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ACCOUNTING THE PECLET DIFFUSION NUMBER IN ECONOMIC ESTIMATE OF THE EFFICIENCY OF EVAPORATION REFINING

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The possibility of assessing the economic efficiency of multiple evaporative refining depending on the yield and frequency of repetitions taking into account the Peclet number is shown.

INTRODUCTION

Distillation and sublimation are the main methods for obtaining high-purity substances, and therefore there is interest in the theory of these refining methods [1-8]. In particular, a methodology for calculating evaporative refining processes was developed, which takes into account two factors: the kinetic separation coefficient β_0 and the Peclet number

$$Pe = v\frac{X}{D},$$

where v is the linear speed of movement of the evaporation surface; D is the diffusion coefficient of the impurity; X is the size factor of the evaporated material (for example, the initial thickness of the liquid layer in the crucible) [4–6].

One of the aspects of the theory of evaporative refining is the assessment of the economic efficiency of the processes being carried out. For such an assessment (following the authors of an earlier work [9]), we considered using the factor

$$\Phi_n = \frac{G}{n\left(\frac{C}{C_0}\right)^n},$$

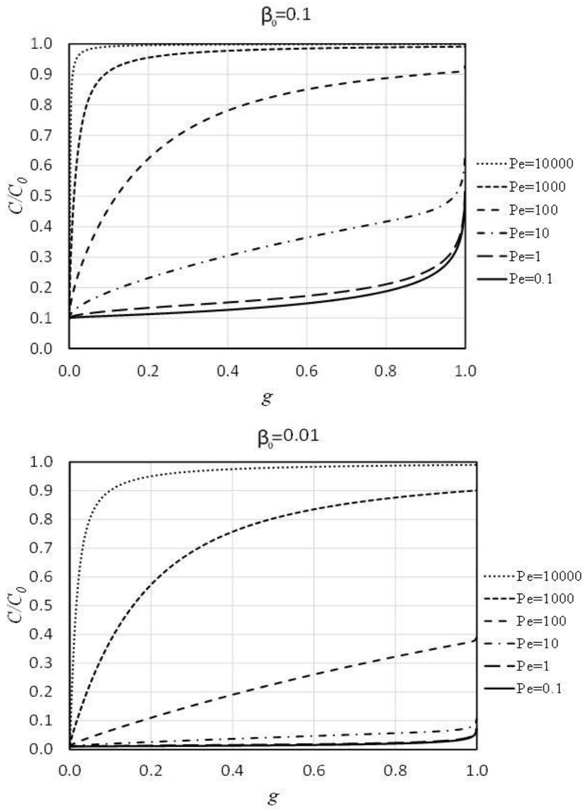
where C is the average impurity concentration in the condensate; C_0 is the initial impurity concentration; n is the repetition rate of the process; G is the final yield of the process [10]. ($G = g^n$, where g is the yield of each unit process). The value of Φ_n increases with increasing purity of the product and its yield and decreases with increasing labor and energy costs associated with an increase in the number of repetitions of the process.

Using examples of processes with multiple repetitions, the patterns of dependence of Φ_n on the final output at small values of Pe ~ 0.1…10 (when simplified calculations are possible) were shown. The main attention was paid to the position of the maximum Φ_n in the indicated dependence.

The advisability of taking into account the Peclet number for a more accurate assessment of the economic efficiency of evaporative refining was noted. This consideration of factor Φ_n in calculations was the goal of this work.

CALCULATIONS

Calculations of the factor Φ_n were carried out using graphs of the dependence of C/C_0 on g, constructed at various values of β_0 and Pe (Figure [4, 7]), with n = 1, 2, and 4 – with the final yield $G = g, g^2$, and g^4 respectively. Graphs were used for β_0 = 0.1 and 0.01 at Pe = 10 and 100.



Dependence of the relative average concentration C/C_0 of the impurity in the condensate on the degree of distillation g in evaporation refining with a flat and constant evaporation surface – at different values of β_0 and Pe (C_0 is the initial impurity concentration) [4, 7]

RESULTS AND DISCUSSION

The results of calculating the dependence $\Phi_n(G)$ for various values of β_0 and Pe are presented in Table 1 (maximum Φ_n are highlighted). The found values G^* of the final yield G, at which the maximum of the criterion Φ_n are achieved, are indicated in Table 2 (in which, for comparison, the calculated values of the criterion Φ_n at an economically feasible value of G of about 80%) are also given.

Knowledge of the dependence of Φ_n on G, β_0, Pe, and n allows optimizing the evaporative refining process, taking into account the economics of the process.

Table 1

Dependence $\Phi_n(G)$ at various β_0, *Pe*, and *n* ($G = g^n$, $\Phi_n = G/[n(C/C_0)^n]$)

β_0	*Pe*	$G = g^n$ at various *n*			$(C/C_0)^n$ at various *n*			Φ_n at various *n*		
		g	g^2	g^4	1	2	4	1	2	4
0.1	10	0	0	0	0.1	0.01	0.0001	0	0	0
		0.4	0.16	0.03	0.30	0.09	0.008	1.3	0.9	0.8
		0.8	0.64	0.41	0.41	0.17	0.03	**2.0**	1.9	3.7
		0.9	0.81	0.66	0.45	0.20	0.04	**2.0**	**2.0**	**4.0**
		0.95	0.90	0.81	0.48	0.23	0.05	**2.0**	**2.0**	3.8
		0.99	0.98	0.96	0.55	0.30	0.09	1.8	1.6	2.7
		1	1	1	1	1	1	1	0.5	0.25
	100	0	0	0	0.1	0.01	0.0001	0	0	0
		0.4	0.16	0.03	0.79	0.62	0.39	0.5	0.13	0.02
		0.8	0.64	0.41	0.84	0.71	0.50	0.7	0.25	0.07
		0.9	0.81	0.66	0.89	0.79	0.63	0.9	0.40	0.16
		0.95	0.90	0.81	0.90	0.81	0.66	1.0	0.50	0.25
		0.99	0.98	0.96	0.91	0.83	0.69	1.0	0.54	0.30
		1	1	1	1	1	1	1	0.5	0.25
	1000	0	0	0	0.1	0.01	0.0001	0	0	0
		0.4	0.16	0.03	0.98	0.96	0.92	0.41	0.08	0.01
		0.8	0.64	0.41	0.99	0.98	0.96	0.61	0.18	0.03
		0.9	0.81	0.66	0.99	0.98	0.96	0.81	0.33	0.11
		0.95	0.90	0.81	0.99	0.98	0.96	0.91	0.41	0.17
		0.99	0.98	0.96	0.99	0.98	0.96	0.96	0.42	**0.52**
		1	1	1	1	1	1	1	0.5	0.25
0.01	10	0	0	0	0.01	0.0001	≈ 0	0	0	0
		0.4	0.16	0.03	0.03	0.0009	$8\cdot10^{-7}$	**13**	**89**	**$8\cdot10^3$**
		0.8	0.64	0.41	0.065	0.004	$1.6\cdot10^{-5}$	12	76	$6\cdot10^3$
		0.9	0.81	0.66	0.07	0.005	$2.4\cdot10^{-5}$	12	**81**	**$7\cdot10^3$**
		0.95	0.90	0.81	0.08	0.006	$4.1\cdot10^{-5}$	12	70	$5\cdot10^3$
		0.99	0.98	0.96	0.09	0.008	$6.6\cdot10^{-5}$	11	60	$4\cdot10^3$
		1	1	1	1	1	1	1	0.5	0.25
	100	0	0	0	0.01	0.0001	≈ 0	0	0	0
		0.4	0.16	0.03	0.19	0.036	0.001	2.1	0.4	5.0
		0.8	0.64	0.41	0.32	0.102	0.010	2.5	3.2	10.3
		0.9	0.81	0.66	0.35	0.123	0.015	**2.6**	3.3	10.9
		0.95	0.90	0.81	0.36	0.130	0.017	**2.6**	**3.5**	**11.9**
		0.99	0.98	0.96	0.38	0.144	0.021	**2.6**	3.4	11.4
		1	1	1	1	1	1	1	0.5	0.25
	1000	0	0	0	0.01	0.0001	≈ 0	0	0	0
		0.4	0.16	0.03	0.75	0.56	0.32	0.53	0.14	0.02
		0.8	0.64	0.41	0.88	0.77	0.60	0.91	0.42	0.17
		0.9	0.81	0.66	0.89	0.79	0.63	1.01	0.51	0.26
		0.95	0.90	0.81	0.90	0.81	0.66	1.06	**0.59**	0.31
		0.99	0.98	0.96	0.91	0.83	0.69	**1.43**	**0.59**	**0.35**
		1	1	1	1	1	1	1	0.5	0.25

Table 2

G^* (at which maximum Φ_n are reached) at various β_0, *Pe* and *n* (and Φ_n at $G \approx 0.8$)

Pe	*n*	G^* at various β_0		Φ_n at $G \approx 0.8$, at various β_0	
		$\beta_0 = 0.1$	$\beta_0 = 0.01$	$\beta_0 = 0.1$	$\beta_0 = 0.01$
10	1	0.9	0.4	2.0	12
	2	0.8	0.8	2.0	70
	4	0.7	0.7	3.8	$\sim10^3$
100	1	0.99	0.95	0.9	2.5
	2	0.98	0.90	0.5	3.3
	4	0.96	0.81	0.25	11.9
1000	1	0.99	0.99	0.8	0.9
	2	0.98	0.98	0.4	0.5
	4	0.8	0.96	0.5	0.3

CONCLUSIONS

The possibility of assessing the economic efficiency of multiple evaporative refining depending on the yield and frequency of repetitions, taking into account the diffusion of impurities, is shown. A calculation technique is used that takes into account the kinetic separation coefficient and the Peclet number.

REFERENCES

1. C.J. King. *Separation processes* / Second edition. N.Y.: "Dover Publication", 2013.

2. G.G. Devyatykh, Yu.E. Yelliev. *Glubokaya ochistka veshchestv* M.: "Vysshaya Shkola", 1990 (in Russian).

3. Yu.I. Dytnerskii. *Protsessy i apparaty khemi-cheskoi tekhnologii:* Uchebnik dlya vuzov. M.: "Himiya", 1995 (in Russian).

4. A.I. Zhukov, A.I. Kravchenko. Calculation of sublimation with taking into account of diffusion of impurity // *Inorganic materials.* 2017, v. 53, N 6, p. 648-653; DOI: 10.1134/S0020168517060164

5. A.I. Kravchenko, A.I. Zhukov. Temperature dependence of the Peclet diffusion number in the processes of sublimation of some simple substances // *Inorganic materials.* 2021, v. 57, N 7, p. 753-759; DOI: 10.1134/S0020168521070104

6. A.I. Kravchenko, A.I. Zhukov, O.A. Datsenko. Temperature dependences of the Peclet number in sublimation processes of simple substances *// Problems of Atomic Science and Technology*. 2022, N 1, p. 13-16; https://doi.org/10.46813/2022-137-13

7. A.I. Zhukov, A.I. Kravchenko. Calculation of distribution of impurities in solidified condensate into account of Peclet number // *Problems of Atomic Science and Technology.* 2024, N 1, p. 25-28; https://doi.org/10.46813/2024-149-025

8. A.I. Kravchenko. On theory of evaporation refining *// Problems of Atomic Science and Technology*. 2024, N 1, p. 33-34; https://doi.org/10.46813/2024-149-033

9. A.Ye. Vol'pyan, G.N. Kurdyumov, V.A. Molochko. Optimization of process of multiple directional crystallization // *Teoreticheskiye osnovy khimicheskoy tekhnologii.* 1971, v. 5, N 4, p. 602-604 (in Russian).

10. A.I. Kravchenko, O.A. Datsenko. Efficiency of multiple distillation or crystallization refining: economic aspect // *Present release,* p. 29-31.

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ВРАХУВАННЯ ЧИСЛА ПЕКЛЕ В ЕКОНОМІЧНІЙ ОЦІНКИ ЕФЕКТИВНОСТІ ВИПАРНОГО РАФІНУВАННЯ

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Показано можливість оцінки економічної ефективності багаторазового випарного рафінування залежно від виходу та кратності повторень з урахуванням числа Пекле.