

This article was downloaded by:

On: 25 January 2011

Access details: *Access Details: Free Access*

Publisher *Taylor & Francis*

Informa Ltd Registered in England and Wales Registered Number: 1072954 Registered office: Mortimer House, 37-41 Mortimer Street, London W1T 3JH, UK



## Separation Science and Technology

Publication details, including instructions for authors and subscription information:

<http://www.informaworld.com/smpp/title~content=t713708471>

### Some Observations on Asymmetrical Separation in Thermal Diffusion Columns

M. F. L. Morgado<sup>a</sup>; J. D. R. S. De Pinheiro<sup>b</sup>; T. R. Bott<sup>a</sup>; M. Bourkiza<sup>c</sup>

<sup>a</sup> INSTITUTO SUPERIOR DE ENGENHARIA PORTO, PORTUGAL <sup>b</sup> CENTRO DE QUIMICA PURA E APPLICADA UNIVERSIDADE DO MINHO BRAGA, PORTUGAL <sup>c</sup> CHEMICAL ENGINEERING DEPARTMENT, UNIVERSITY OF BIRMINGHAM, BIRMINGHAM, UNITED KINGDOM

**To cite this Article** Morgado, M. F. L. , De Pinheiro, J. D. R. S. , Bott, T. R. and Bourkiza, M.(1983) 'Some Observations on Asymmetrical Separation in Thermal Diffusion Columns', *Separation Science and Technology*, 18: 4, 387 — 395

**To link to this Article:** DOI: 10.1080/01496398308068572

**URL:** <http://dx.doi.org/10.1080/01496398308068572>

PLEASE SCROLL DOWN FOR ARTICLE

Full terms and conditions of use: <http://www.informaworld.com/terms-and-conditions-of-access.pdf>

This article may be used for research, teaching and private study purposes. Any substantial or systematic reproduction, re-distribution, re-selling, loan or sub-licensing, systematic supply or distribution in any form to anyone is expressly forbidden.

The publisher does not give any warranty express or implied or make any representation that the contents will be complete or accurate or up to date. The accuracy of any instructions, formulae and drug doses should be independently verified with primary sources. The publisher shall not be liable for any loss, actions, claims, proceedings, demand or costs or damages whatsoever or howsoever caused arising directly or indirectly in connection with or arising out of the use of this material.

## NOTE

### Some Observations on Asymmetrical Separation in Thermal Diffusion Columns

---

**M. F. L. MORGADO**

INSTITUTO SUPERIOR DE ENGENHARIA  
PORTO, PORTUGAL

**J. DE D. R. S. PINHEIRO**

CENTRO DE QUIMICA PURA E APPLICADA  
UNIVERSIDADE DO MINHO  
BRAGA, PORTUGAL

**T. R. BOTT and M. BOURKIZA**

CHEMICAL ENGINEERING DEPARTMENT  
UNIVERSITY OF BIRMINGHAM  
BIRMINGHAM B15 2TT, UNITED KINGDOM

#### Abstract

Data have been obtained in steady-state batch operated thermogravitational separation columns using different binary mixtures to test the theory recently published by Morgado et al. The experimental results confirm that separations by thermal diffusion are asymmetrical except when the initial concentration is 0.5 and that the asymmetry is larger as the initial concentration deviates from 0.5 and as the separation potential increases.

#### INTRODUCTION

In a recent paper Morgado et al. (1) developed the theory of Furry et al. (2) for nonsymmetrical separations in thermal diffusion columns. The conclusion from the studies was that all separations are generally asymmetric, and that for particular initial concentrations the asymmetry is larger as the separation potential increases. Only when the initial composition of the binary mixture is 0.5 mol fraction can the separation be regarded as

symmetrical. The majority of experimental data reported often relate to equimolar test mixtures which from the developed theory (1) would give symmetrical separation; this can lead to misinterpretation. No recognition of the possibility of nonsymmetrical separation, for instance, was made in the papers of some workers (3-6).

From the theory of Furry et al. (2) for thermogravitational columns in steady-state batch separation, expressions for concentration distribution of the specified component can be derived:

$$c_{B\infty} = \frac{e^{\lambda c_0} - 1}{e^\lambda - 1} \quad (1)$$

and

$$c_{T\infty} = \frac{1 - e^{-\lambda c_0}}{1 - e^{-\lambda}} \quad (2)$$

If the symmetry of separation is defined as an "asymmetry factor"  $A_f$ ,

$$A_f = \ln \frac{c_{T\infty} - c_0}{c_0 - c_{B\infty}} \quad (3)$$

where  $c_{T\infty}$  refers to the extremity where the specified product accumulates.

By substitution of Eqs. (1) and (2) into Eq. (3):

$$A_f = \ln \frac{(e^\lambda - 1)(e^{-\lambda c_0} - 1 - c_0 e^{-\lambda} + c_0)}{(e^{-\lambda} - 1)(c_0 e^{-\lambda} - c_0 - e^{\lambda c_0} + 1)} \quad (4)$$

A symmetrical separation can be defined if

$$c_{T\infty} - c_0 = c_0 - c_{B\infty} \quad (5)$$

i.e.,  $A_f = 0$ , and the solutions to Eq. (4) are zero when  $\lambda = 0$  and there is no separation, and  $c_0 = 0.5$ .

For each value of the separation potential, the asymmetry of separation increases as the initial concentration is further removed from 0.5. Furthermore for a given initial concentration, the asymmetry is larger as the separation potential increases.

## EXPERIMENTAL

Mixtures with different initial concentrations  $c_0$  were introduced into two experimental thermogravitational columns and the concentrations at the extremities of the columns measured after steady-state separation had been achieved. Steady-state was assumed to have been reached when variations less than 0.5% in the concentration of samples taken from ports located at the top and bottom of the respective columns were observed over a period of 2 h.

The dimensions of the two columns are listed in Table 1. Both columns were cooled on one side with water pumped from a thermostatically controlled tank. Column 1 was heated by water pumped from another thermostatically controlled tank whereas Column 2 was electrically heated.

The binary systems investigated in the experimental equipment are listed in Table 2.

Measurements of the refractive index were used to analyze the composition of the liquid samples by using an accurate Abbe refractometer at 25°C. Calibration curves for each mixture were made by using mixtures of known composition so that sample composition could be directly determined.

The asymmetry factor  $A_f$  was obtained directly from Eq. (3), and the separation potential  $\lambda$  was calculated from

$$\lambda = \ln \frac{c_{T\infty}(1 - c_{B\infty})}{c_{B\infty}(1 - c_{T\infty})} \quad (6)$$

Theoretical values of  $A_f$  were obtained from Eq. (4).

The data obtained are shown in Fig. 1 to 4 which are plots of asymmetry factor  $A_f$  against separation potential  $\lambda$  for different initial compositions of the feed mixture. Although there is considerable scatter in the results, it is possible to determine trends which would be expected from the theory (as defined by the line shown on the curves). The asymmetry is larger as the initial concentration is removed from 0.5 and, furthermore, is larger as the separation potential increases.

TABLE 1

Column no.	Length (m)	Annulus width, $m \times 10^4$
1	0.83	5.00
2	1.27	3.09

TABLE 2

Column no.	Binary mixture	Symbol used in Figs. 1-4
1	<i>n</i> -Heptane, toluene	⊙
	<i>n</i> -Heptane, methylcyclohexane	▽
2	Cyclohexanol, <i>n</i> -hexanol	●
	Benzyl alcohol, <i>n</i> -octanol	△
	Acetophenone, <i>n</i> -nonane	×
	<i>m</i> -Xylene, isooctane	◻
	Ethylbenzene, <i>n</i> -octane	∅
	<i>n</i> -Butanol, 1,1,2,3-tetrachloroethylene	+
	<i>n</i> -Hexanol, benzyl alcohol	●

## SYMBOLS

$A_f$	asymmetry factor
$c_o$	initial concentration
$c_{B\infty}$	concentration in the bottom of the column in steady-state
$c_{T\infty}$	concentration in the top of the column in steady-state
$\lambda$	separation potential

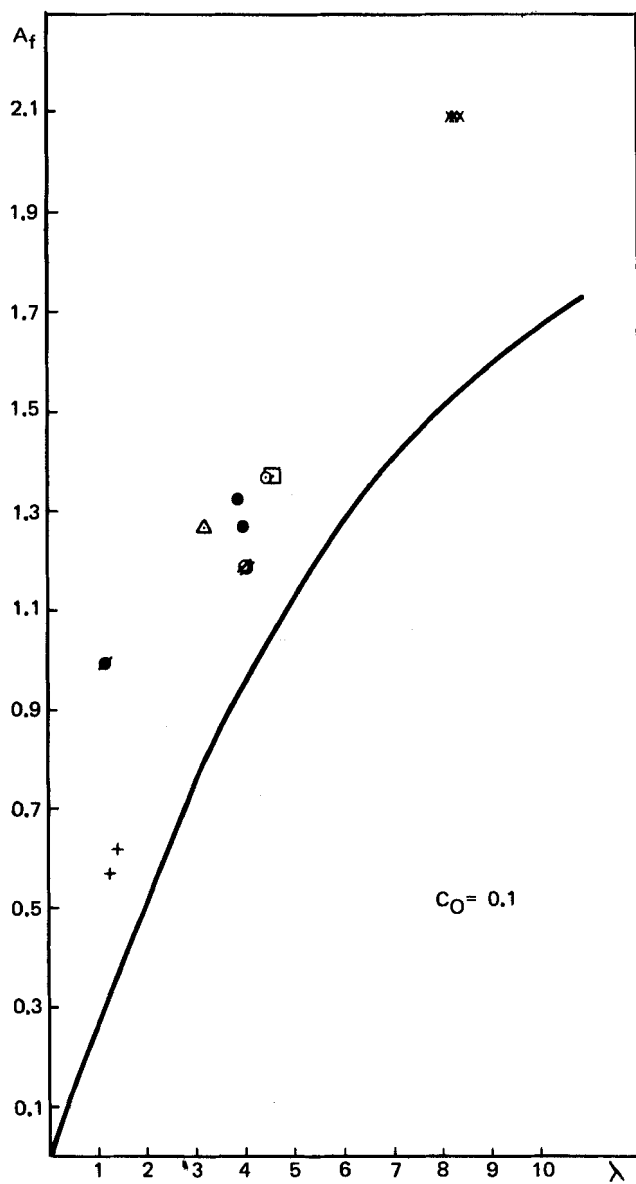


FIG. 1. Asymmetry factor vs separation potential for initial concentration 0.1 mol fraction.

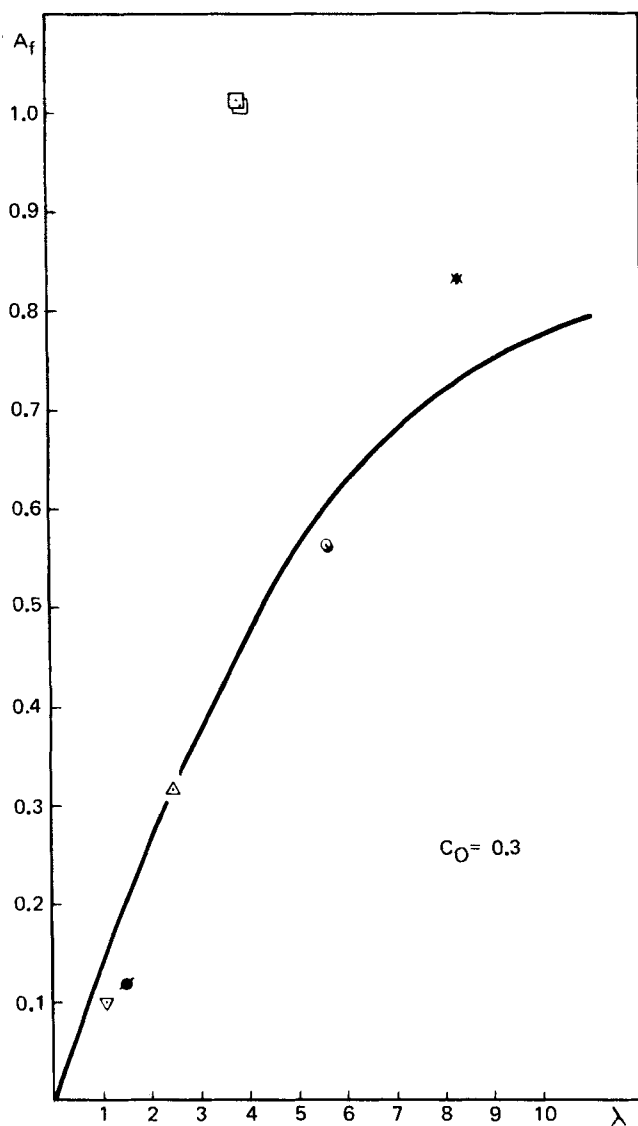


FIG. 2. Asymmetry factor vs separation potential for initial concentration 0.3 mol fraction.

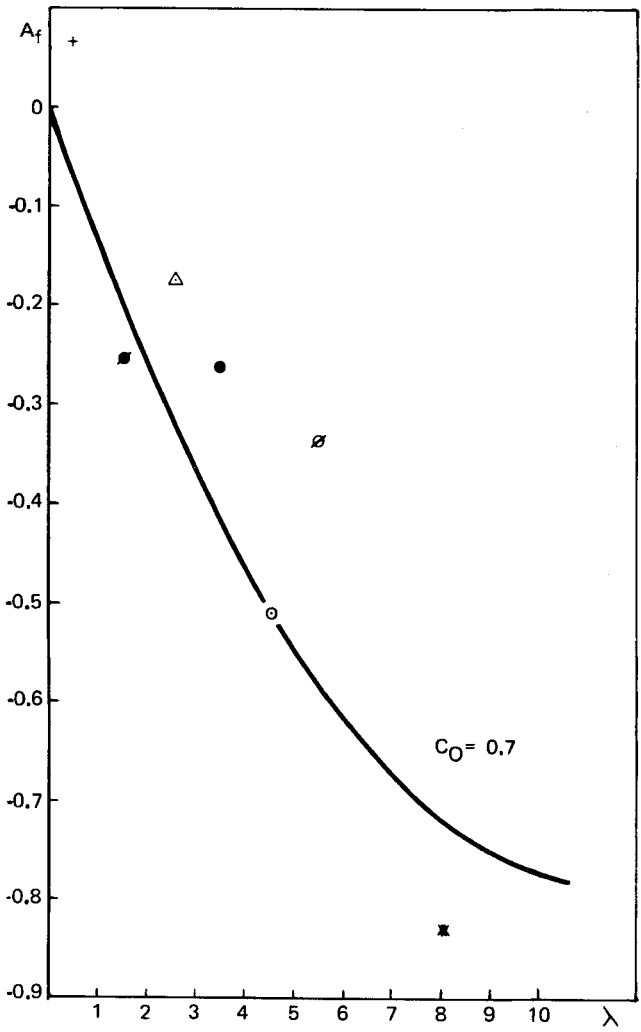


FIG. 3. Asymmetry factor vs separation potential for initial concentration 0.7 mol fraction.



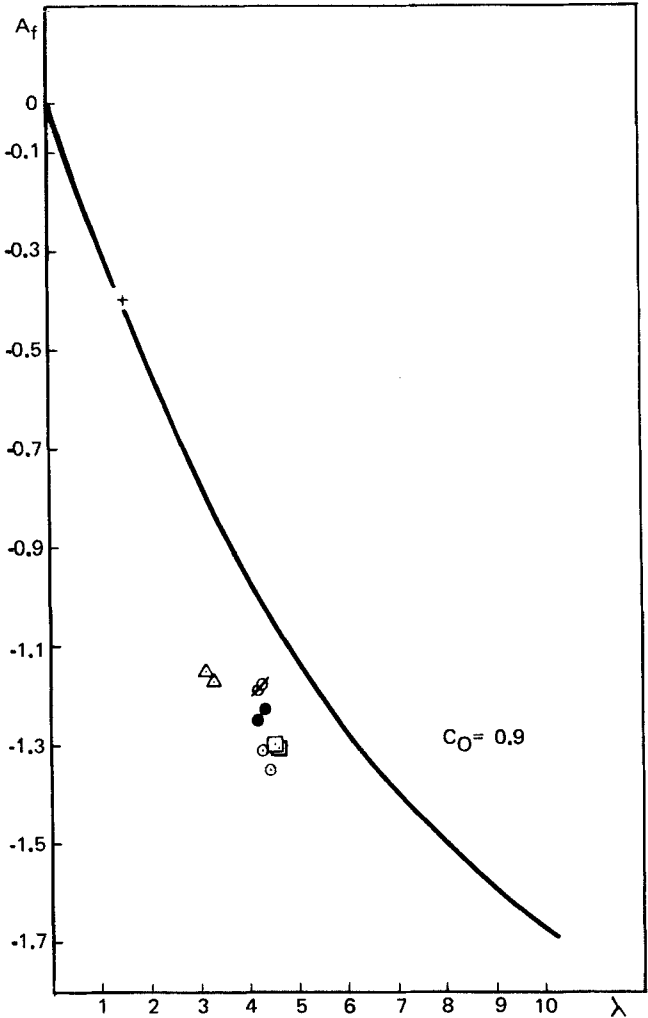


FIG. 4. Asymmetry factor vs separation potential for initial concentration 0.9 mol fraction.

## Acknowledgment

The authors would like to acknowledge, with thanks, the grant awarded by NATO (Scientific Affairs Division) which enabled some of this work to be carried out.

## REFERENCES

1. M. F. Morgado, J. D. R. Pinheiro, J. J. B. Romero, and T. R. Bott, *Sep. Sci. Technol.*, **16**(8), 897 (1981).
2. W. H. Furry, R. C. Jones, and L. Onsager, *Phys. Rev.* **35**, 1083 (1939).
3. F. H. Horne, and R. J. Bearman, *J. Chem. Phys.*, **37**, 2840 (1962).
4. T. C. Ruppel and J. Coull, *Ind. Eng. Chem., Fundam.*, **3**, 368 (1964).
5. D. J. Hoffman, and A. H. Emery, *AIChE J.*, **9**, 653 (1963).
6. Powers, J. E., in *New Chemical Engineering Separation Techniques* (H. M. Schoen, ed.), Wiley-Interscience, New York, 1962.

*Received by editor July 26, 1982*

*Revised November 2, 1982*