N E W S
OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN
SERIES CHEMISTRY AND TECHNOLOGY
ISSN 2224-5286 **https://doi.org/10.32014/2019.2518-1491.6**
Volume 1, Number 433 (2019), 39 – 46

UDC 378(075.8): 544

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STUDYING THE PROCESS OF OBTAINING PHOSPHATES OF METALS BASED ON THE PHASE EQUILIBRIA OF FOUR COMPONENT SYSTEMS

Abstract. In this article the literature data on phase equilibria in four-component reciprocal systems are given and the solubility in the mutual quaternary systems $FeCl_2$-H_3PO_4-H_2O was determined in the range of concentrations of phosphoric acid from 5 to 55% H_3PO_4 at temperatures of 25, 60 and 80°C.

The calculated data on the construction of the crystallization fields of salts in the studied system, taking into account the possible formation of one- and two-substituted iron phosphates, are given. The optimum consumption of phosphoric acid solution to obtain the desired product is defined. The maximum possible yield of the finished product in these conditions of the process from a unit mass of ferric chloride is also established.

The consumption of phosphoric acid was determined according to the diagram according to the lever rule as the ratio of the segments BM5 and M5D. The excess acid ratio over the stoichiometric norm was calculated for the formation of monosubstituted phosphates for the $FeCl_2$-H_3PO_4-H_2O system.

Keywords: multicomponent system, phase equilibrium, phase diagrams, phosphatizing, isothermal method, Yeneke diagram.

Introduction

The study of state diagrams of multicomponent systems, depicting the relationship between the property (temperature) and composition is of scientific interest. The interest and importance of the study of such state diagrams is not only to establish the presence of phases in the system, but also to clarify the nature and nature of the interaction between the components of the system, as far as possible, on the basis of studying the type of obtained diagrams [1].

For complex systems consisting of many phases and components, the construction of a state diagram is the only method that allows one to determine in practice how many phases and what phases form the system for given values of state parameters. Each real-life state of a system in a state diagram is depicted by a so-called figurative point; areas of existence of one phase correspond to sections of space [2-3].

The theoretical basis for the construction and interpretation of state diagrams of equilibrium systems are phase equilibrium condition, according to which the chemical potentials of each component in all phases at equilibrium are equal; the condition of chemical equilibrium, according to which the sum of the chemical potentials of the reacting substances at equilibrium is equal to the same amount for the reaction products; phases of the Gibbs rule [4-5].

In order to construct state diagrams by calculation, it is necessary to know the dependencies of the chemical potentials of all components of the system. The study of state diagrams is the main content of physico-chemical analysis.

Up to date the problem of anticorrosive protection of metals is still extremely topical one, and it requires fast decision. Herewith one of directions of development of effective phosphate protective coatings is using waste of chemical-metallurgical productions for that purpose.

In work [6], the possibility of using the electrochemical method - cyclic voltammetry for determining the applying the phosphate coatings on brass samples from phosphating solutions was considered.

The proposed voltammetric method is based on measuring the amount of current (amount of electricity) for cathode maxima of electroreduction of ionization products of disk brass electrodes in the absence of a phosphate coating and coated with a wide potential range against a background of 0.3 M Na_2SO_4. In work [7], the influence of zinc phosphonat ZnHTΦ and sodium lingosulphate on speed of a steel corrosion is studied. It is established, that the greatest inhibitory effect is observed at a ratio 1:1.

Phosphatizing of non-ferrous metals, in particular brass, is used less frequently than phosphatization of ferrous metals. However, in the case of applying paint coatings, the preliminary application of a phosphate layer leads to a significant increase in the resistance of the applied coating, which is very important for non-ferrous metals with low adhesive properties [8-20].

Determining the optimal phosphatizing conditions for brass samples — the composition and nature of phosphating solutions, temperature, phosphating time, hydrodynamic conditions is associated with conducting a large number of laborious tests using chemical and physical methods [6, 21-24].

The use of such methods does not always allow to obtain unambiguous information about the physico-chemical characteristics of phosphate coatings. To establish the optimal conditions for monitoring and controlling the phosphating process on the samples used, the most informative method may be an electrochemical method based on fixing cyclic current-voltage curves.

For determination of the reactivity and conditions of applying the phosphate coatings on metals and alloys of different nature, chemical optical and physicochemical methods are widely used. Among electrochemical methods, the most widely used method is a method, based on the measurement of the potential of time. Using this method, the time of formation of phosphate coatings on the studied samples can be estimated.

It is known that chloride sublimates of oxidizing-chloridizing roasting of lead-zinc ore contain 28.9% of chloride-ions, including 38.3% of $ZnCl_2$ and 6.85% of $FeCl_2$ and 6,75% $PbCl_2$ [25]. When phosphoric-acid processing of these sublimates to obtain phosphating anticorrosive coatings four-component (quaternary) $FeCl_2$-H_3PO_4-H_2O systems is formed. Formation of five-component (quinary) $FeCl_2$-$ZnCl_2$-H_3PO_4-H_2O system is possible as well. Researched processes represent complex chemical-technological systems, including both chemical and phase transformations in equilibrium conditions. Therefore the technology of processing of chloride sublimates with a certain composition using phosphoric acid is impossible to develop without complex physical-chemical analysis of these mutual systems and setting regularities of phenomena taking place in the systems. The analysis is performed by studying properties of a heterogeneous system depending on its composition and parameters and imaging these dependences on state diagrams.

The analysis of the latest news from literature sources for the question of phase equilibrium in pointed systems testifies that similar investigations weren't conducted. There are data only about composition and properties of two-component systems $FeCl_2$-H_2O and $ZnCl_2$-H_2O in the literature [26], but those don't correspond with composition of waste under investigation. Acid-containing ternary systems like $FeCl_2$-HCl-H_2O and $ZnCl_2$- HCl-H_2O, $Fe_3(PO_4)_2$-H_3PO_4-H_2O and $Zn_3(PO_4)_2$-H_3PO_4-H_2O aren't studied. Phase equilibrium in a system Fe_2O_3-P_2O_5-H_2O is established only, and this system has absolutely another composition with crystallization of iron (III) phosphates.

The system FeO-P_2O_5-H_2O is researched at temperature 70°C in the interval of diluted solutions only (less than 5,54% FeO and 15,1% P_2O_5) forming amorphous products like $2FeO{\cdot}P_2O_5{\cdot}3H_2O$ in solid phase. Hence, information about solubility in the given system is limited and it doesn't correspond to conditions of process behavior.

Phase equilibrium in quaternary mutual systems $FeCl_2$-H_3PO_4-H_2O and $ZnCl_2$-H_3PO_4-H_2O, as well as in quinary system $FeCl_2$-$ZnCl_2$-H_3PO_4-H_2O aren't studied. There isn't data about solubility and crystallization fields in given systems even at standard temperature.

In this connection, it is necessary to study the state diagrams of the above-mentioned four-component systems, which are the basis for the development of the theoretical foundations of technological processes occurring during the phosphoric acid processing of chloride sublimates.

METHODS

The solubility was studied by an isothermal method, the essence of which is to mix the solution at a constant temperature with an excess amount of solid phase until equilibrium is established. In the studied systems, chemical interaction of the initial reagents - a solution of phosphoric acid of a certain concentration and ferric (II) chloride proceeds until equilibrium is established in accordance with the reaction equation:

$$3FeCl_2 + 2H_3PO_4 = Fe_3(PO_4)_2 + 6HCl \quad (1)$$

Depending on the degree of saturation of the acid with the cation, one-, two-, or three-substituted phosphates are formed; however, in order to reach the saturation state and determine the equilibrium composition of the system at a certain temperature, it is necessary to introduce chlorides in an amount exceeding the stoichiometric rate for the indicated reactions.

The experiments were carried out in a thermostated reactor, equipped with a refrigerator, a mixer with a water seal and a thermometer. The temperature was maintained using a contact thermometer with an accuracy of +/- 0.5 ° C. Due to the release of hydrogen chloride as a result of the reaction, the process was carried out in a fume hood, and a reflux condenser and an absorber with cold water were used to remove the formed gas. Removal of gas from the reactor to the absorber is provided by connecting it to a water jet pump.

In a solution of phosphoric acid (chemical pure) of a certain concentration was added a portion of ferric chloride in an amount to saturate the solution with salt after the reaction, which is determined by the remaining excess salt in the solid phase. Upon reaching saturation every half hour using a thermostated sampler, samples were taken of the liquid phase for analysis on the content of chloride ions. About the time to reach equilibrium was judged by the constancy of the content of chloride ions in the last two or three selected samples. The content of chloride ions was determined by argentometric method.

Solubility was calculated on the basis of 3-4 parallel experiments results at allowable discrepancy less than 0.5% between two parallel analyses of liquid phase in every experiment. It is established experimentally that equilibrium in systems $FeCl_2$-H_3PO_4-H_2O is reached in 2.5 hours at any temperature [27]. Solubility is studied in phosphoric acid concentration interval from 5 to 55% of H_3PO_4 at temperatures 25, 60 and 80ºC. The last ones correspond to conditions of chloride sublimate processing.

RESULTS AND DISCUSSION

In order to construct solubility isotherms for mutual quaternary systems on flat square Yeneke diagram the ionic salt composition of the system is expressed in Yeneke indexes, which are determined on the basis of the equality of the sum of the number of moles of cations and anions. So for the system $FeCl_2$-H_3PO_4-H_2O the sum of cation moles $3Fe^{2+}$ (bounded as chlorides and phosphates in the solution) and $6H^+$ (bounded as phosphoric and hydrochloric acids) is to be equal to the sum of anion moles $6Cl^-$ and $2PO_4^{3-}$, are also in the composition of the corresponding salts and acids. Based on this, the ionic composition of the system at any point in the diagram is defined as the molar ratio of one of the anions to the sum of anions and the molar ratio of $6H^+$ to the sum of cations [28].

For this purpose, the data on the composition of the equilibrium system obtained as a result of the studies carried out are recalculated taking into account the proceeding chemical reaction (1). The content of chloride ions in the solution takes into account their presence both in the form of ferric chloride and hydrogen chloride, and the high content of these ions in dilute phosphoric acid solutions (5-15% H_3PO_4 at 25 °C) indicates that in equilibrium with a stable pair salts of $Fe_3(PO_4)_2$-6HCl is also a salt of $FeCl_2$, and H_3PO_4 is absent. For higher temperatures, the region of such a composition of the equilibrium system expands to 20 and 25% H_3PO_4 at 60 and 80 °C, respectively. In the $FeCl_2$-H_3PO_4-H_2O system, the temperature dependence is traced: with increasing temperature, the solubility increases, and the point of triple eutonics shifts to the area of higher concentrations.

Recalculation of the content of system components with regard to the reactions taking place shows that, starting from the inflection point, phosphoric acid is in equilibrium with a stable pair of salts up to the maximum concentration of this acid, which indicates a wide crystallization range of iron phosphates.

Next, we calculated the number of moles of compounds and the number of moles of individual ions in the composition of these compounds, and then the total number of moles of like ions. Based on the obtained data, the coordinates of the points on the solubility isotherms were calculated in accordance with the above method. The composition of the solid phase, equilibrium with the solution in the $FeCl_2$-H_3PO_4-H_2O system is given in table 1.

Table 1 - The composition of the solid phase, equilibrium with the solution in the $FeCl_2$-H_3PO_4-H_2O system

Composition of the initial acid,%	Content of P_2O_5/Cl^- in solid phase, %, at temperatures of			The composition of the equilibrium solid phase at temperatures of		
H_3PO_4	25°C	60°C	80°C	25°C	60°C	80°C
5	0/37,2	0/39,1	0/42,2	$FeCl_2 \cdot H_2O$	$FeCl_2 \cdot H_2O$	$FeCl_2 \cdot H_2O$
10	0/45,1	0/40,4	0/47,7	$FeCl_2 \cdot H_2O$	$FeCl_2$	$FeCl_2$
15	3,0/43,5	0/46,9	0/50,3	$FeCl_2$+ $Fe_3(PO_4)_2$	$FeCl_2$	$FeCl_2$
20	29,2/16,1	0/51,2	0/50,2	$FeCl_2$+ $Fe_3(PO_4)_2$	$FeCl_2$	$FeCl_2$
25	38,7/1,3	28,7/12,1	0/48,9	$FeCl_2$+$Fe_3(PO_4)_2$+ $FeHPO_4$	$FeCl_2$+ $Fe_3(PO_4)_2$	$FeCl_2$
30	50,3/0	42,0/0	27,7/10,4	$Fe_3(PO_4)_2$+ $FeHPO_4$	$Fe_3(PO_4)_2$+ $FeHPO_4$	$FeCl_2$+ $Fe_3(PO_4)_2$
35	51,9/0	52,1/0	40,9/0	$Fe(H_2PO_4)_2$	$Fe(H_2PO_4)_2$	$Fe_3(PO_4)_2$+ $FeHPO_4$
40	54,3/0	55,0/0	50,5/0	$Fe(H_2PO_4)_2$	$Fe(H_2PO_4)_2$	$Fe(H_2PO_4)_2$
45	53,8/0	53,5/0	53,7/0	$Fe(H_2PO_4)_2$	$Fe(H_2PO_4)_2$	$Fe(H_2PO_4)_2$
50	53,0/0	53,9/0	54,4/0	$Fe(H_2PO_4)_2$	$Fe(H_2PO_4)_2$	$Fe(H_2PO_4)_2$
55	54,1/0	54,0/0	53,1/0	$Fe(H_2PO_4)_2$	$Fe(H_2PO_4)_2$	$Fe(H_2PO_4)_2$

Applying certain compositions of saturated solutions (X_{PO4}, X_H) on the Jeneke diagram, we obtain the line of solubility isotherms in the studied system at temperatures of 25, 60 and 80°C.

Based on the obtained data, salt crystallization fields were constructed in the studied system, taking into account the possible formation of one- and two-substituted iron phosphates, which compositions are indicated by points F_1 and F_2, respectively (Fig. 1).

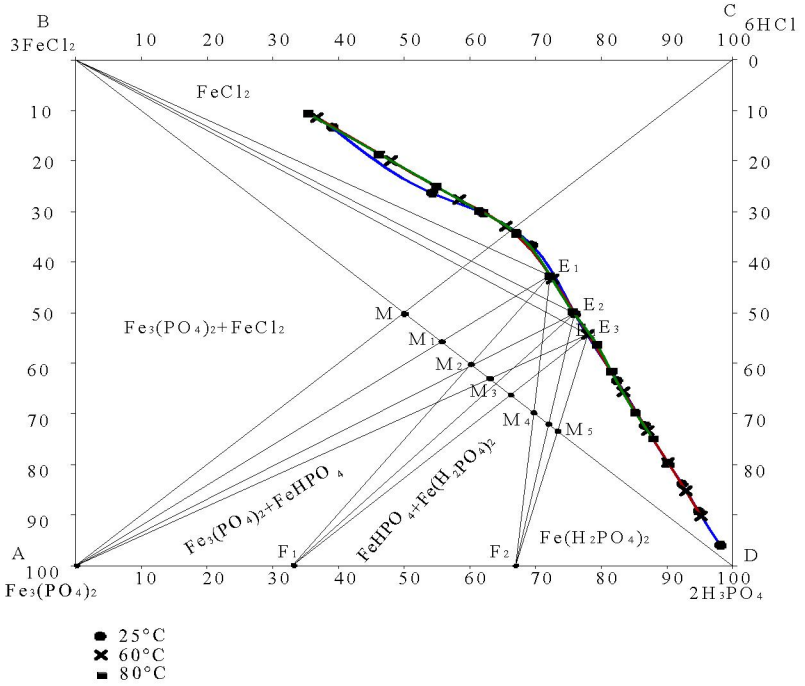

Figure 1 - Diagram of the $FeCl_2$-H_3PO_4-H_2O phase system

From Fig. 1 it is seen that in the $FeCl_2$-H_3PO_4-H_2O system, the displacement of triple eutonics, the increase in solubility and the expansion of the co-crystallization region of $Fe_3(PO_4)_2$ and $FeCl_2$ and $FeCl_2$ salts with increasing temperature are traced. The fields of crystallization of iron phosphate are reduced, which affects the choice of optimal conditions for obtaining monosubstituted iron phosphates. The points of the triple eutonic E_1, E_2 and E_3 are determined by the extreme point in the composition of the saturated solution at a given temperature and confirmed by the composition of the solid phase determined by the content of phosphate ions and chloride ions in it (Table 1).

According to the rule, the connecting direct process of the interaction of chlorides with phosphoric acid is depicted in the diagram by the BD line, connecting the composition points of the initial pure reagents [29]. At their equimolecular ratio, the figurative point of the composition of system M will be in the region of the joint crystallization of the $Fe_3(PO_4)_2$ and $FeCl_2$ salts, which does not allow to obtain the desired product in the solid phase. In order to achieve the maximum yield of the product, the initial reagents should be taken in such a ratio that the figurative point of the system composition is on the crystallization beam, connecting the point of the salt composition, for example, $Fe_3(PO_4)_2$, and the eutonic point corresponding to the process temperature - E_1, E_2 and E_3, determining the composition of the solutions, saturated simultaneously with three salts, for temperatures of 25, 60 and 80°C, respectively. These are respectively points M_1, M_2 and M_3. In this case, the crystallization of the production salt occurs over a longer segment, which makes it possible to isolate the maximum amount of the product in the solid phase. For the formation of the target product - iron dihydrogen phosphate, the process must be carried out at such a ratio of initial compounds that the figurative point of the system composition is on the crystallization line of $Fe(H_2PO_4)_2$ salt connecting the points of their composition F1 and the eutonic point. In the case of carrying out the process at a temperature of 80 °C, the desired point M5 is located at the intersection of the line of interaction between the initial reagents and the crystallization beam F_1E_3, which ensures the maximum yield of the product.

In order to obtain the specified composition of the system, the consumption of phosphoric acid solution is determined according to the lever rule and, more precisely, by the method of compiling the material balance of the process [30]. As a result of its decision, the yield of the finished product, the $Fe(H_2PO_4)_2$ salt, is also determined.

The consumption of phosphoric acid is determined according to the diagram according to the lever rule as the ratio of the segments BM_5 and M_5D. For the $FeCl_2$-H_3PO_4-H_2O system, the excess acid ratio over the stoichiometric norm for the formation of monosubstituted phosphates is calculated as 98: 43 = 2.28. Then the consumption of a phosphoric acid solution, taking into account its concentration of 45% for the interaction with the initial 5 grams of chloride in accordance with the equation of reaction (1) is determined as (5·196:381)·2.28):0.45 = 13.02 g per reaction with iron chloride. Taking into account the density of the solution of a given concentration, equal to 1.293 g/cm^3, the volume flow of the phosphoric acid solution will be 13.02:1.293 = 10.07 cm^3. We will carry out a refined calculation of the optimal consumption of phosphoric acid for carrying out the reaction by preparing a complete and partial equation of the material balance of the process per unit mass of the initial chloride. The complete material balance equation for the process of the interaction of pure ferric chloride and phosphoric acid on the salt mass of the system is determined as follows:

$$1\ FeCl_2 + X\ H_3PO_4 = Y\ Fe(H_2PO_4)_2 + Z\ \text{solution}\ E_3 \qquad (2)$$

Substituting into the equation the composition of the solution E_3, calculated when constructing solubility isotherms for extreme points (table 2-4), we get:

$$1FeCl_2 + XH_3PO_4 = YFe(H_2PO_4)_2 + Z(0{,}426PO_4^{3-} + 0{,}574Cl^- + 0{,}772H^+ + 0{,}228Fe^{2+}) \qquad (3)$$

Table 2 - Results of the recalculation of data by Jeneke at 25 °C

The initial system 25°C		The composition of the solution in the equilibrium system, %				The number of moles of components			
H_3PO_4	$FeCl_2$	$Fe_3(PO_4)_2$	6HCl	$3FeCl_2$	$2H_3PO_4$	$Fe_3(PO_4)_2$	6HCl	$3FeCl_2$	$2H_3PO_4$
5	29,71	-	5,59	43,43	0	0,0255	0,0255	0,114	-
10	23,54	9,13	11,17	22,67	0	0,0510	0,051	0,0595	-
15	23,54	-	16,76	12,95	0	0,07654	0,07653	0,03399	-
20	21,07	27,40	21,66	0	0,62	0,09891	0,0989	-	0,00316
25	18,58	35,41	19,10	0	7,90	0,08723	0,0872	-	0,04031
30	14,87	24,99	15,29	0	16,32	0,0698	0,0698	-	0,0833
35	12,39	20,82	12,74	0	23,60	0,05816	0,05817	-	0,1204
40	9,91	16,66	10,19	0	30,88	0,04654	0,0465	-	0,1576
45	8,67	14,57	8,92	0	37,02	0,0407	0,0407	-	0,1889
50	6,19	10,41	6,37	0	44,30	0,0291	0,0291	-	0,226
55	2,48	4,16	2,55	0	52,72	0,01162	0,01164	-	0,269

Table 3 - Results of recalculation of data by Jeneke at 60 ° C

The initial system 60°C		The composition of the solution in the equilibrium system, %				The number of moles of components			
H_3PO_4	$FeCl_2$	$Fe_3(PO_4)_2$	6HCl	$3FeCl_2$	$2H_3PO_4$	$Fe_3(PO_4)_2$	6HCl	$3FeCl_2$	$2H_3PO_4$
5	35,93	9,13	5,59	54,55	-	0,0255	0,0255	0,143	-
10	33,45	18,26	11,17	40,40	-	0,051	0,051	0,106	-
15	28,50	27,40	16,76	21,81	-	0,0765	0,0765	0,0572	-
20	26,02	36,53	22,35	7,66	-	0,102	0,102	0,0201	-
25	22,30	37,48	22,93	-	4,48	0,105	0,105	-	0,0229
30	19,82	33,32	20,38	-	11,76	0,093	0,093	-	0,060
35	16,11	27,07	16,56	-	20,18	0,0756	0,0756	-	0,103
40	13,63	22,91	14,01	-	27,46	0,064	0,064	-	0,140
45	11,20	18,82	11,51	-	34,70	0,0526	0,0526	-	0,177
50	8,68	14,57	8,92	-	42,02	0,0407	0,0407	-	0,214
55	6,19	10,40	6,37	-	49,30	0,0291	0,0291	-	0,252

Table 4 - Results of recalculation of data by Jeneke at 80 ° C

The initial system 80°C		The composition of the solution in the equilibrium system, %				The number of moles of components			
H_3PO_4	$FeCl_2$	$Fe_3(PO_4)_2$	6HCl	$3FeCl_2$	$2H_3PO_4$	$Fe_3(PO_4)_2$	6HCl	$3FeCl_2$	$2H_3PO_4$
5	39,65	9,13	5,59	61,20	-	0,0255	0,0255	0,161	-
10	37,17	18,26	11,17	47,05	-	0,051	0,051	0,125	-
15	34,69	27,40	16,76	32,90	-	0,0765	0,0765	0,0864	-
20	32,34	36,53	22,35	18,97	-	0,102	0,102	0,0498	-
25	29,74	45,66	27,93	4,59	-	0,128	0,128	0,012	-
30	27,26	45,82	28,03	-	4,92	0,128	0,128	-	0,025
35	26,12	43,91	26,86	-	10,96	0,123	0,123	-	0,056
40	24,78	41,65	25,48	-	17,20	0,116	0,116	-	0,088
45	23,54	39,57	24,20	-	23,34	0,111	0,111	-	0,119
50	19,82	33,32	20,38	-	31,76	0,093	0,093	-	0,162
55	17,35	29,16	17,84	-	39,04	0,081	0,081	-	0,199

Next, we compose the partial equations for the individual components - ions, taking into account their mass fraction in the anhydrous compound, and solve them with respect to the unknowns:

$$\text{By } Fe^{2+}: 1 \cdot 0{,}441 = Y \cdot 0{,}224 + Z \cdot 0{,}228 \quad (4)$$

$$\text{By } Cl^{-}: 1 \cdot 0{,}559 = Z \cdot 0{,}574 \quad (5)$$

$$\text{By } PO_4^{3-}: X \cdot 0{,}969 = Y \cdot 0{,}776 + Z \cdot 0{,}426 \quad (6)$$

Hence the mass of the eutonic solution E_3 is Z = 0.974; the mass of production dihydrogen phosphate of iron is Y = 0,977; mass of phosphoric acid is X = 1.210 per unit mass of $FeCl_2$, or 2.69 in terms of 45% phosphoric acid. On 5 grams of this reagent, the consumption of the acid solution will be 13.44 g, and taking into account its density, 13.44: 1.293 = 10.4 cm^3, which is slightly more than the volume flow, calculated using the lever rule.

Conclusion

Thus, the optimal consumption of a phosphoric acid solution to obtain a specified product from a unit mass (1 kg) of iron chloride — 2.69 kg was determined. The maximum possible yield of the finished product in these conditions of the process from a unit mass of iron chloride - 0.977 is also established. Also, the studied phase diagram of the $FeCl_2$-H_3PO_4-H_2O system at temperatures of 25, 60 and 80°C represents new scientific data on solubility in reciprocal four-component systems, which significantly expand the area of knowledge in the physico-chemical analysis of multicomponent systems and provide a theoretical basis for the analysis and justification of the optimal conditions of the processes occurring in the studied systems.

ӘҚК 378(075.8): 544

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ТӨРТ КОМПОНЕНТТІ ЖҮЙЕЛЕРДІҢ ФАЗАЛЫҚ ТЕПЕ-ТЕҢДІГІ НЕГІЗІНДЕ ТЕМІР ФОСФАТЫН АЛУ ҮРДІСІН ЗЕРТТЕУ

Аннотация: Бұл мақалада өзара әрекеттесетін төрт компонентті жүйелердегі фазалық тепе-теңдігі туралы әдебиеттік мәліметтердің талдауы келтірілген, сонымен қатар фосфор қышқылының шоғыры 5 және 55% H_3PO_4 аралығында 25, 60 және 80°С температураларда $FeCl_2$-H_3PO_4-H_2O жүйесінің ерігіштігі қарастырылған.

Сондай-ақ зерттеліп отырған жүйеде бір немесе екі негізді темір фосфатының түзілуін ескере отырып, тұздардың кристалдану алаңдарын тұрғызудың есептік мәліметтері келтірілген. Аталған өнімді алу үшін қажетті фосфор қышқылының тиімді шығыны анықталған. Сонымен қатар, үрдістерді жүргізудің берілген шарттарында темір хлоридінің бір бірлігінен дайын өнімнің мүмкін максималды шығымы тағайындалған.

Фосфор қышқылының шығыны диаграмма бойынша иінтірек ережесіне сәйкес, BM_5 және M_5D кесінділерінің қатынасы ретінде анықталды. $FeCl_2$-H_3PO_4-H_2O жүйесі үшін бір орын басқан фосфаттардың түзілуіне стехиометриялық нормадан жоғары қышқылдың артық мөлшерінің коэффициенті есептелді.

Түйін сөздер: Көп компонентті жүйе, фазалық тепе-теңдіктер, фазалық диаграммалары, фосфаттау, изотермиялық әдіс, Йенеке диаграммасы.

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ИЗУЧЕНИЕ ПРОЦЕССА ПОЛУЧЕНИЯ ФОСФАТА ЖЕЛЕЗА НА ОСНОВЕ ФАЗОВЫХ РАВНОВЕСИИ ЧЕТЫРЕХКОМПОНЕНТНЫХ СИСТЕМ

Аннотация: В данной статье приведен анализ литературных сведений по фазовым равновесиям в четырехкомпонентных взаимных системах, также изучена растворимость системы $FeCl_2$-H_3PO_4-H_2O в интервале концентраций фосфорной кислоты от 5 до 55% H_3PO_4 при температурах 25, 60 и 80°С.

Приведены расчетные данные по построению полей кристаллизации солей в изучаемой системе с учетом возможного образования одно- и двухзамещенных фосфатов железа. Определено оптимальный расход раствора фосфорной кислоты на получение заданного продукта. Установлен также максимально возможный выход готового продукта в данных условиях проведения процесса из единицы массы хлорида железа.

Расход фосфорной кислоты определяли по диаграмме согласно правилу рычага как отношение отрезков BM_5 и M_5D. Рассчитывали коэффициент избытка кислоты сверх стехиометрической нормы для образования однозамещенных фосфатов для системы $FeCl_2$-H_3PO_4-H_2O.

Ключевые слова: многокомпонентая система, фазовое равновесие, фазовые диаграммы, фосфатирование, изотермический метод, диаграмма Йенеке

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