density at the top drop dramatically much more than the density at the bottom . This could be explained that any extra energy gained by the molecules could be enough cause for leaving the substance (evaporation).

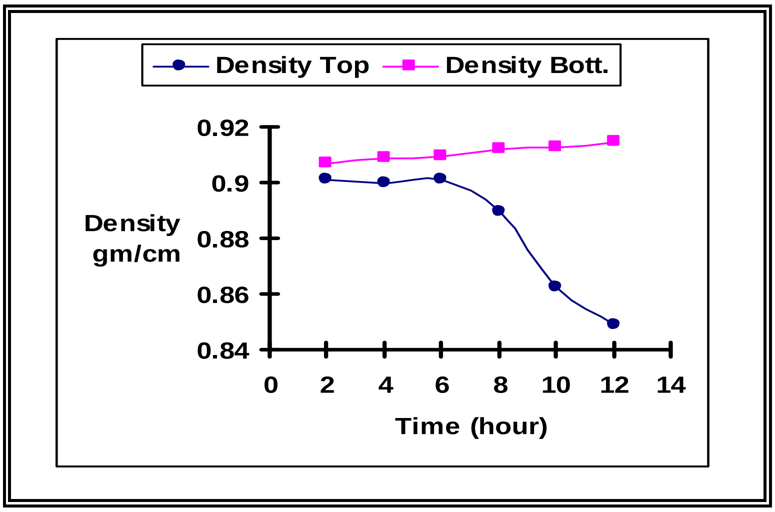

Fig. (2): The density differences at concentration 50%

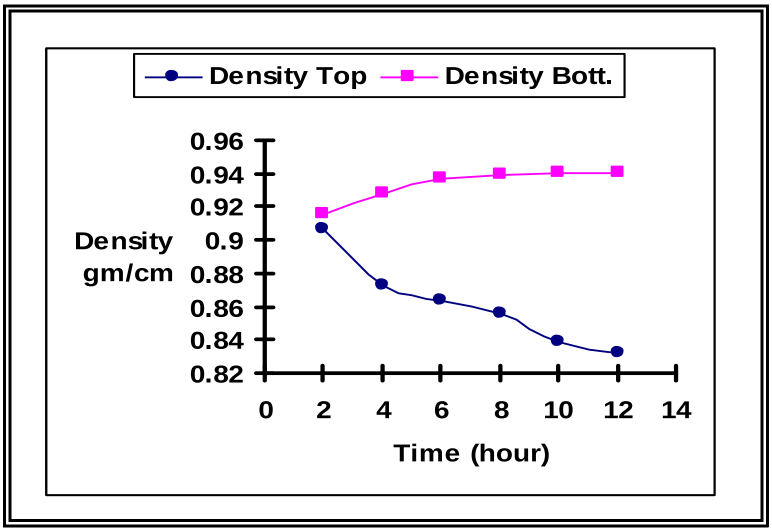

Fig. (3) The density differences at concentration 60%

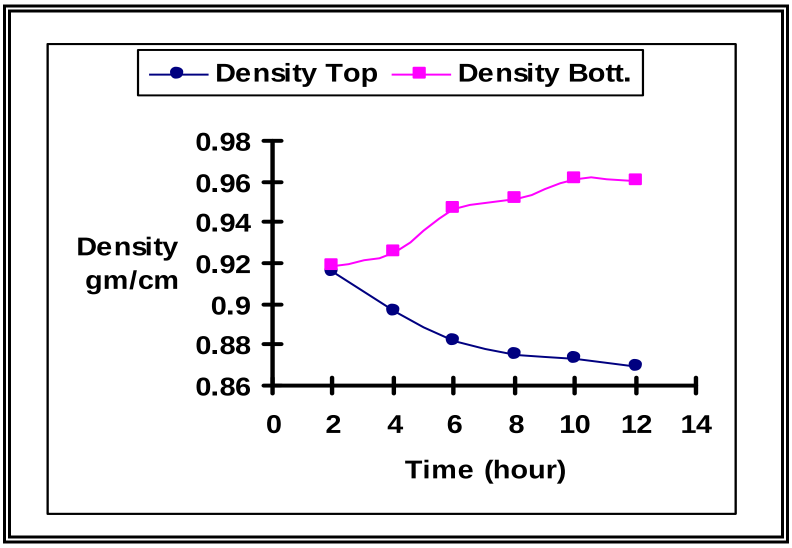

Fig. (4) The density differences at concentration 70%

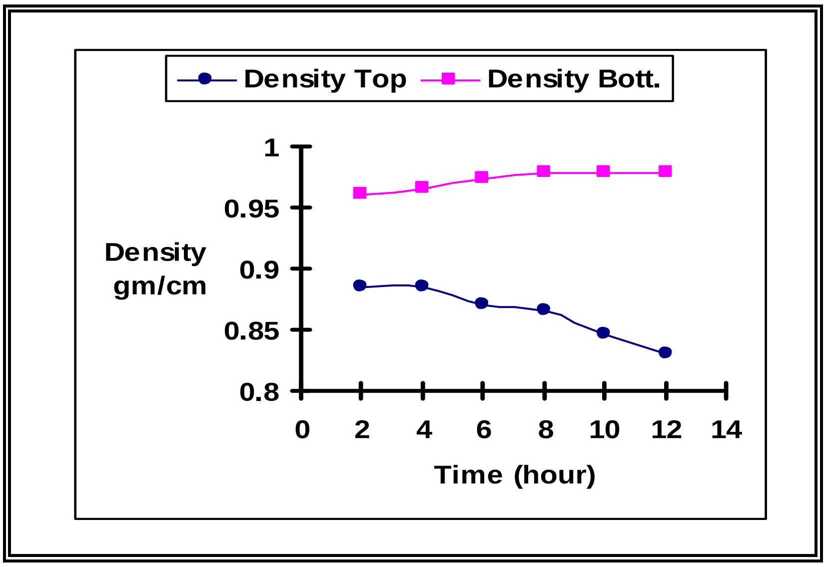

Fig. (5) The density differences at concentration 80%

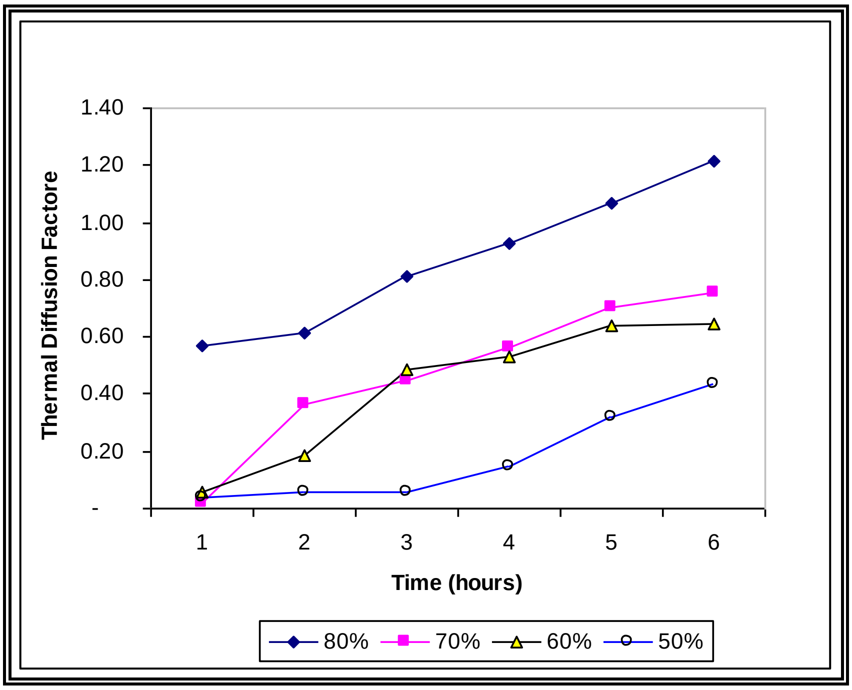

Fig. (6) The Effect of The Mixing Ratio on the Thermal Diffusion Factor (α_T)

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