UDC 53.09

ABLATION SELECTIVITY OF SALTS IN EVAPORATORS OF THE CHEMICAL INDUSTRY

A.V. Bazanov[*], V. N. Blinichev[**]

*Solution Chemistry Institute of Russian Academy of Science, Ivanovo, Russia, bazanov@hotbox.ru

**Ivanovo state university of chemistry and technology, Ivanovo, Russia

In the given work the mechanism of selective ablation of solute from evaporated solutions is observed by secondary steams of evaporator systems at various physical and chemical characteristics of the carried out process of distillation. Research of the major factors influencing purity of gained distillate has been carried out.

Keywords: selective ablation, distillation, secondary steam, concentration of ions, condensate.

For thermal water-freshening of salty waters and reception of high-grade distillate in various industries (chemical, food, metallurgical, etc.) evaporation processes are widely applied. Quality of gained distillate, is defined, among other factors, by magnitude of pollution of distillate at the expense of ablation of solute from the evaporated solution, interfering use of distillate for reception of highly pure solutions.

Principal views of ablation of solute depending on installation type can be presented as follows:

a) Spray-drop ablation;

b) Scumming and ablation by steam of its part, or products of its destruction into the evaporator system volume of steam;

c) Molecular ablation of chemical compounds owing to transpiration and their solubility in water vapour.

At high solution strengths and a high water surface duty ablation of salts with steam occurs mainly on two first mechanisms.

It is noted by many researchers [1, 2], that all aspects of ablation are selective, however at the estimation of the practical significance of this selectivity opinions differ. In the domestic and foreign literature there are no systematised data experimentally proving selectivity of ablation of salts in distillatory kettles of chemical industry.

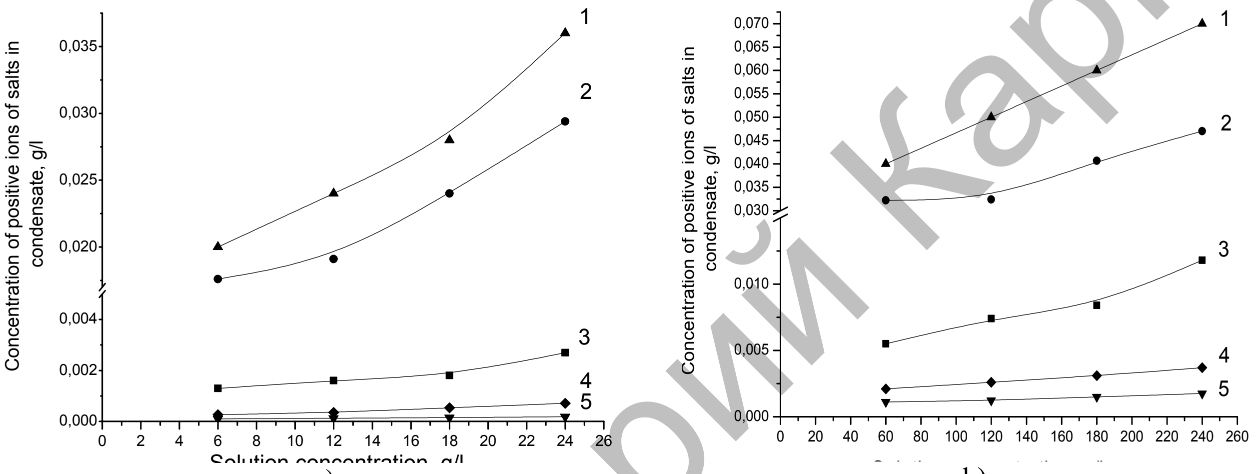
Selectivity of ablation of solute from an evaporated solution depends on characteristics of ions and molecules of dissolvent, concentration of solute, temperatures of the proceeding process, etc. Their basic part is connected with properties (nature) of the dissolved combination. On this basis the purpose and the research problem was the analysis of the influence of the basic physical and chemical nature of the solution on ablation of solute with steam.

For research of ablation of solutes at transpiration and evaporation the laboratory-scale plant representing a distillatory kettle with a separator has been designed and made. The evaporator system case, the capacitor, the hotwell, the separator are made of glass that expelled probability of hit of additional ions, for example, products of corrosion of equipment. The temperature in the zone of boiling and in the thermostat was controlled by thermometers with accuracy ±0,5°C.

Subjects of inquiry were evaporated solutions of salts NaCl, KCl, BaCl2, MgCl2, CaCl2, Na2SO4, MgSO4, CuSO4, ZnSO4. The given salts have been chosen for the following reasons: they do not decompose at heating; possess good solubility in water; cation-anion composition of salts allows to analyse the influence of both positive, and a negative ion on ablation of solute from an evaporated solution; the given combinations are widely applied in chemical and technological processes. All work was conducted with solutions of salts of a brand «chemically pure». In the capacity of dissolvent distilled water was used.

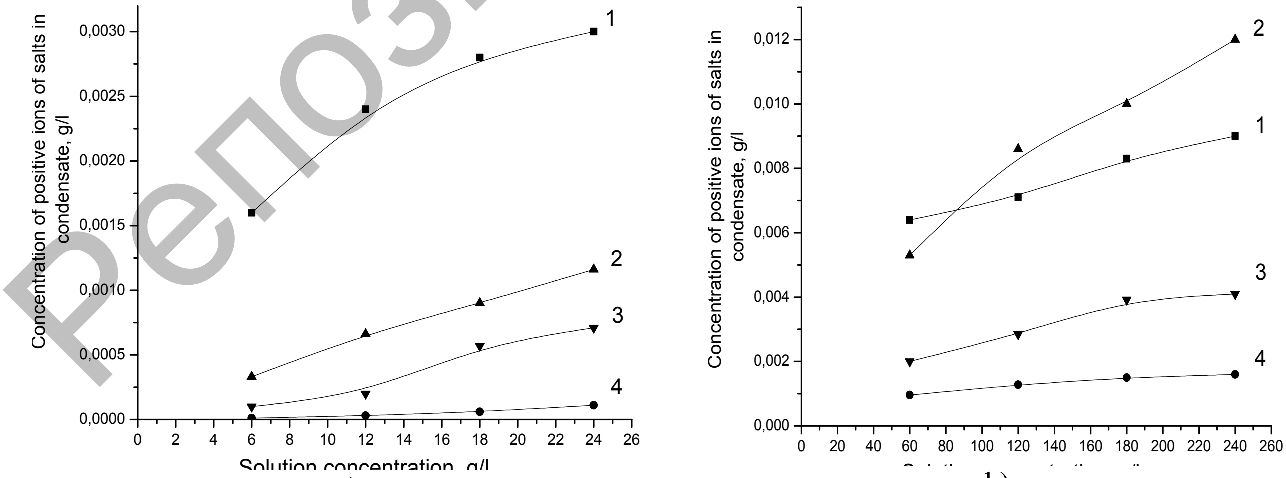
The salt solution of various initial concentration was located in the evaporator system volume then there was a process of evaporation and the condensate was collected. Researches were carried out both at evaporation of solutions at which drop ablation had been expelled, and in regimes of stable and unstable boiling. The gained condensate was analysed by means of absorption spectroscopy (spectrophotometer "SATURN") for definition of concentration of positive ions of salts (basic ions) in the condensate, the relative standard deviation made ±2 %. The titrimetry method was used for definition of concentration of negative ions of salts (anions) in condensate, the relative standard deviation being ±8 %.

For definition of dependence of ablation of solute from evaporated solutions from their initial concentration in the transpiration regime (the temperature – 98°C) a number of experiments has been carried out. Results are presented on fig. 1 – 2.



a) b)

Fig. 1 Dependence of concentration of positive ions (1 Ba2 + (BaCl2); 2 K + (KCl); 3 Na + (NaCl); 4 Ca2 + (CaCl2); 5 Mg2 + (MgCl2)) in the condensate from the initial solution concentration at transpiration (t =98°C). a) in the range of concentrations 6-24 g/l; b) in the range of concentrations 60-240 g/l



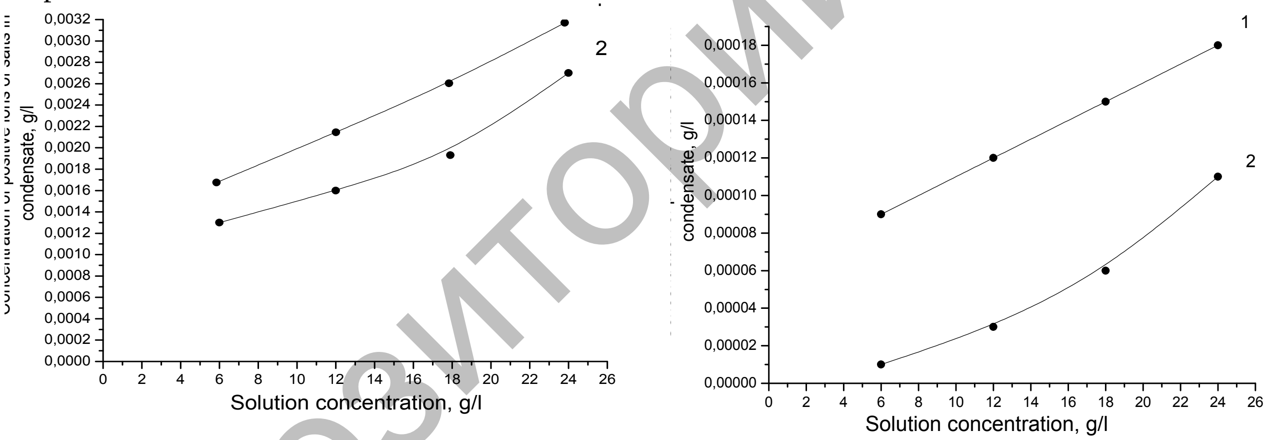
a) b)

Fig. 2 Dependence of concentration of positive ions (1 Na^+ (Na_2SO_4); 2 Cu^{2+} ($CuSO_4$); 3 Zn^{2+} ($ZnSO_4$); 4 Mg^{2+} ($MgSO_4$)) in the condensate from the initial solution concentration at transpiration (*t* =98°C). a) in the range of concentrations 6-24 g/l; b) in the range of concentrations 60-240 g/l

Results of experimental researches (fig. 1, fig. 2), show that at increase in the solution concentration from 6 to 240 g/l, concentration of solute in a condensate essentially increases. So, at initial concentration 6 г/л concentration Na+ in the condensate made 0,001 g/l, and at the initial solution concentration 240 g/l – 0,011 g/l.

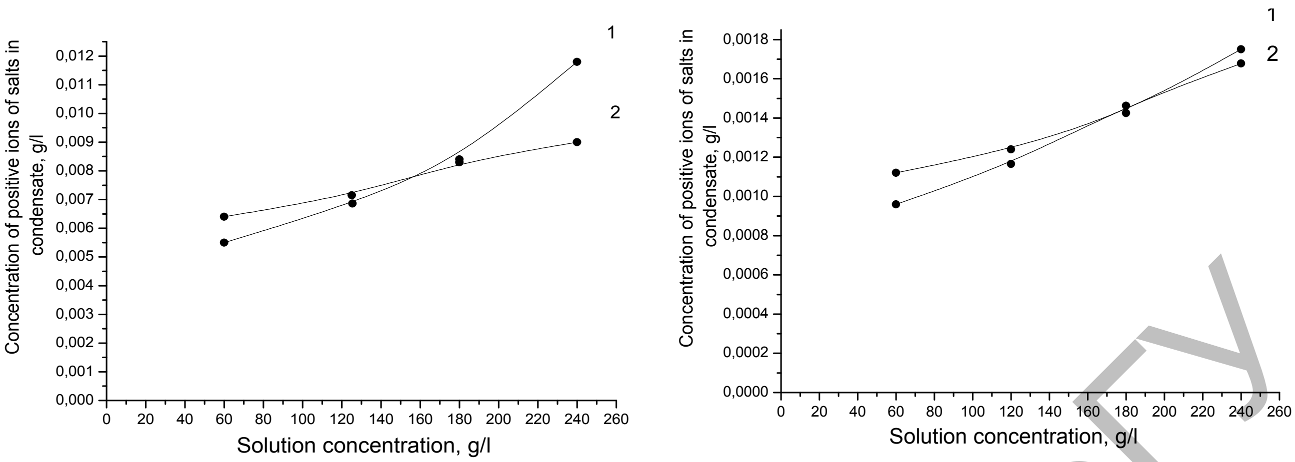
From the experimental data presented on fig. 1, it follows, that the positive ion nature makes exclusively big impact on concentration of ions in the condensate. Comparing concentration of positive ions in the condensate at evaporation of solutions NaCl and KCl (initial concentration – 120 g/l), it is possible to note, that the concentration of ion K + is 4 times as much as the concentration of ion Na +. The concentration in the condensate of ion Ba2 + (at evaporation of solution BaCl2) is dozens of times as much as the concentration of ion Ca2 + (CaCl2) and Mg2 + (MgCl2) in the whole range of initial solution concentration changes. Especially low ablation (fig. 1, fig. 2) is observed for ions Mg2 + (MgCl2, MgSO4). For example, concentration of ions Ba2 + (at evaporation of solution BaCl2) in the condensate at the initial concentration of the evaporated solution 60 g/l made 0,04 g/l, and for ions Mg2 + (MgCl2) at the same initial solution concentration – 0,001 g/l, i.e. it is almost in 35 times less. With the growth of the initial concentration of evaporated solutions the difference in the concentration of the above-mentioned ions in the condensate becomes even more. Molecular ablation of salts at transpiration wears obviously selective character. At constant saltcontaining of the evaporated solution various salts pass into steam in quantities, far from proportional to their saltcontaining in the solution.

On fig. 3 – 4 influence of the nature of the negative ion of evaporated solutions of salts on solute ablation by secondary steam on an example of chloride and sodium and magnesium sulphates is presented.



a) b)

Fig. 3 Influences of the nature of a negative ion on solute ablation by secondary steam at initial concentration of an evaporated solution 6–24 g/l (t =98°C). 1 Na + (Na2SO4); 2 Na + (NaCl); 1 Mg2 + (MgCl2); 2 Mg2 + (MgSO4)



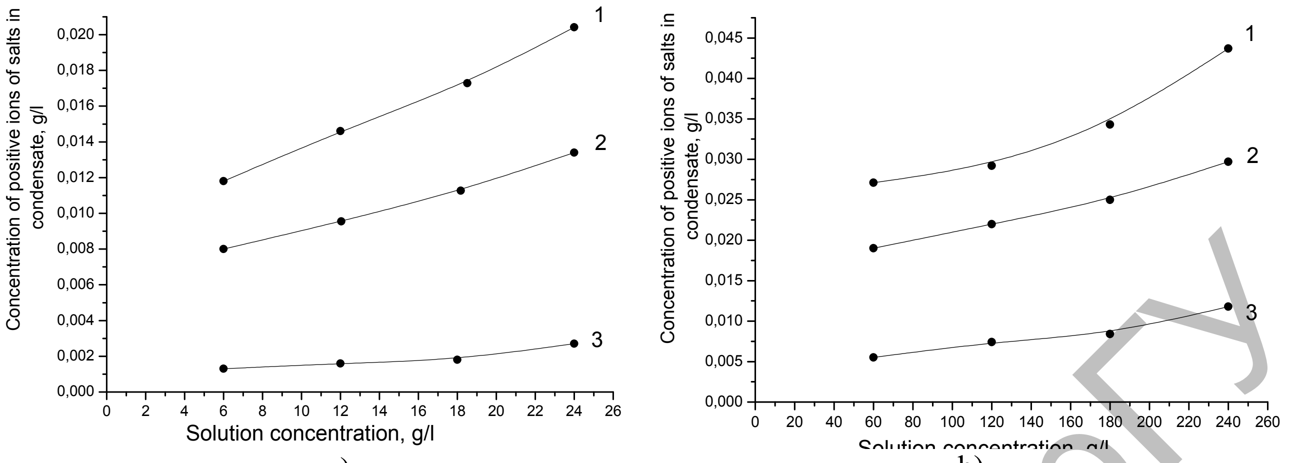
a) b)

Fig. 4 Influences of the nature of the negative ion on solute ablation by secondary steam at the initial concentration of an evaporated solution 60–240 g/l (t =98°C). 1 Na + (NaCl); 2 Na + (Na2SO4); 1 Mg2 + (MgCl2); 2 Mg2 + (MgSO4)

From fig. 3 it is visually evident, that in the field of the initial concentration of evaporated solutions from 6 to 24 g/l the difference in the concentration of the solute in the condensate is defined by both the positive ion nature, and the negative ion. For example, at the initial solution concentration 18 g/l concentration of positive ions in the condensate makes for Na + (at evaporation of solution NaCl) – 0,0018 g/l, (Na2SO4) – 0,0028 g/l, Mg2 + (MgCl2) – 0,00015 g/l, (MgSO4) – 0,00006 g/l, i.e. the difference between concentration of Na + at evaporation of solutions NaCl and Na2SO4 makes 1,5 times, and a difference between concentration of Mg2 + at evaporation of solutions of MgCl2 and MgSO4 2,5 times.

The analysis of the gained experimental results in the field of the initial solution concentration ≥60 g/l (fig. 4) shows, that solute ablation practically does not depend on the nature of the negative ion, and depends only on the nature of the solute positive ion. From fig. 4 it is evident, that concentration of positive ions in the condensate is close for salts with equal positive ions, but different for negative ions, for example NaCl and Na2SO4, MgCl2 and MgSO4. At the initial concentration of an evaporated solution 180 g/l concentration of positive ions makes for Na + (NaCl) – 0,0084 g/l, (Na2SO4) – 0,0083 g/l, Mg2 + (MgCl2) – 0,0015 g/l, (MgSO4) – 0,0015 g/l, i.e. the difference between concentration of positive ions in a condensate for chloride and sulphates of sodium and magnesium in the field of high initial solution concentration is insignificant.

Influence of temperature of transpiration and solution boiling (98 – 103°C) on ablation of solute from evaporated solutions on the example of NaCl and Na2SO4 solutions was also investigated. Dependences of ablation of solute on temperature and initial concentration for NaCl solution are presented on fig. 5.



a) b)

Fig. 5 Dependence of concentration of ions Na + in a condensate from temperature: 1 103°C; 2 101°C; 3 98°C. a) in the range of concentrations 6-24 g/l; b) in the range of concentrations 60-240 g/l

The analysis of the gained experimental material has shown, that ablation by secondary steam increased with the growth of temperatures (fig. 5). The increase of temperature from 98°C to 101°C has shown, that by its nature gas-liquid flow in a boundary unstable zone of boiling is not stable. Owing to it the size of the bubbles formed on a heating surface cannot be stable. The first regime of unstable barbotage is characterized by the whole spectrum of sizes that leads to big lapses at estimated indications of ablation of solute from the evaporated solution by secondary steam at the expense of local intensive emissions of drops in the unstable zone of boiling. At the further growth of temperature, and, hence, the water surface duty, it has been noticed, that elevating traffic of bubbles at intensive boiling causes acceleration of corpuscles of the liquid barbotaged by bubbles, and, finally, participation of a part of the liquid in elevating traffic together with the bubbles. The stream characterized by presence of chains of bubbles (fig. 5, temperature 103ºC), is the most resistant since it is answered by self-controlled, and therefore, the most resistant to distribution of phases, it being the condition of stable barbotage.

At unstable and resistant to boiling regimes the major factor of ablation of solute steam is drop ablation. From the data presented on fig. 5, it is evidently visible, that even in the presence of the installation of the separating device solute ablation in the regime of unstable boiling (101°C) has more increased in comparison with transpiration approximately 6 times as much, and in the regime of resistant boiling (103ºC) up to 8 ÷ 10 times.

Conclusions

1) The gained quantitative values of ablation of solute by the secondary steam from evaporated solutions NaCl, KCl, BaCl2, MgCl2, CaCl2, Na2SO4, MgSO4, CuSO4, ZnSO4 (in the range of the initial concentrations from 6 to 240 g/l) have shown, that even in the transpiration regime (t =98°C) the concentration of ions in the condensate has essentially increased.

2) It is established, that the solute nature makes huge impact on solubility of substances in the steam. In the field of initial concentrations from 6 to 24 g/l the difference in the solubility of substances in the secondary steam is defined by the nature of both positive and negative ions. At the initial concentrations of solutions (≥60 g/l) solubility of substances in the steam does not depend on the nature of the negative ion, and depends only on the nature of the solute positive ion.

3) The analysis of experimental data has shown, that the size of steam nanoparticles coming off the transpiration surface depends on the solute nature.

4) It is shown, that transition from the transpiration regime to regimes of unstable and resistant boiling of the solution leads to sharp increase in ablation of solute from evaporated solutions by the

secondary steams. At regimes of unstable and resistant boiling the major factor of ablation of solute with steam is drop ablation.

References:

18. Katkovskaya K. Y., Dubrovsky I.J. Investigation of solubility of inorganic compounds in water heat-transfer agent of the supercritical parametres. – M, MPI, 1973. - 160 p.
19. Styrikovich M. A, Martynova O. I, Miropolsky Z.L. Processes of steam generation on power stations. - M, Energy, 1969. - 312 p.