Gas Mixture Separation by Thermal Diffusion Column

V. K. SAXENA *

Physics Department, University of Rajasthan, Jaipur, India

and S. C. SAXENA

Thermophysical Properties Reserach Center, Purdue University, Lafayette, Indiana, U.S.A.

(Z. Naturforsch. **23 a**, 471—472 [1968]; received 24 December 1967)

A thermal diffusion column is a very simple device to achieve nonisotopic gas mixture separation, the primary shortcoming being that no procedure is available to theoretically estimate the separation. In this note, we outline a method to compute for a given column the optimum operating pressure and the maximum separation.

For discontinuous operation, the steady state separation factor of a mixture of isotopes, q, is given according to the theory of FURRY and JONES [1] as

$$\ln q = \frac{a/p^2}{1+(b/p^4)} . \qquad (1)$$

Here p is the pressure of the gas mixture, and the constants a and b depend in a complicated way on the geometry of the column, nature of the gas and operating conditions. This relation suggests that a plot of $\ln q$ versus p will have a maximum at a value of p such that

$$p^4 = b . \qquad (2)$$

This value of p is referred as p_{opt} and

$$p_{\text{opt}} = b^{1/4}. \qquad (3)$$

Consequently the maximum separation, $q_{\max}$, is

$$q_{\max} = \exp(a/2\sqrt{b}) . \qquad (4)$$

The validity of these relations for isotopic mixtures is examined by many workers [1]. For binary and multicomponent mixtures of nonisotopic gases, similar relations have not yet been derived. This is because the development of column theory for nonisotopic mixtures is quite complicated. However, one can still expect Eq. (1) to hold qualitatively. Physically, this amounts to approximating the situation in a column by an equivalent but fictitious pure gas having appropriate properties. Because of the large probable difference in the conductivity values of the pure components of the mixture, the hot-wall temperature will be nonuniform. Similar other considerations will suggest the effective column dimensions to be different from the actual ones. This necessitates an adequate check of the applicablity of Eq. (1) to nonisotopic mixtures as described below.

A careful survey of the available literature on binary systems revealed that suitable data reported as a function of pressure are of: DRICKAMER, O'BRIEN, BRESEE and OCKERT [2] on $CO_2-C_3H_8$; DRICKAMER, MELLOW and TUNG [3] on Ar–Ne; TUNG and DRICKAMER [4] on CH_4-Xe; HEYMAN [5] on H_2-Xe and D_2-Xe; SLIEKER [6] on $HT-{}^4He$, $DT-{}^4He$ and $T_2-{}^4He$; and VASARU [7] on $He-H_2$. A discussion of the available less extensive data on other systems and the detailed interpretation of the above systems is available elsewhere [8] and here only a brief reference will be presented.

In Fig. 1, the results for $CO_2-C_3H_8$ are displayed. The continuous curve is the least square fit of the experimental points according to Eq. (1). The curve represents the data well, and an equally good success is achieved for the Ar–Ne and CH_4-Xe systems. The constants a and b are listed for all the systems in Table 1. The data from Amsterdam are also well correlated by Eq. (1). In Fig. 2, we reproduce a representative plot for H_2-Xe. Similar agreement is found for all the other systems except $HT-{}^4He$, where even a reversal in the sign of the thermal diffusion factor is observed [6] necessitating a special interpretation.

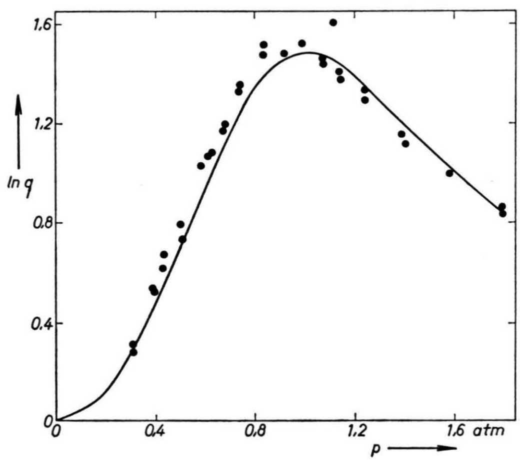

Fig. 1. Plot of $\ln q$ versus p for $CO_2-C_3H_8$. ● Experimental points, the curve represents a least square fit through the experimental points on the basis of Eq. (1).

* Present address: Department of Pharmacy, University of Saugar, Sagar, M.P., India.

1 S. C. SAXENA and S. RAMAN, Rev. Mod. Phys. **34**, 252 [1962].
2 H. G. DRICKAMER, V. J. O'BRIEN, C. J. BRESEE, and C. E. OCKERT, J. Chem. Phys. **16**, 122 [1948].
3 H. G. DRICKAMER, E. W. MELLOW, and L. H. TUNG, J. Chem. Phys. **18**, 945 [1950].
4 L. H. TUNG and H. G. DRICKAMER, J. Chem. Phys. **18**, 1031 [1950].
5 D. HEYMAN, Z. Naturforsch. **14 a**, 603 [1959]; See also Ph. D. Thesis, Amsterdam University 1958.
6 C. J. G. SLICKER, Ph. D. Thesis, Amsterdam University 1964.
7 G. VASARU, C. UNGUREANU, and T. FODAR, Stud. Cercet. Fiz. **12**, 825 [1961].
8 V. K. SAXENA, P. D. Thesis, Unpublished, Physics Department, Rajasthan University, Jaipur, India 1967.

System	a (Eq. 1) atm^2	b (Eq. 1) atm^4	p_{opt} (Eq. 3) atm	q_{max} (Eq. 4)	Reference
$CO_2-C_3H_3$	2.970	1.005	1.00	4.40	[2]
$Ar-Ne$	4095	747400	29.4	10.7	[3], Column II
$Ar-Ne$	82150	4823×10^4	83.4	369	[3], Column II
CH_4-Xe	25640	1312×10^4	60.2	34.5	[4], Column II
$Xe-H_2$	1.483	0.02815	0.41	83	[5]
$Xe-D_2$	1.716	0.02054	0.38	397	[5]
$HT-{}^4He$	0.03023	0.1524	0.625	1.04	[6], $\Delta T = 110\ °K$
$DT-{}^4He$	1.259	1.030	1.008	1.86	[6], $\Delta T = 110\ °K$
$T_2-{}^4He$	1.021	0.6693	0.90	1.87	[6], $\Delta T = 110\ °K$
$He-H_2$	−302.9	−56.83	2.75	5.4×10^8	[7]

Table 1. Values of the constants a and b (Eq. 1), p_{opt} (Eq. 3), and q_{max} (Eq. 4).

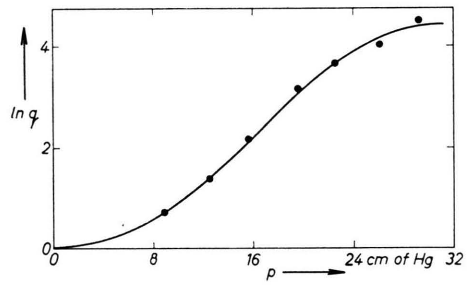

Fig. 2. The legend is the same as for Fig. 1 except that it refers to H_2-Xe.

The only other system where relatively inferior reproduction is found is $He-H_2$ [7]. Here the constants a and b are negative. The results are reproduced in Fig. 3. The reason for the large disagreement, in our opinion, is due to the large experimental uncertainty. When Eq. (1) is adequate for $DT-He$ and T_2-He [6], we would expect it to be valid for H_2-He too.

In Table 1 we report, in addition to the constants a and b of Eq. (1), p_{opt} and q_{max} as computed from Eqs. (3) and (4) respectively. Both these quantities are very useful to know, and when planing the thermal diffusion separation for a system, we suggest to make a few measurements of q as a function of p to determine both these quantities. This work and the effort of YOUSSEF, HANNA and MIGAHED [9] establish a base for the suggested procedure.

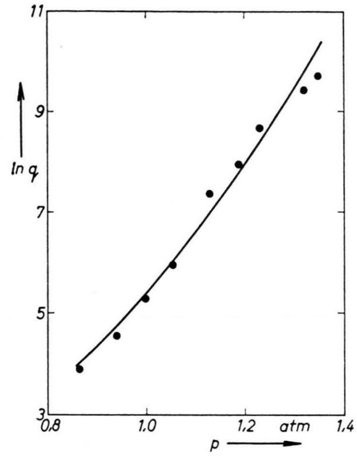

Fig. 3. The legend is the same as for Fig. 1 except that it refers to H_2-He.

[9] A. YOUSSEF, M. M. HANNA, and M. D. MIGAHED, Z. Naturforsch. **20 a**, 655 [1965].