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Calculation of Thermal Diffusion Factor α_T for Liquid Mixture in a Two Bulbs System

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ABSTRACT

In this study a two bulbs system have been designed and constructed we have design and construct to demonstrate the separation of Ethanol – Distilled water liquid operation (50% for each). The operation of separation was checked using the density test and acidity function and calculating the Thermal diffusion factor. The comparison of the result for the same binary mixture but driven from different method (Thermal diffusion column) shows a reasonable agreement.

حساب عامل الانتشار الحراري (α_T) لخليط سائل في منظومة ذات بصلتين

الملخص

في هذه الدراسةِ تم تصميم وبناء نظام البصلتين الزجاجيتين وحساب فصل مزيج السوائل الإيثانول – ماء مقطر (بنسبة 50% لكل منهما). وقد تم التاكد من عملية الفصل من خلال فحص الكثافة وكذلك دالة الحامضية وتم حساب عاملَ الإنتشار الحراري للمزيج بهذه الطريقة وبالمقارنة الاولية للنتيجةِ مع قيمة عاملَ الإنتشار الحراري لنفس المزيج والمستخرجة بطريقة مختلفة تماما (عمود الانتشار الحراري) فقد وجد توافق معقول.

INTRODUCTION

Thermal diffusion is regarded as a powerful tool for the measurement of interaction potential between molecules. These measurements are achieved through the direct measurements of the thermal diffusion factor α_T. As is well known, the thermal diffusion factor is far more sensitive to the type of molecular interaction than the other transport coefficients (Youssef et al., 1989). It follows therefore that the determination of the intermolecular forces from thermal diffusion data will be much more accurate and useful than their determination from viscosity, diffusion and virial coefficients which is usually done (Youssef et al., 1989).

Thus, in order to calculate α_T for any liquid binary mixture, two bulbs binary system was designed and built as shown in fig. (1).

The Ethanol – distilled water mixture was used for several reasons and the mixing ratio was equal.

Ethanol, C_2H_5OH, (also called Ethyl Alcohol) is the second member of the aliphatic alcohol series. It is a clear colourless liquid with a pleasant smell. Except for alcoholic beverages, nearly all the ethanol used industrially is a mixture of 95% ethanol and 5% water, which is known simply as 95% alcohol. Although pure ethyl alcohol (known as absolute alcohol) is available, it is much more expensive and is used only when definitely required. (Melting Point -1150˚C, Boiling Point 780˚C, Specific Gravity 0.79). (The Columbia Encyclopaedia, 2001).

Most of the ethanol used in industry is made, not by alcoholic fermentation, but by an addition reaction between ethane and steam.

$$\underset{\text{Ethane}}{C_2H_4} + \underset{\text{Steam}}{H_2O} \rightarrow \underset{\text{Ethanol}}{C_2H_5OH}$$

THEORY

When heat flows through a mixture initially of uniform composition, small diffusion currents are set up, with one component transported in the direction of heat flow and the other in the opposite direction. This is known as the thermal diffusion effect. The existence of thermal diffusion was predicted theoretically in 1911 by Enskog (Kobayashi et al., 2001), from the kinetic theory of gases and confirmed experimentally by Chapman in 1916. The thermal diffusion phenomena was used frequently to calculate thermal diffusion factor (α_T) experimentally which is used to study the internal interaction between various molecules which is very sensitive for secondary changes appeared in the interaction (Ecenaro, 1989). The Thermal diffusion measurements are achieved through the direct measurements of the thermal diffusion factor α_T.

Recently Ecenarro et al. (1989 and 1999), have carried out experiments on organic liquids mixture separation. However, no attempt was cited in literature involving the separation of constituents of aqueous solutions using the two bulbs method.

The aim of the present work is to measure the α_T as a function temperature and composition according to equation (Youssef et al., 1989).

$$(\alpha_T) = \ln Q / \ln (T_h / T_c) \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Where T_h represent hot temperature of water and T_c represent cold temperature of water while Q represent the separation factor and according to (Rijab, 2000), this quantity could be calculated as:

$$Q = (\rho_H - \rho_2)(\rho_1 - \rho_C)/(\rho_1 - \rho_H)(\rho_C - \rho_2) \ldots\ldots\ldots\ldots (2)$$

Where ρ_H, ρ_C represent the density of the hot and cold bulb respectively and ρ_1, ρ_2 represent the density of the 1^{st} and 2^{nd} substitute respectively. 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.

EXPERIMENTAL

The thermal diffusion factor α_T of the Ethanol – Distilled water mixture were measured as a function of temperature and composition by using a two bulbs apparatus as shown in fig. (1). The two bulbs were (5 cm) both in apart and diameters.

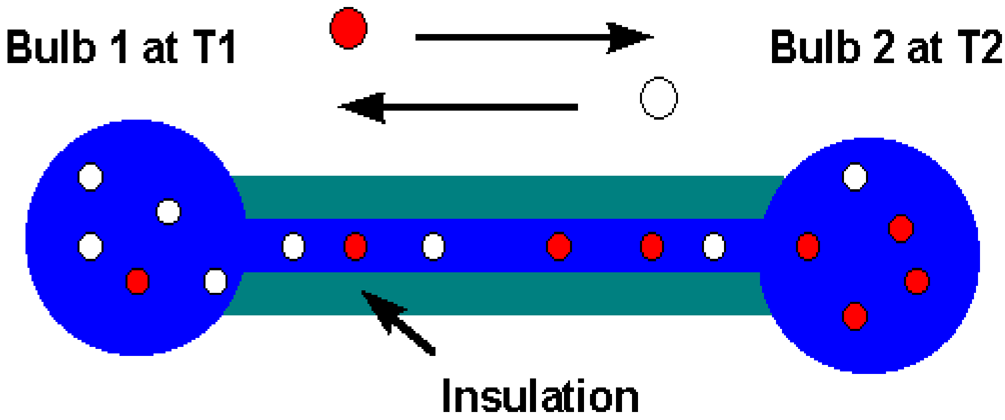

Fig. 1: The two bulb apparatus.

The temperature of the cold bulb T_2 is adjusted at (7 ˚C) controlled and circulating water from an ultra thermostat into a cooling jacket by Massgerate – werk - lauda (ultra – Kryomat)(German made). The hot temperature T_1 of the other bulb is adjusted at (40 ˚C) and controlled through constructed furnace. Another different set of temperature were applied (50 and 60 ˚C) for hot temperature and (7 and 6 ˚C) for cold temperature.

Sufficient time was allowed for the operation to reach the limit and it was found that if we start from 30 min. up to 5 hours we will have a considerable values.

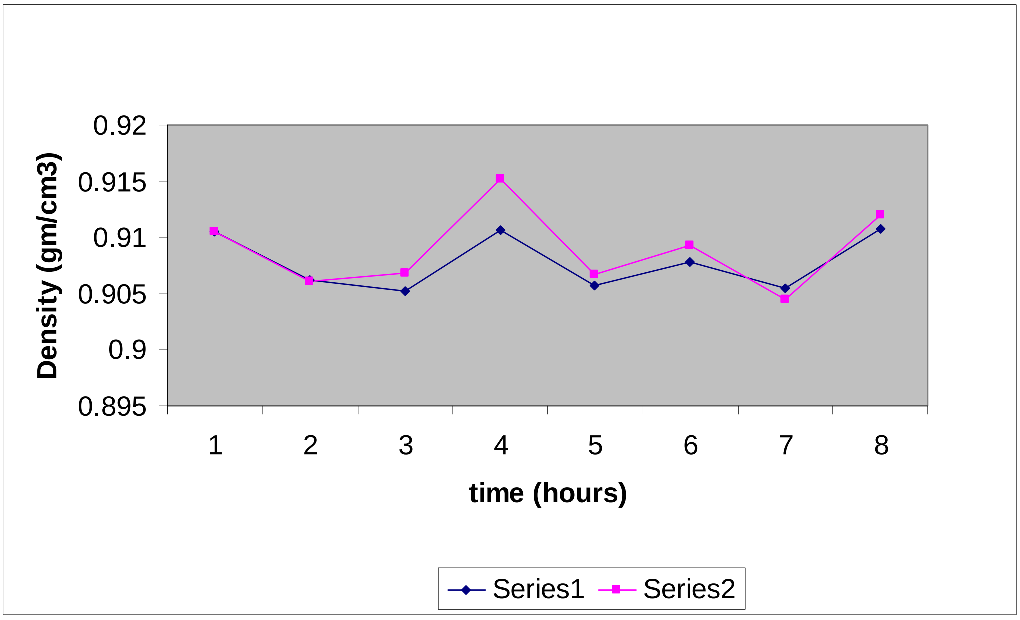

Fig. 2: T_h =40 ˚C and T_c= 7 ˚C.

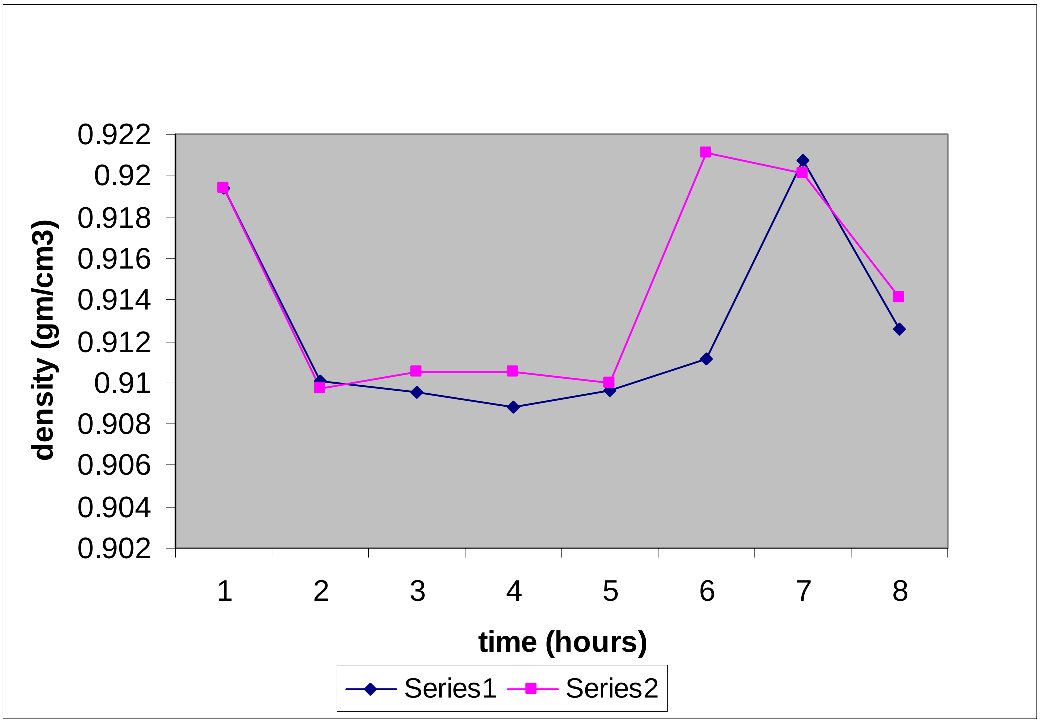

Fig. 3: At T_h = 50 ˚C and T_c = 7 ˚C.

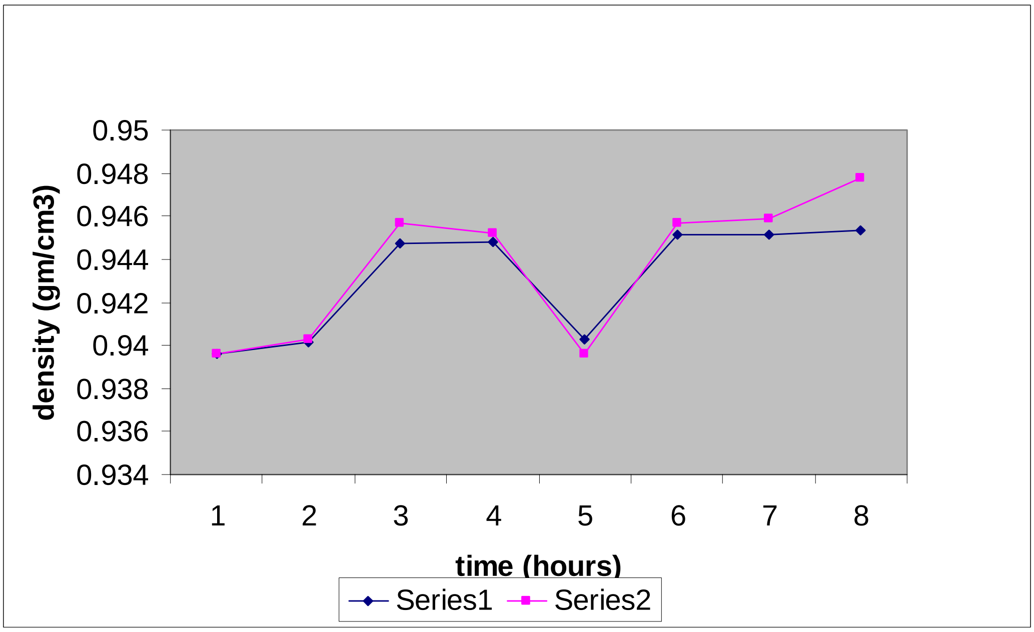

Fig. 4: At T_h = 60 ˚C and T_c= 6 ˚C.

RESULTS AND DISCUSSION

The density is used as a good indicator to investigate the separation processes (Ecenarro, 1991) and the results are shown in figs. (2), (3) and (4). It was used two kinds of liquid materials, Ethanol and distilled water with a percentage mixture of 50% for each. After repeating several times(7 to 8 times each to minimize the percentage of error) the results revealed consistency of the thermal diffusion theory where the heavy density concentrate at the cold part and vice versa for the light one. The result appeared that this design could be account for experimentally acceptable measurements were separation of liquids proved by density measurements as in figs. (2), (3) and (4), where the density from cold bulb is represented in series (1) and the density from hot bulb is represented in series (2). The pH meter readings reported in tables (1), (2) and (3), represents another proof for the separation processes. Also it revealed nearly the constancy of separation factor Q for a slightly changes in hot temperature but as temperature increase the required time for best density differences increase.

Table 1: pH meter readings at T_h= 40 ˚C And T_c= 7 ˚C.

Time/min	30	60	90	120	150	180	240	300	T_h= 40 ˚C and T_c= 7 ˚C
pH/Hot	6.42	6.8	6.93	6.42	6.485	6.222	6.127	6.275	
pH/Cold	6.7	6.55	6.71	6.9	7.095	6.695	6.27	6.20	

Table 2: pH meter readings at T_h= 50 ˚C And T_c= 7 ˚C.

Time/min	30	60	90	120	150	180	240	300	T_h= 50 ˚C and T_c= 7 ˚C
pH/Hot	6.60	7.28	7.27	7.36	7.54	7.45	7.2	7.64	
pH/Cold	6.56	6.96	7.48	7.35	7.47	7.82	7.15	7.81	

Table 3: pH meter readings at T_h= 60 ˚C And T_c= 6 ˚C.

Time/min	30	60	90	120	150	180	240	300	T_h= 60 ˚C and T_c= 6 ˚C
pH/Hot	6.84	6.85	6.1	6.06	6.775	6.22	6.127	6.275	
pH/Cold	6.7	6.55	6.71	6.9	7.095	6.98	7.23	6.72	

More of that the value of thermal diffusion factor α_T in this research calculated using equations (1) and (2) and found to equal to (0.05987) which is close enough for the same mixture but in deferent procedure as in Al-Faydhi and Al-taie (2005), which is (0.05) .

CONCLUSION

As first the system designed and approved in this work appeared to have a good qualification and also the mechanism of heating using hot water and recycled cold water proved to be good and safe tool for laboratory experimental setup. Second the ordinary diffusion was affected by the increase of temperature differences result in more required time for best separation. Finally, the experimentally calculated value of α_T were in reasonable agreement with that calculated by Al-Faydhi and Al-taie (2005), (for 2 hours run) in very different method (TDC).

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