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COMPARISON OF EQUILIBRIUM AND IDEAL SEPARATION FACTORS IN DISTILLATION PROCESSES

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The effective, equilibrium, and ideal separation factors in distillation processes (β, β_0, and β_i respectively) are considered in relation to dependences $\beta(\beta_0)$, $\beta_0(\beta_i)$, and $\beta(\beta_i)$. On the examples of substances "base (Cd, Te, S, Zn, Se or As) – impurity", a comparison of β_0 and β_i was made. The conclusion is made about the limited possibility of using the factor β_i instead of β_0 in distillation calculations: $\beta_0 \sim \beta_i$ if β_i differs from unity by no more than one order of magnitude; the divergency β_0/β_i increases with increasing deviation β_i from unity.

INTRODUCTION

As is known, distillation is one of the main methods for obtaining high-purity substances [1–4]. One of the two parameters of the evaporative purification processes of substances is the equilibria separation factor β_0 as the ratio of the impurity concentration in the vapor leaving the evaporation surface to the impurity concentration in the evaporated liquid on the evaporation surface (the other parameter is the Peclet number [5–10]).

Due to the fact that the coefficient β in the real conditions of the process depends not only on the properties of the evaporated substance, but also on the conditions of the process, which cannot be strictly taken into account in theory, the value of β is unknown before experiment. If the main factor of the process is the diffusion of the impurity in the evaporated liquid, then β is related to the equilibrium separation factor β_0 by the Burton-Prim-Slichter (BPS) equation with the parameter $v\delta/D$, where v is the velocity of the evaporation surface, D is the diffusion coefficient of the impurity at the process temperature and δ is the thickness of the diffusion layer in the evaporated material [2–4, 10, 11].

Since the values of β_0 are known for a very limited number of "base–impurity" substances in distillation processes [11], there is a desire to rely in preliminary calculations distillation on such a characteristic of the distilled substance, the values of which can be established, and the ideal separation factor β_i can be considered as such a characteristic. Coefficient $\beta_i = p/p_0$, where p_0 and p are the vapor pressure of pure components (bases and impurities, respectively). (Data on the vapor pressure of pure components can be taken from reference literature, for example [12]). Previously, the relationship between the effective and ideal separation factors (between β and βi) in the processes of distillation and sublimation was considered [13, 14]. It was found that the divergence between β and β_i grows as β_i deviates from unity, and that a moderate divergence β/β_i is observed when β_i differs from unity by no more than two to three orders of magnitude. It was assumed that one of the possible reasons for the divergence between β/β_i is the capture of impurities by the vapor of the main component. The same phenomenon as a possible reason for the decrease in the efficiency of distillation refining was also mentioned earlier [15]. (Taking into account subsequent works [5–9], it can be noted, however, that the results of comparison of β and β_i [14, 15] are not quite correct, since these studies did not take into account the second, in addition to β, parameter of evaporative refining: the Peclet number.) Efforts have been made to calculate β_0 from the characteristics of the components, but these efforts have not yielded results: the experimental values of β_0 differ from the calculated values by an order of magnitude [16, 17].

Meanwhile, when considering the possibility of using the coefficient β_i instead of β_0 to find β using the BPS is the equation, then the question arises of the divergence between the equilibrium and ideal separation factors (i.e., between β_0 and β_i). The aim of the work was to compare the coefficients β_0 and β_i to answer the question of the possibility of using β_i instead of β_0 in distillation calculations.

COMPARISON OF β_0 AND β_i

To compare β_0 and β_i in substances in distillation processes, "base-impurity" substances were chosen, for which the values of β_0 are known [11]. The corresponding values of β_i at temperatures of technological processes of refining the considered substances were calculated using the data about the pressure of pure components from monograph [12]. For comparability, particular attention has been given to substances for which β_0 data are available for at least two impurities on the same basis.

RESULTS AND DISCUSSION

The results of comparing β_0 and β_i for these substances are presented in Table. It can be seen that $\beta_0 \sim \beta_i$ if β_i differs from unity by no more than one order of magnitude and that the divergence β_0/β_i increases as β_i deviates from unity. It can be noted that this observation, in particular, forces us to abandon the previously made assumption about the capture of impurities by the vapor of the main component as the main reason for the discrepancy β/β_i between the effective and ideal separation factors [13–15] – although the reason for the discrepancy β_0/β_i remains unclear. Obviously, $\beta_0(\beta_i)$ has a temperature dependence due to the dependence $\beta_i(T)$ – see for example [18]. Also, the observation made allows to formulate a conclusion

about the applicability of β_i instead of β_0 in distillation calculations.

Comparison of β_0 and β_i for different substances

Substance		β_0 [11]	β_i [12]	β_0 / β_i
Base	Impurity			
Cd	Zn	~0.1	~0.1	~1
	Pb	$\sim 10^{-4}$	$\sim 10^{-7}$	$\sim 10^{3}$
	Sb	$\sim 10^{-4}$	$\sim 10^{-10}$	$\sim 10^{6}$
Te	Pb	~0.1	~0.1	~1
	Cu	$\sim 10^{-4}$	$\sim 10^{-9}$	$\sim 10^{5}$
	Ag	$\sim 10^{-4}$	$\sim 10^{-9}$	$\sim 10^{5}$
S	Se	~0.1	$\sim 10^{-3}$	$\sim 10^{2}$
	As	~0.1	$\sim 10^{-15}$	$\sim 10^{14}$
Zn	Pb	~0.1	$\sim 10^{-5}$	$\sim 10^{4}$
Se	Te	~0.1	$\sim 10^{-6}$	$\sim 10^{5}$
As	Si	$\sim 10^{-6}$	$\sim 10^{-16}$	$\sim 10^{10}$

CONCLUSIONS

Using the examples of "base-impurity" substances with Cd, Te, S, Zn, Se or As as the basis, a comparison was made of the equilibrium and ideal separation coefficients (β_0 and β_i, respectively) in distillation processes. It is noted that the discrepancy β_0/β_i increases when βi deviates from unity. The use of the coefficient β_i instead of β_0 in distillation calculations is possible for substances with values of β_i with a deviation from unity of no more than one order of magnitude when $\beta_0 \sim \beta_i$.

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ПОРІВНЯННЯ РІВНОВАЖНОГО ТА ІДЕАЛЬНОГО КОЕФІЦІЄНТІВ ПОДІЛУ У ПРОЦЕСАХ ДИСТИЛЯЦІЇ

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Розглядаються ефективний, рівноважний та ідеальний коефіцієнти поділу у процесах дистиляції (β, β_0 та β_i відповідно) стосовно залежностей $\beta(\beta_0)$, $\beta_0(\beta_i)$ та $\beta(\beta_i)$. На прикладах речовин "основа (Cd, Te, S, Zn, Se або As) – домішка" виконано порівняння β_0 та β_i. Зроблено висновок про обмежену можливість застосування коефіцієнта β_i замість β_0 у розрахунках дистиляції: $\beta_0 \sim \beta_i$, якщо β_i відрізняється від одиниці не більше ніж на один порядок; розбіжність β_0/β_i збільшується із збільшенням відхилення β_i від одиниці.