Design and construction of thermal diffusion column heated by the flow of recycled water and used to calculate thermal diffusion factor for Ethanol – Distilled Water mixture

Dr. Anwar M. Ezzat Al-Faydhi
Mosul University
College Of Science

Saffaa Aldeen A. Sulyman Al-taie
Mosul University
College of Basic Education

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Abstract:

In this work a new design for the thermal diffusion column which uses the flow of a hot water instead of heating wire as often used. The system was tested to find the thermal diffusion factor (α_T) for a mixture of Ethanol (CH_3CH_2OH) and distillery water. It was found that using the flow of hot water has two main advantages the first is avoiding the disconnection problems of the heating wire and the second is the equal distribution of heat in the inner tube (heating tube) which leads to increase the speed of heat stability in the heat exchange operation.

تصميم و بناء عمود الانتشار الحراري يعمل بطريقة دوران الماء الساخن
و استخدامه لايجاد عامل الانتشار الحراري لخليط (الايثانول - ماء مقطر)

د. أنور مصطفى عزت الفيضي
جامعة الموصل / كلية العلوم

صفاء الدين عبدالله سليمان الطائي
جامعة الموصل / كلية التربية الأساسية

ملخص البحث :

تم في هذا البحث عمل تصميم جديد لعمود الانتشار الحراري و الذي يعمل لاول مرة بطريقة التسخين بتدفق الماء الحار بدلا من سلك التسخين الكهربائي و الذي أستخدم في معظم البحوث السابقة و قد تم اختبار المنظومة لايجاد عامل الانتشار الحراري (α_T) لخليط من الايثانول و الماء المقطر بنسب متعادلة . لقد وجد ان استخدام الماء الساخن قي عملية التسخين لـه فائدتان اساسيتان الاولى هي التخلص من مشاكل انقطاع السلك الكهربائي المتكرر خلال

عمليـة التسـخين و الثانيـة هـي توزيـع متسـاوي فـي الانبـوب الـداخلي (انبـوب التسـخين) لدرجـة الحرارة و الذي يؤدي الى سرعة الاستقرار الحراري في عملية التبادل الحراري.

Introduction:

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 were used frequently to calculate thermal diffusion factor (α_T) experimentally which is used to study the internal interaction between various of molecules which is very sensitive for secondary changes appeared in the interaction (Ecenaro 1989).

Isotopes separation using thermal diffusion column (TDC) has been attracting extensive attention since 1966 (Bates, 1966) .The use of TDC in this respect have always been connected with two purposes the first is the separation of isotopes for use in practical purposes. The most recent work in this respect is that of Yamamoto et al. The work is described in several papers (Ecenarro et al., 1989, Ecenarro et al., 1999, Rijab, 2000, Yamamato et al., 1990 and Yamamato et al., 1988). .The main aim here is to study the feasibility of using the TDC for separation of hydrogen isotopes deuterium and tritium for potential use as fuel in future nuclear reactors.

The second is that 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, which is defined in terms of the concentrations of the constituents of a binary gas or isotopic mixture as:

$$Q = (X_1/X_2)_T / (X_1/X_2)_B \qquad \text{..................} \quad (1)$$

Where X1 and X2 are the concentrations of the two constituents.

The subscripts $_T$ and $_B$ indicates that samples are taken from the top and the bottom of the TDC. Several authors have made predictions concerning the value of Q (Yamamato et al., 1990 and Ecenarro et al., 1999). These predictions are based on phenomenological models concerning the interaction potential between molecules. Thus experimental measurements of Q provide a good mean of testing such models.

It must be pointed out that most TDC measurements were concerned with separation of gases or isotopic mixtures in the gaseous states. Recently Ecenarro et al. (1989 and 1999), have carried out experiments on organic liquid mixture separation. However no attempt was cited in literature involving the separation of constituents of aqueous solutions. This may be due to electrical insulation problems associated with the nature of the TDC where electric current, cooling water and the mixture to be separated are so close to each other in the system.

Thermal diffusion factor (α_T) defined by the equation

$$(\alpha_T)= \ln Q / \ln (T_h / T_c) \quad \ldots\ldots\ldots\ldots \quad (2)$$

where T_h represent hot temp. of water and T_c represent cold temp. of water.

Experimental work :

The thermal diffusion column used in this work consists of two cylindrical tubes with diameters 0.5 and 1.25 inches 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 (references Kobayashi N., 2001, Ecenaro O., 1989, etc.) while in this work we used for the first time 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 (50:50) used and the thermal diffusion factor (α_T) determined experimentally after the saturation period (~ 8 hrs) approved. The hot temperature was set as (75)°C and the cold temperature set as (17) °C

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

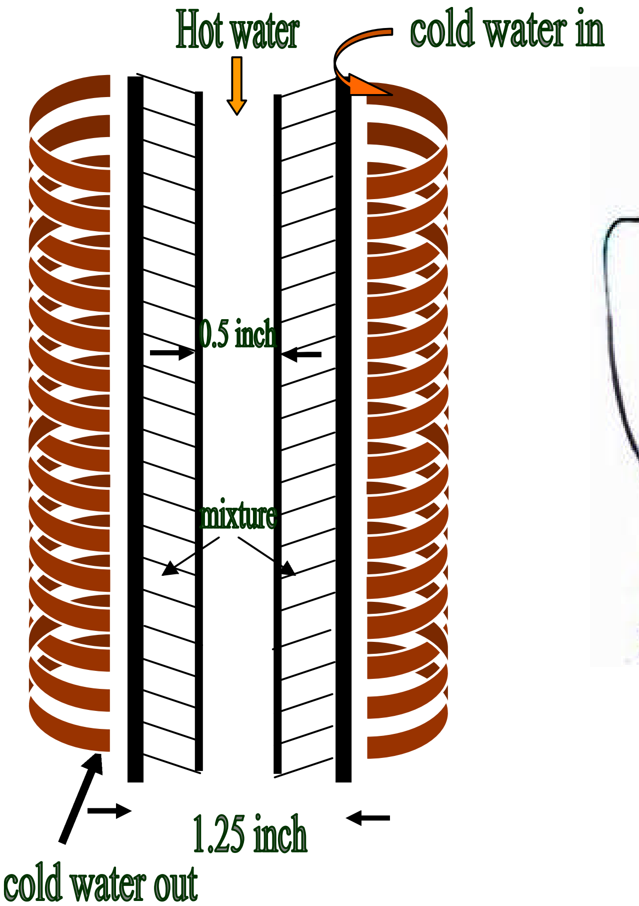

Fig. (1-a) Experimental Apparatus

Fig. (1-b)Schematic diagram of the T.D.C.

Results and Calculations:

After repeating several times the results revealed consistency of the thermal diffusion theory where the heavy density concentrate in the lower part and the light density concentrate at the higher part of the column. Table (1) reveals values of (α_T) and Q values for different times (the average of relative percentage error is 3%).

Table (1)

Time hour	ρ_{top} gm.cm^{-3}	$\rho_{bott.}$ gm.cm^{-3}	Q	α_T
2	0.90001	0.904055	1.079015	0.05
4	0.89347	0.91235	1.426952	0.239538
6	0.863647	0.913706	2.585825	0.640073
8	0.861011	0.920145	3.094581	0.76108
10	0.861002	0.920141	3.094901	0.76115
12	0.861005	0.920137	3.094466	0.761055

To understand the behavior of separation operation a figure was sketch for the relation of the separation factor versus time fig. (2). Also the relation of thermal diffusion factor with time was sketch, fig. (3).

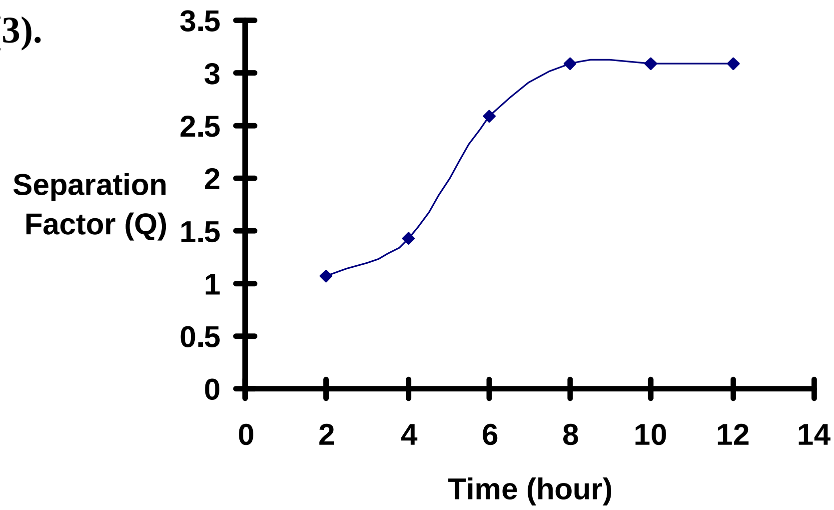

Fig.(2) : The relation between the separation factor and time

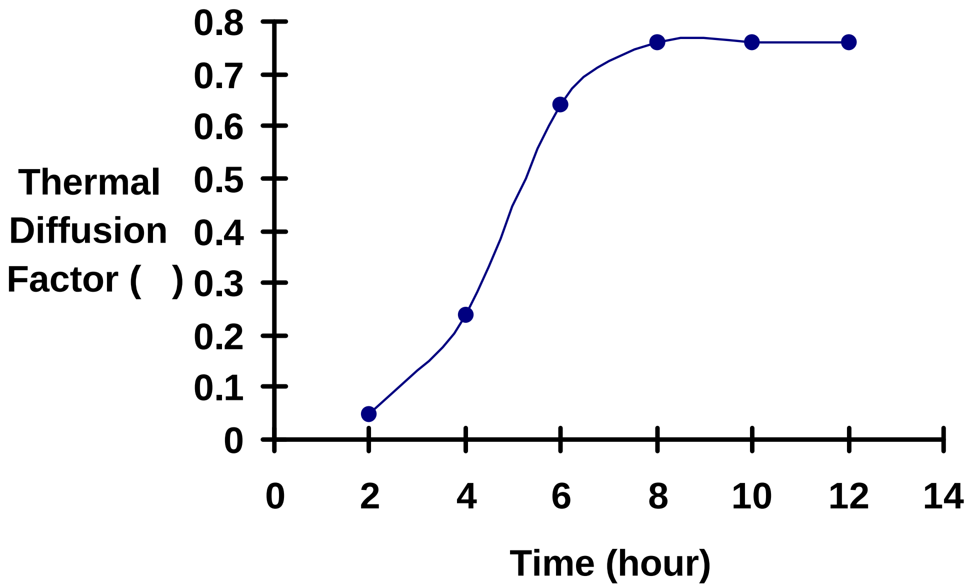

Fig.(3) : The relation between thermal diffusion factor and time

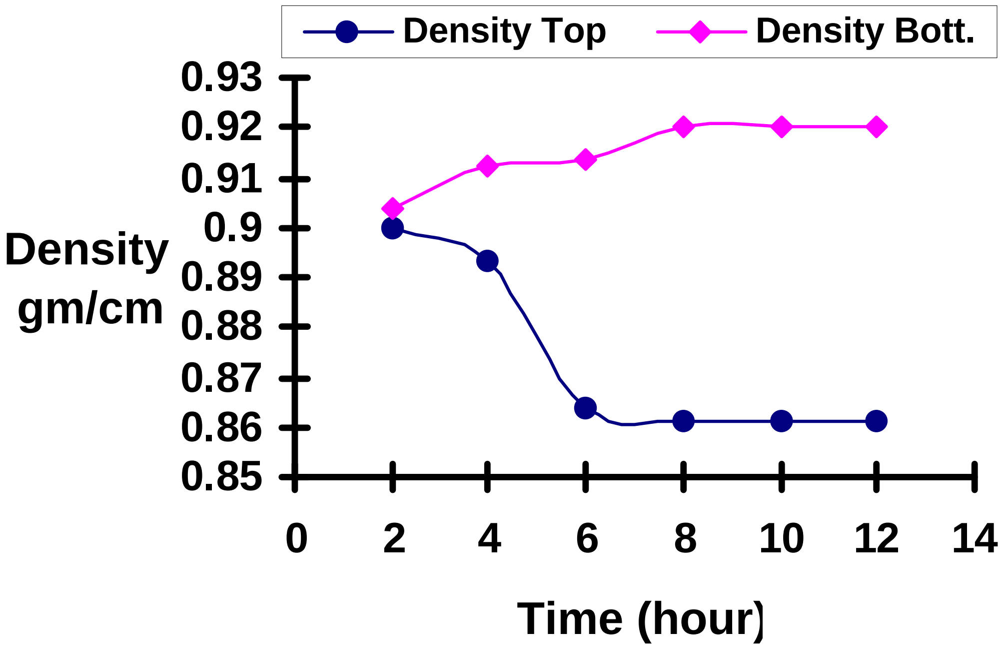

Fig.(4) : The relation between the densities of upper and lower samples with time

Conclusions :

As first the system designed and approved in this work appeared to have a good qualification and also the mechanism of heating using hot recycled water proved to be good and safe tool for TDC systems where there is no isolator requirements or contact problems. The equal distribution of heat exchange is another benefit achieved through using hot recycled water instead of heating wire. Fig. (2) And fig.(3) illustrate the separation processes which reached the saturation limit nearly after (8) hours The separation qualification was good according to the result of density analysis as in fig.(4).

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