

ZONE DISTILLATION: JUSTIFICATION

A.I. Kravchenko

*National Science Center "Kharkov Institute of Physics and Technology",
Kharkov, Ukraine*

E-mail: alex@krawa.net

The features of zone distillation (with zone melting of refined material and with pulling of condensate) as a new purification method are shown. The method is based on similarity of equations of distillation and crystallization refining. The analogy between some distillation and condensation methods (particularly between zone distillation and zone re-crystallization) is should up.

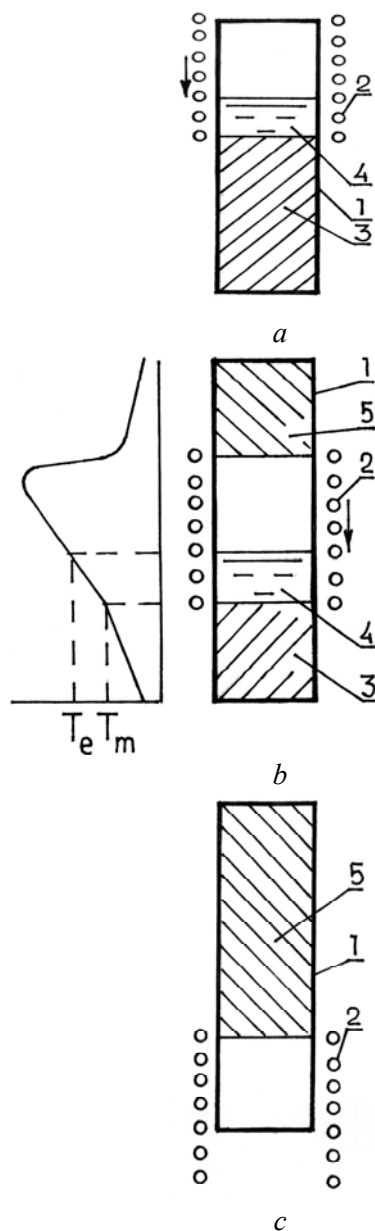
As it is known distillation and crystallization in variant modifications are basic purification methods. The efficiency of using of either the first or the second method for refining of specific system depends on values of interphase distribution coefficients (on distribution efficient k at crystallisation or separation factor α at distillation) and on depending on product yield [1-4].

Crystallisation methods (normal direct crystallisation and zone re-crystallisation) are based on that irregular distribution of impurities along the crystal appears in grown extended crystal. Then the most pure part of crystal may be extracted as product. For these methods the equations of impurity distribution in crystal for different growth conditions are deduced [1, 2, 5-7]. Zone re-crystallisation supports more efficiency of purification at multiple iteration of process.

Recently it was determined that distillation (with condensation in solid phase and pull of condensate) may be used as well for obtaining of material with long form and with irregular impurity distribution [8]. The equations of impurity distribution in pulled condensate is deduced and it is ascertained that distillation and crystallization refining are described by similar equations – at corresponding substitution of k for crystallization or $\beta=1/\alpha$ (as relation of concentration of impurity in vapor to concentration of impurity in liquid) for distillation [4, 9].

In development of distillation method it was proposed to carry out of distillation in regime of zone distillation: with partial melting of refined matter [10]. The aim of this article is consideration of features of zone distillation.

Zone distillation is a distillation process in long container with partial melting of refined matter in moving liquid zone and condensation of vapor in the solid phase at condensate pulling in cold area (Figure). When zone heater is moving from the top to the bottom of the container then solid condensate with irregular impurity distribution is forming. Then most pure part of the condensate may be extracted as product. The process may be iterated many times by moving (without turnover) the received condensate to the bottom part of the container on the place of refined matter. The irregular impurity distribution in the condensate (that is efficiency of purification) increases with number of repetitions of the process.



The scheme of distillation in a start of process (a), in process (b) and in finish of process (c) scheme of temperature distribution on container height: 1 – container; 2 – zone heater; 3 – refined matter; 4 – liquid zone in purified matter; 5 – condensate. (Pointer shows the direction of moving of heater container relative container; T_m – melting temperature, T_e – evaporation temperature)

Zone distillation is a distillation analog of zone recrystallization (Tabl. 1). Impurity distribution in the condensate is described by known equations of zone recrystallization with various numbers of iteration of process – with replacement distribution efficient k of crystallization on separation factor β of distillation. For example the equation of zone distillation for one zone passage is:

$$\frac{C}{C_0} = 1 - (1 - \beta) \exp(-\beta \frac{x}{\lambda}),$$

where C is the concentration of impurity at distance x from start of condensate, C_0 is initial concentration of impurity, λ is a length of liquid zone.

Table 1
Analogues of distillation and crystallization refining methods

Distillation	Crystallization
Simple distillation (with condensation in liquid)	–
Distillation with direct solidification of condensate [8]	Normal direct crystallization
Zone distillation [10]	Zone recrystallization
Rectification	Countercurrent crystallization [1]

In stabilized regime the velocity v of liquid zone moving is linked with vaporization velocity w and density ρ of basic component by correlation: $v=w/\rho$ (Tabl. 2).

Table 2
Calculation values of velocity v of liquid zone moving for some refined matters at melting temperature

Matter	v , mm/h
Mg	54.8
Zn	1.4
Cd	1.0

For realization of multiple zone distillation without reboot between steps the device with circular turning container is designed [11].

Thus zone distillation must examine as a perspective method of refining of line of matters.

The author thanks prof. I.I. Papirov for support in work.

REFERENCES

1. G.G. Devyatykh and Yu.E. Elliev. *Vvedenie v teoriyu glubokoi ochistki veshchestv (Introduction to the Theory of Fine Purification of Substances)*. Moscow: "Nauka", 1981 (in Russian).
2. A.I. Belyayev. *Fiziko-khimicheskie osnovy metallov i poluprovodnikovoykh materialov (Physical and chemical foundation of purification of metals and semiconductors)*. Moscow: "Metallurgiya", 1973 (in Russian).
3. L.A. Nisel'son, A.G. Yaroshevskii. *Mezhfazovye koeffitsyenty raspredeleniya (Interphase Distribution Coefficients)*. Moscow: "Nauka", 1992 (in Russian).
4. A.I. Kravchenko. Purification efficiency of distillation and crystallization processes // *Inorganic Materials*. 2010, v. 46, №1, p. 93-95.
5. W.G. Pfan. *Zone melting* (J. Willey and Sons, inc.; New York, London, Sydney, 1966).
6. R.A. Laudise. *The growth of single crystals*. (Prentice-hall, inc. Englewood Cliffs, New Jersey, 1970).
7. A.Ya. Nashel'skii, V.I. Mevius. Calculation of impurity distribution along crystals grown by the methods of directed crystallization // *Vysocochistyye veshchestva*. 1994, №1, p. 5-21 (in Russian).
8. A.I. Kravchenko. Distillation with pulling of distillate: a new method of purification of matters // *Problems of Atomic Science and Technology. Series "Vacuum, pure materials, superconductors" (17)*. 2008, №1, p. 18-19.
9. A.I. Kravchenko. Equation of impurity distribution in a solidified distillates // *Inorganic Materials*. 2007, v. 43, №8, p. 916-917.
10. Pat. of Ukraine N. 47601 (C22B9/00). *The method of distillation refining* / A.I. Kravchenko. Bull. №3, 2010.
11. Pat. of Ukraine N. 48267 (C22B9/00). *The device for zone distillation* / A.I. Kravchenko. Bull. №5, 2013.

Статья поступила в редакцию 31.10.2013 г.

ЗОННАЯ ДИСТИЛЛЯЦИЯ: ОБОСНОВАНИЕ

А.И. Кравченко

Рассмотрены особенности зонной дистилляции (с зонной плавкой рафинируемого вещества и вытягиванием конденсата) как нового метода рафинирования. Метод основан на подобию уравнений дистилляционного и кристаллизационного рафинирования. Выявлена аналогия между отдельными дистилляционными и кристаллизационными методами рафинирования, в частности, между зонной дистилляцией и зонной перекристаллизацией.

ЗОННА ДИСТИЛЛЯЦІЯ: ОБҐРУНТУВАННЯ

О.І. Кравченко

Розглянуто особливості зонної дистилляції (з зонною плавкою речовини, яка рафінується, і витягуванням конденсату) як нового методу рафінювання. Метод базується на подібності рівнянь дистилляційного і кристалізаційного рафінювання. Виявлена аналогія між окремими дистилляційними і кристалізаційними методами рафінювання, зокрема, між зонною дистилляцією і зонною перекристалізацією.