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Study of the mechanism of pre-burned ash leaching by hydrochloric acid

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ABSTRACT

The use of hydrochloric acid for processing aluminum-containing raw materials has a number of advantages over other acids, which include: easy decomposition of aluminum compounds with the transfer of aluminum into solution; low solubility of silica in HCl, the possibility of complete separation of the solid residue without significant losses of acid, etc. The paper considers the possibility of using the method for processing ash and slag dumps accumulated in large volumes in the country. Based on the thermodynamic analysis of reactions of interaction between ash components and hydrochloric acid, the behavior of aluminum, iron and nonferrous metal compounds during leaching is studied. It was shown that the preliminary roasting of ash with calcium chloride provides a high extraction of aluminum in the solution from the cinder. Based on experimental studies, the influence of time, temperature and acid consumption on the degree of aluminum extraction into the solution has been established. At optimal conditions of leaching conducted at S:L = 1:3, T = 60 °C, τ = 60 min extraction of aluminum in a solution as chloride amounted to 99.92 %. At the same time the extraction of silica in solid sediment due to the maximum transfer of impurities in the solution was 99.8 %. The mechanism of the leaching process is proposed. The values of activation energy and the order of the reaction, indicating the complex 3-step character of the reactions, have been calculated. It is established that the limiting stage during leaching is the dissolution of anorthite.

Keywords: carbon black, leaching, hydrochloric acid, process mechanism, time, temperature, extraction, activation energy.

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Introduction

Ash is the largest type of waste produced by large thermal power plants and steel mills as a result of coal combustion. More than 100 million tons of ash are produced in the U.S. each year. Annual ash output by developed country is, in million tons: India - 112, China - 100, Germany - 40 and UK - 15 [1, 2, 3].

In the Russian Federation there are more than 170 coal-fired thermal power plants, which burn 650 million tons of coal with the formation of 300 million tons of ash annually. More than 20 thousand km² of land plots are alienated for ash and slag waste storage in Russia, where 1.3-1.5 billion tons of ash are located [4].

In Kazakhstan, the annual output of ash and slag waste is about 19 million tons. To date, more than 300 million tons of waste has been accumulated in ash dumps [5]. In one major megalopolis in Kazakhstan, Almaty, more than 2 million tons of ash and slag waste have been accumulated as a result of three thermal power plants. Only during one heating season about 600 thousand tons of ash waste is added to the accumulated volumes of ash from coal combustion. The generated ash dumps have taken vast areas out of land use and have a negative impact on the environment (pollution of soil, air, groundwater).

The relevance and significance of the issues under consideration are enhanced with the fact that there is

no rational technology for ash processing. Significance of researches in the direction of development of highly efficient technology for ash processing consists in solving two key problems - ecological and technological. Solution of the first problem comes to involving the accumulated and current ash and slag wastes in processing and liberating large territories, and reducing the burden on the environment by reducing the volume of ash and its fine dispersion by the wind (20-40 μ). Solution of the second problem ensures the use of ash as an additional source of raw materials with complex extraction of valuable metals with high added value.

The existing methods of ash processing [6, 7] allow extracting small amounts of valuable components. At the same time, according to the material composition ash can be considered as an independent complex raw material for the extraction of a whole range of metals [8, 9, 10]. Ashes compare favorably with conventional mineral deposits, they are located on the surface and do not require large expenses for extraction.

Positive research results [11, 12] allowed us to formulate a general concept of technology for the processing of ash of different chemical and mineralogical composition. Of particular interest is the application of the technology for the utilization of ash from small boiler plants, located within the boundaries of large cities and megacities.

The proposed technology can become an alternative for the production of alumina, silica and REM in countries where there are no bauxite deposits suitable for the production of alumina by the Bayer method and no natural sources for the production of pure silica and REM.

This paper presents the results of studies of the interaction of cinder components during its leaching with hydrochloric acid together with calcium chloride. Based on thermodynamic analysis of reactions of interaction between the components of the cinder with hydrochloric acid, the behavior of aluminum, iron and nonferrous metal compounds in the leaching process has been studied.

As a result of experimental studies, regularities of aluminum compounds dissolution during hydrochloric acid leaching depending on time, temperature, and hydrochloric acid consumption have been established. Optimal parameters of the leaching process providing maximum aluminum extraction into the solution as its chloride 99.92 % and high silica extraction into solid commercial sediment - 99.8 % have been determined.

Research methods

The main methodological principle for studying the mechanism of ash leaching with hydrochloric

acid is the thermodynamic approach to the description of cinder leaching, which provides reliable determination of qualitative and quantitative characteristics of the formed complex composition solid (cinder) and liquid solutions of hydrochloric acid leaching.

Determination of the influence of hydrochloric acid consumption, temperature and time on the completeness of silica extraction into the commercial product in the form of precipitate and the maximum extraction of aluminum, nonferrous metals, REM and other associated elements in the solution was based on experimental results.

For the experiments a firing result, obtained under optimal burning conditions ($T=1100$ °, CaCl_2 consumption was twice higher than the required from stoichiometry for mullite decomposition, $\tau=60$ min) of non-magnetic ash fraction together with calcium chloride, was used. The non-magnetic fraction of ash was obtained by magnetic separation of ash from a thermal power plant in Almaty [12].

The elemental and phase composition of solid and liquid products of cinder leaching with hydrochloric acid was performed using a D8 Advance analyzer (Bruker), α -Cu, tube voltage 40 kV, current 40 mA. Processing of the obtained data of the diffraction patterns and calculation of the interplanar distances were performed using the EVA software. Sample interpretation and phase search were performed by Search/match using the PDF-2 powder diffractometer database.

In order to clarify and obtain reliable results of the phase composition of the initial cinder and leach products the X-ray diffractometric analysis on diffractometer DRON-3 with CuCa-radiation, β -filter was additionally performed. The diffractogram conditions: $U=35$ kV; $I=20$ mA; $\theta=2\theta$; detector 2 deg/min. X-ray phase analysis on a semi-quantitative basis was performed on powder sample diffractograms using the method of equal weights and artificial mixtures. Quantitative ratios of crystalline phases were determined. Interpretation of the diffractograms was performed using the data from the ICDD: Powder Diffraction File (PDF2) and diffractograms of clean minerals. For the main phases the calculation of the content was carried out.

The total number of experiments ($3k=9$) was determined based on the influence of two parameters on the required parameters, each of which was set in three levels: $S:L = 1:2; 1:3; 1:4$ and temperature - 40, 60, 80 °C. 30 % HCl hydrochloric acid was used in the experiments. Initial weight of cinder in all experiments was 243 g. Time of cinder

leaching was 60 minutes. For each experiment by results of elemental composition of the received products the material balance was calculated, their data were used for a choice and substantiation of optimum parameters of process.

The technique of carrying out of experiments consisted in the following. The 243 g of crushed char was loaded into a glass flask and concentrated hydrochloric acid was added to it in the specified quantity S:L. The beaker with the contents was then placed on a thermostat and leaching was started using an agitator. The stirrer speed was 300 rpm. The thermostat was used to set the desired leaching temperature.

After the required time the suspension was filtered and the solid sediment was separated from the productive solution. The solid sediment (cake) after washing with water (pH=5-7) and drying was sent for chemical and X-ray phase analysis.

Productive solution was analyzed for aluminum, calcium, iron, nonferrous metals and REM. Composition of washing solution was determined by the difference of loaded and received materials based on the material balance of each experiment.

Under the conditions of the established optimum regimes the experience of leaching of slag with hydrochloric acid was carried out on an enlarged laboratory scale. The methodology of the experiment was as follows. Source materials (cinder and HCl) were continuously fed for leaching. HCl-acid consumption was 4 l/h. The consumption of cinder was 0.8 kg/h. The leaching time was 60 minutes. The slurry obtained after the set leaching time was continuously discharged from the reactor through the overflow into a laboratory batch filter. The solid precipitate (cake) after leaching was filtered and after washing with water was sent for drying. The total amount of cinder subjected to leaching - 1091,38 g. The received products of leaching - a solution and cake, were subjected to the elemental and phase analysis.

On the basis of the received results, the material balance of enlarged-balance leaching of cinder under the conditions of an optimum mode of conducting process: S:L=1:3, T=60 °C and τ =60 min was made up.

Results and discussion

The complete elemental composition of the initial cinder obtained under optimal firing conditions is presented in Table 1.

The phase composition of the cinder subjected to leaching is presented in Table 2.

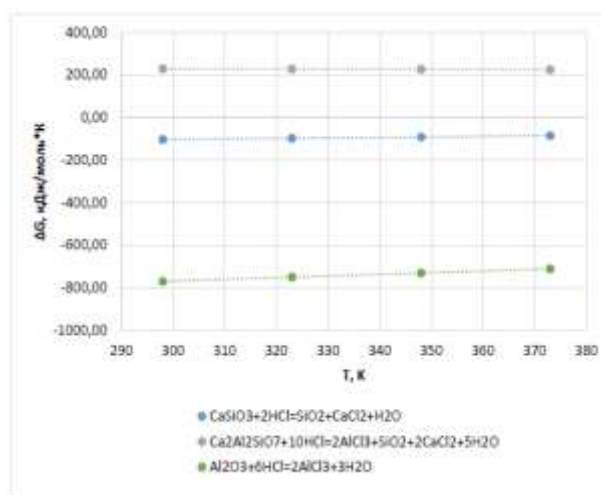
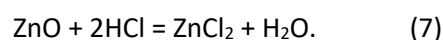
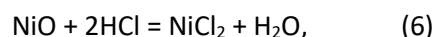
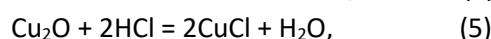
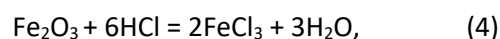
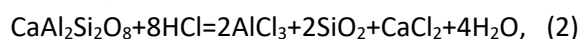
Table 1 - Elemental composition of the cinder

| Elements | Content, % |
|-----------------------------|--------------|
| Al | 9,87 |
| Si | 19,7 |
| Ca | 25,7 |
| Fe | 0,8 |
| O ₂ | 22,7 |
| Cl | 19,5 |
| (Cu + Zn + Ni), ppm: | 298,0 |
| Cu | 22,0 |
| Zn | 221,0 |
| Ni | 55,0 |
| ΣREM, ppm: | 74,0 |
| Sc | 29,0 |
| Y | 45,0 |

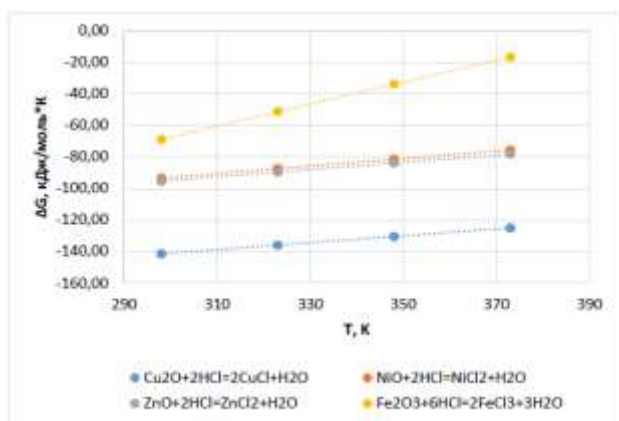
Table 2 - Results of semi-quantitative X-ray phase analysis of the cinder

| Name of phase | Formula | Concentration, % |
|--------------------|--------------------------------------------------|------------------|
| Gehlenite | Ca ₂ Al(SiAl)O ₇ | 25,68 |
| Anorthite | CaAl ₂ Si ₂ O ₈ | 5,34 |
| Pseudowollastonite | CaSiO ₃ | 30,13 |
| Hematite | Fe ₂ O ₃ | 0,64 |
| Other | | 38,21 |

Taking into account the established phase composition of the cinder, the mechanism of its leaching process with hydrochloric acid can be represented by reactions:



A)



B)

Figure 1 - The dependence of the Gibbs free energy on temperature for reactions (1) - (7)

The temperature dependence of the Gibbs free energy loss for reactions (1) - (7) is shown in Fig. 1.

We can see that the probability of reactions of interaction of gehlenite and anorthite with hydrochloric acid in the temperature range 298...373 K, providing the transition of aluminum in the solution as its chloride, is almost impossible because of the positive values of the Gibbs free energy of reactions (1), (2). There is a high probability of wollastonite decomposition by hydrochloric acid in reaction (3) with the formation of calcium chloride and quartz. The formation of a free amount of CaCl₂ seems not crucial, as it is recycled and returns to the head of the technology - to the process of burning ash.

High negative values of the Gibbs free energy of reactions (4) - (7) indicate the possibility of iron and non-ferrous metals transfer in the form of their chlorides into the solution. The established regularities show that according to thermodynamic calculations the transfer of aluminum from its readily soluble compounds (gelenite, anorthite) into the solution by leaching the cinder with hydrochloric acid is not possible. At the same time, the results of experimental studies fully confirm the possibility of high aluminum extraction into solution from the cinder. The observed pattern indicates a complex mechanism of the cinder leaching process with hydrochloric acid and can be interpreted by the results of the experiments.

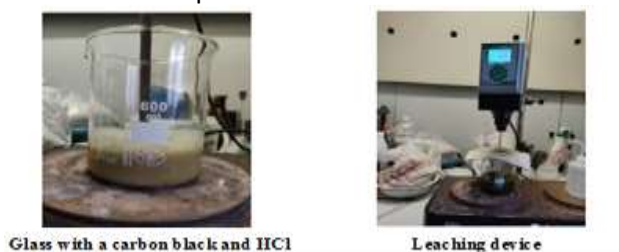


Figure 2 - Laboratory equipment for leaching

The cinder leaching with hydrochloric acid was carried out using laboratory equipment, the general view of which is shown in Fig. 2.

Fig.3 shows products of cinder leaching with hydrochloric acid obtained under optimum conditions of leaching: T:L=1:4; T=60 °C; τ=60 min.



Figure 3 - Products of cinder leaching with hydrochloric acid (S:L=1:4; T=60 °C; τ=60 min)

Dependence of aluminum extraction into solution on leaching time and process temperature is shown in Fig. 4.

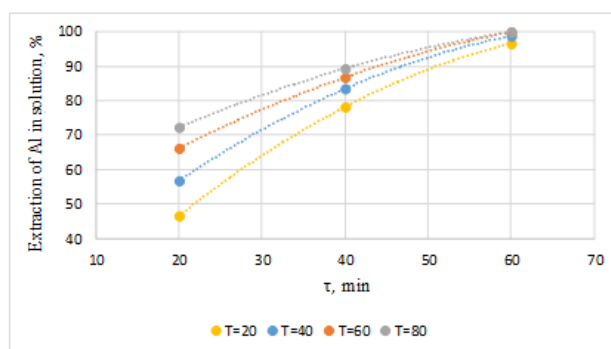


Figure 4 - Dependence of aluminum extraction into solution on leaching time and temperature

It can be seen from fig.4 that aluminium recovery into solution during initial stage of leaching - during leaching time increase from 20 to 40 minutes - significantly increases in temperature change from 20 to 80 °C. A further increase in the leaching time has little effect on the aluminum extraction in solution. The maximum aluminum extraction into solution is reached at 60 minutes.

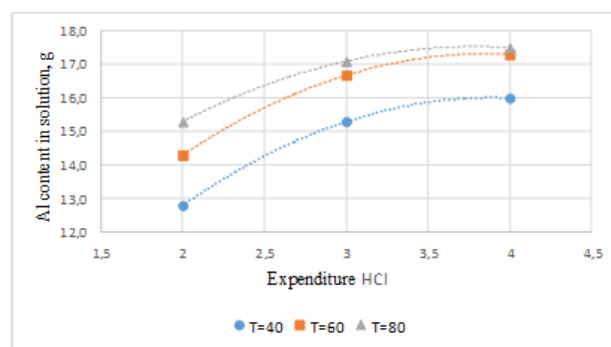


Figure 5 - Dependence of the aluminum content in the solution on the HCl flow rate (S:L) and temperature

An increase in temperature in this area has only an insignificant influence on aluminum extraction into solution.

The dependence of aluminum content in solution on HCl consumption and temperature is shown in Fig. 5.

It is easy to see that the influence of the HCl consumption on the solubility of aluminum from the cinder is more significant than the temperature. If the ratio T:L=1:4, the increase in temperature from 40 to 60°C has no significant effect on the transfer of aluminum into solution. This is also confirmed by the dependence of aluminum recovery into solution, which at T:L=1:4, in the temperature variation interval from 60 to 80 °C does not change, and remains practically on the same level ~99,96 % (Fig.6).

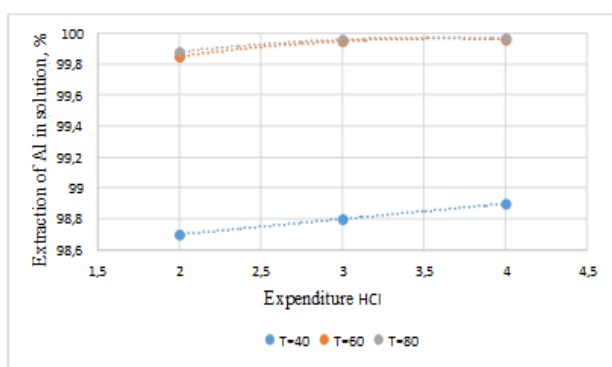


Figure 6 - Dependence of aluminum extraction into solution on the dependence of HCl (S:L) and temperature

SiO₂ content in the sediment at S:L=1:2 and temperature 40 °C, is ~ 98,8 % (Fig.7), which indicates a weak dissolution of silica in HCl and its maximum concentration in the solid sediment. A sharp increase in silica content in the precipitate from 98 to 99.5 % at 40°C is observed when the T:L ratio increases from 2 to 4. At T:L=1:4 the increase in temperature from 60 to 80 °C has only a small effect on the increase in silica content in the sediment, from 99.6% to 99.7%.

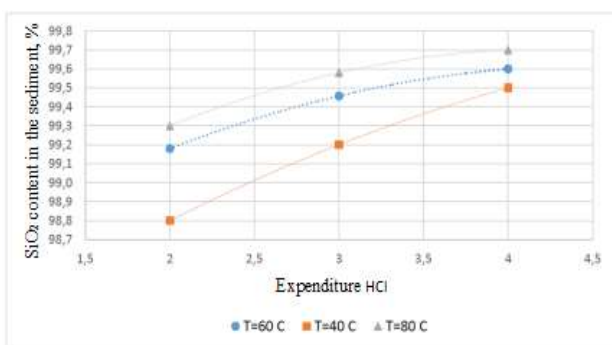


Figure 7 - Dependence of silica content in sediment on the HCl flow rate (S:L) and temperature

The maximum silica extraction into sediment ~99.9 % is reached at S:L=3, and remains constant at this level regardless of further temperature increase, as it can be seen in Fig.8.

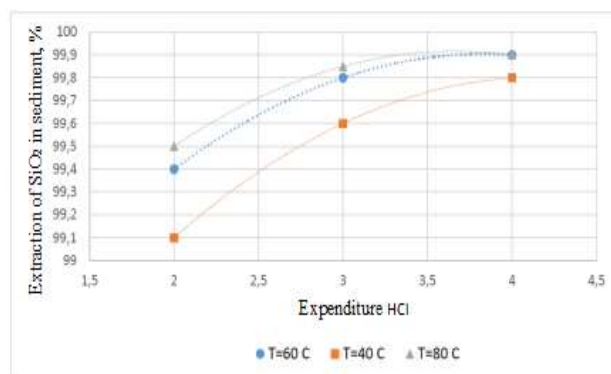


Figure 8 - Dependence of silica extraction on the HCl flow rate (S:L) and temperature

Determination of kinetic parameters of the leaching process

To determine the kinetic parameters of the cinder leaching process with hydrochloric acid, experimental data on the dependence of aluminum extraction degree in the solution on temperature, duration and concentration of hydrochloric acid were used (Fig. 4, 5). Based on these data, using the known kinetic equations and the Arrhenius equation [13], the values of apparent activation energy and the order of reactions were calculated.

$$dC / dt = K(T) \cdot C^n, \quad (8)$$

$$K(T) = A \cdot \exp(-E_a / RT), \quad (9)$$

where: K - reaction rate constant;
C - concentration of the reactant;
n - order of reaction;
A - pre-exponential multiplier or frequency factor of the constant characteristic of this reaction;
E_a - activation energy;
R - universal gas constant, R = 8.31 J/K-mol.

Determination of the activation energy (E_a) was carried out for the standard concentration of the reagent (30 % HCl) for four temperatures (20, 40, 60 and 80 °C).

After transforming equation (9) we can obtain expressions for determining the activation energy:

$$\text{Lg}K = \text{Lg}A + E_a / 2,3 \cdot T, \quad (10)$$

$$E_a = 2,3 \cdot \text{tg}\alpha. \quad (11)$$

The dependence of the logarithm of the reaction rate constant on 1/T is shown in Fig. 9.

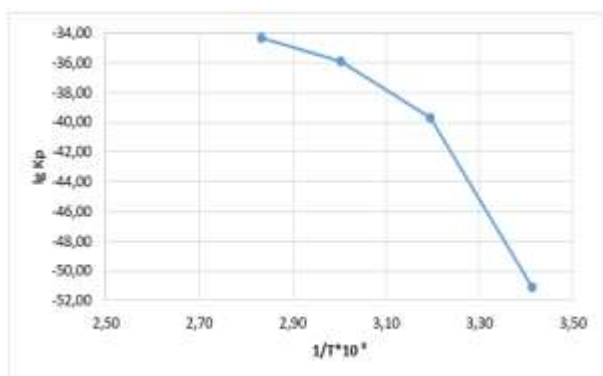


Figure 9 - Dependence of the rate constant of the reaction of dissolution of cinder dissolution by hydrochloric acid from inverse temperature

On fig. 9 it is possible to allocate 3 sites that testifies to change of character of interaction between reacting components. For each area by the slope tangent (11) was determined the value of apparent activation energy: at 20 °C - 83.4 kJ/mol, at 40 °C - 53.12 kJ/mol, at 60 °C - 32.34 kJ/mol.

Bauxite leaching is caused by the step nature of dissolution and strongly depends on the duration of the process. In the initial period, when there is enough reagent, there is a simultaneous dissolution of all the components of bauxite and the speed of the entire process is determined by the rate of the chemical reaction. At 40 °C and leaching duration of 20 minutes the wollastonite (reaction (3)), hematite by reaction (4) and nonferrous oxides by reactions (5) - (7) are dissolved completely. A further increase in time up to 40 min leads to the dissolution of helenite and anorthite by reactions (1) and (2). This begins to form amorphous silicon dioxide, which is present in the form of silicic acid, makes it difficult to supply the reagent (HCl) to the reaction zone. The process moves into the mixed region. A further increase in the leaching time leads to an increase in the amount of amorphous silica, indicating that the process proceeds in the diffusion region. At this stage, the main source of aluminum in the solution is helenite, while anorthite still remains in the solid residue. Consequently, the limiting reaction of the cinder leaching process is the dissolution of anorthite by reaction (2).

Table 3 – Material balance of the process of leaching pellet with hydrochloric acid under optimal conditions. S:L = 1:3; T = 60 °C; τ = 60 min

| Name | g | % | Al | | | SiO ₂ | | | Ca | | | Fe | | |
|-------------------|---------|-------|-------|------|--------|------------------|-------|--------|--------|-------|--------|------|------|--------|
| | | | I | II | III | I | II | III | I | II | III | I | II | III |
| Uploaded | | | | | | | | | | | | | | |
| Initial deposit | 1091.38 | 22.44 | 66.98 | 6.07 | 100.00 | 286.24 | 26.23 | 100.00 | 338.07 | 30.65 | 100.00 | 5.40 | 0.49 | 100.00 |
| Hydrochloric acid | 3771.66 | 77.56 | | | | | | | | | | | | |

To determine the order of reaction for the reagent (HCl), we used experimentally obtained dependences of aluminum content in the solution on the leaching duration at different concentrations of hydrochloric acid and constant temperature (Fig. 5). For two concentrations of reagent under condition of identical technological regimes, equation (8) can be written in the form [14]:

$$d\tau_1 / d\tau_2 = (C_1 / C_2)^n. \quad (12)$$

By logarithmizing equation (8), we can obtain an expression to calculate the order of the reaction:

$$n = \text{Lg}(d\tau_1 / d\tau_2) / \text{Lg}(C_1 / C_2). \quad (13)$$

Using equations (8) and (13), we determined the values of the reaction order. It was found that the kinetics of the process is significantly affected by the consumption of hydrochloric acid. At low values of HCl consumption (S:L=1:2) and temperature 60°C, the index of reaction order is fractional (n = 0.57), which corresponds to the kinetic region. When the HCl flow rate increases to S:L=1:4, the reaction order value, n ≈ 1, which indicates that the reaction (2) proceeds in the diffusion mode.

On the basis of the received results optimum parameters of process of cinder leaching by hydrochloric acid have been determined:

- hydrochloric acid consumption, S:L - 1:3;
- HCl concentration - 30 %;
- Leaching temperature - 60 °C;
- Extraction of aluminum in the solution - more than 99.0%;
- silica yield (precipitate) - more than 25% of the weight of the cinder;
- silica content in the sediment - more than 99.7%;
- extraction of silica in the sediment - more than 99,0%.

Material balance of enlarged-laboratory leaching of sludge (1091.38 g) with hydrochloric acid obtained under conditions of optimal process parameters is shown in Table 3.

| | | | | | | | | | | | | | | |
|-----------------|----------------|---------------|--------------|------|---------------|---------------|-------|---------------|---------------|------|---------------|-------------|------|---------------|
| Total: | 4863.04 | 100.00 | 66.98 | | 100.00 | 286.24 | | 100.00 | 338.07 | | 100.00 | 5.40 | | 100.00 |
| Received | | | | | | | | | | | | | | |
| Precipitate | 287.23 | 4.35 | 0.05 | 0.02 | 0.08 | 285.67 | 99.46 | 99.8 | 0.20 | 0.07 | 0.06 | 0.05 | 0.02 | 1.00 |
| Solution | 4575.81 | 95.65 | 66.93 | 1.46 | 99.92 | 0.57 | 0.01 | 0.2 | 337.87 | 7.38 | 99.94 | 5.34 | 0.12 | 99.00 |
| Total: | 4863.04 | 100.00 | 66.98 | | 100.00 | 286.24 | | 100.00 | 338.07 | | 100.00 | 5.40 | | 100.00 |

| O | | | HCl | | | Прочие | | |
|---------------|-------|---------------|----------------|-------|---------------|----------------|-------|---------------|
| I | II | III | I | II | III | I | II | III |
| 144.99 | 13.29 | 100.00 | | | | 249.70 | 22.64 | 8.64 |
| | | | 1131.50 | 30.00 | 100.00 | 2640.16 | 70.00 | 91.36 |
| 144.99 | | 100.00 | 1131.50 | | 100.00 | 2889.86 | | 100.00 |
| | | | | | | 1.25 | 0.43 | 0.04 |
| 144.99 | 3.17 | 100.00 | 1131.50 | 24.73 | 100.00 | 2888.61 | 63.13 | 99.96 |
| 373.22 | | 100.00 | 1131.50 | | 100.00 | 2889.86 | | 100.00 |

I – quantity, g; II – content, %; III – distribution, %

The yield of silica in the form of precipitate was ~26% of the weight of the cinder in the charge. The chemical composition of the pure silica obtained was, % (wt.): 99,5 SiO₂; 0,02 Al; 0,07 Ca; 0,02 Fe.

The composition of the obtained mother liquor, g/l: 16.68 Al; 0.14 SiO₂; 84.21 Ca; 1.33 Fe; 281.9 HCl; 0.004 Cu; 0.037 Zn; 0.001 Ni; 0.012 ΣREM; others.

High aluminum extraction into the solution was achieved - 99.92 %.

Extraction of silica into solid commercial product - 99.8 %.

Conclusions

Based on the thermodynamic analysis of the reactions of interaction between the components of the cinder with hydrochloric acid, the behavior of aluminum, iron and non-ferrous metal compounds in the leaching process was studied.

As a result of experimental studies, regularities of aluminum compounds dissolution during hydrochloric acid leaching have been established depending on time, temperature, and hydrochloric acid consumption. Optimal parameters of leaching process providing maximum aluminum recovery into solution in a form of its chloride 99.92 % and high

silica recovery into solid commercial sediment - 99.8 % have been determined.

The mechanism of pre-burned ash leaching in hydrochloric acid has been established. It is shown, that the process speed is limited by anorthite dissolution and leaching of ash by hydrochloric acid proceeds stepwise in 3 stages in the temperature interval: at temperatures 20-40 °C - in the kinetic region (E_a = 83.4 kJ/mol, n = 0.57), at 40-60 °C - in the intermediate region (E_a = 53.12 kJ/mol), at 60-80 °C - in the diffusion region (E_a = 32.34 kJ/mol, n ≈ 1).

Conflict of interests. On behalf of all authors, the corresponding author declares that there is no conflict of interest.

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Алдын ала күйдірілген күлді тұз қышқылымен шаймалау механизмін зерттеу

Досмухамедов Н.К., Жолдасбай Е.Е., Даруеш Ғ.С., Арғын А.Ә., Құрмансейтов М.Б

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 Сараптамадан өтті: 03 қыркүйек 2021
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ТҮЙІНДЕМЕ

Құрамында алюминий бар шикізатты өңдеу үшін тұз қышқылын пайдалану басқа қышқылдармен салыстырғанда бірқатар артықшылықтарға ие, ол артықшылықтарға мыналарды жатқызуға болады: алюминий қосылыстарының ерітіндіге ауысып ыдырауының қарапайымдылығы; HCl-да кремнеземнің ерігіштігінің төмен болуы, қышқылды көп шығындамай қатты қалдықты толық бөліп алу мүмкіндігі және т.б. Жұмыста республика аумағында үлкен көлемде жинақталған күл-қож үйінділерін қайта өңдеу тәсілін қолдану мүмкіндігі қарастырылған. Күл компоненттері мен тұз қышқылының өзара әрекеттесу реакцияларын термодинамикалық талдау негізінде шаймалау кезінде алюминий, темір және түсті металдар қосылыстарының әрекеттері (таралуы) зерттелді. Күлді кальций хлоридімен алдын-ала күйдіру арқылы алюминийдің ерітіндіге жоғары дәрежеде бөлінуі қамтамасыз етіледі. Тәжірибелік зерттеулер негізінде ерітіндіге алюминийді бөліп алу дәрежесіне қышқыл шығынының, уақыттың, температураның әсері анықталды. Шаймалауды жүргізудің оңтайлы режимі жағдайында Т:Ж = 1:3, Т = 60 °С, τ = 60 мин. алюминийдің хлорид түрінде ерітіндіге бөлінуі 99,92% құрады. Бұл ретте қоспаларды ерітіндіге барынша максималды ауыстыру нәтижесінде кремнеземді қатты тұнбаға бөліп алу 99,8% болды. Жұмыста шаймалау процесінің механизмі ұсынылды. Белсендіру энергиясының мәндері және реакциялардың күрделі 3 сатылы сипатын көрсететін реакция тәртібі есептелді. Анортит еріген кезде шаймалаудың шекті кезеңі болатындығы анықталды.

Түйін сөздер: күйінді, шаймалау, тұз қышқылы, процестің механизмі, уақыт, температура, бөліп алу, активтендіру энергиясы.

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Исследование механизма выщелачивания предварительно обожженной золы соляной кислотой

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АННОТАЦИЯ

Использование соляной кислоты для переработки алюминий содержащего сырья имеет ряд преимуществ по сравнению с другими кислотами, к которым можно отнести: простоту разложения соединений алюминия с переводом алюминия в раствор; низкую растворимость кремнезема в HCl, возможность полного отделения твердого остатка без существенных потерь кислоты и др. В работе рассмотрена возможность применения способа для переработки золошлаковых отвалов, накопленных в больших объемах на территории республики. На основании термодинамического анализа реакций взаимодействия между компонентами золы с соляной кислотой изучено поведение соединений алюминия, железа и цветных металлов при выщелачивании. Показано, что предварительный обжиг золы с хлоридом кальция обеспечивает высокое извлечение алюминия в раствор из огарка. На основании экспериментальных исследований установлено влияние времени, температуры и расхода кислоты на степень извлечения алюминия в раствор. В условиях оптимального режима ведения выщелачивания Т:Ж = 1:3, Т = 60 °С, τ = 60 мин. извлечение алюминия в раствор в виде хлорида составило 99,92 %. При этом извлечение кремнезема в твердый осадок за

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счет максимального перевода примесей в раствор составило 99,8 %. Предложен механизм процесса выщелачивания. Рассчитаны значения энергии активации и порядок реакции, указывающие на сложный 3-х ступенчатый характер протекания реакций. Установлено, что лимитирующей стадией при выщелачивании является растворение анортита.

Ключевые слова: огарок, выщелачивание, соляная кислота, механизм процесса, время, температура, извлечение, энергия активации.

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Reference

- [1] Elliot Roth and other. Distributions and Extraction of Rare Earth Elements from Coal and Coal By-Products. 2017 World of Coal Ash Conference in Lexington. – 2017, May 9-11. (In Eng.).
- [2] Aakash Dwivedi and Manish Kumar Jain. Fly ash – waste management and overview: A Review, Recent Research in Science and Technology 2014, 6(1): 30-35. (In Eng.)
- [3] Suhas V. Patil, Suryakant C. Nawle, Sunil J. Kulkarni. Industrial Applications of Fly ash: A Review, International Journal of Science, Engineering and Technology Research (IJSETR). – 2013. – Volume 2, Issue 9. September. – P. 1659-1663. (In Eng.).
- [4] Cherkasova T.G., Cherkasova E.V., Tihomirova A.V. i dr. Ugol'nye othody kak syr'e dlya polucheniya redkih i rasseyannykh elementov [Coal waste as raw materials for obtaining rare and scattered elements]. *Vestnik Kuzbasskogo gosudarstvennogo tekhnicheskogo universiteta = Bulletin of the Kuzbass State Technical University*. - 2016. - No. 6. - P. 185-189.) (In Rus.).
- [5] Ahmed'yanov, A.U., K.ZH. Kirgizbaeva, G.I. Turekhanova, Vtorichnaya pererabotka othodov (zoloshlakov) promyshlennykh predpriyatii [Secondary processing of waste (ash and slag) of industrial enterprises]. *Tekhnicheskie nauki. Gornoe delo = Mining*. - 2018. - No. 10. - P. 7-14.) (In Rus.).
- [6] Pashkova G.L., Saikova S.V., Kuz'min V.I. i dr. Zoly prirodnykh uglei – netradicionnyi syr'evoi istochnik redkih elementov [Natural coal ash-an unconventional raw source of rare elements]. *Journal of Siberian Federal University. Engineering & Technologies = Journal of Siberian Federal University. Engineering & Technologies*. – 2012. – Vol.5. - P. 520-530.) (In Rus.).
- [7] Maksimova A.M. Izvlechenie redkih i redkozemel'nykh metallov iz tekhnogennykh ob'ektov kak put' k racional'nomu osvoeniyu nedr [Extraction of rare and rare earth metals from technogenic objects as a way to rational development of mineral resources]. *Internet-zhurnal "Naukovedenie" = Online journal "Naukovedenie"*. – 2016. – №8(5). – P. 1-11.) (In Rus.).
- [8] Gupta S., Singh Pahwa M., Gupta A. Innovative Price Adjustments Technique for Thermal Coal: A Study of operation Function under Changing Techno Environment. *Global Journal of Management and Business Research Finance*. – 2013. – Vol.13 (4). – P. 8-15. (In Eng.)
- [9] Yao Z.T. and other. A comprehensive review on the applications of coal fly ash. *Earth-Science Reviews*. – 2015. (141). – P. 105–121. DOI: <https://doi.org/10.1016/j.earscirev.2014.11.016> (In Eng.)
- [10] Stoch A. Fly ash from coal combustion - characterization, in Thesis to obtain the Master of Science Degree in Energy Engineering and Management 2015, IST Instituto Superior Técnico Lisbon, Portugal. (In Eng.)
- [11] Dosmukhamedov N., Kaplan V., Zholdasbay E., Daruesh G., Argyn A. Alumina and Silica Produced by Chlorination of Power Plant Fly Ash Treatment. *JOM*. – 2020. – Vol.72(10). – P. 3348-3357. DOI:10.1007/s11837-020-04267-5 (In Eng.)
- [12] Dosmuhamedov N.K., Kaplan V.A., ZHoldasbai E.E., Daruesh G.S., Argyn A.A. Vydelenie zheleza v zhelezosoderzhashchii produkt iz zoly ot szhiganiya Ekibastuzskikh uglei [Isolation of iron into an iron-containing product from ash from burning of Ekibastuz coals]. *Ugol'*. 2021. – № 1, pp.56-61. DOI: <http://dx.doi.org/10.18796/0041-5790-2021-1-56-61> (In Rus.)
- [13] Medvedev A.S. Vyshchelachivanie i sposoby ego intensivifikatsii [Leaching and methods of its intensification]. - M.: MISIS. - 2005. – P. 240). (In Rus.).
- [14] Vol'dman G.M. Teoriya gidrometallurgicheskikh processov [Theory of hydrometallurgical processes]. Moscow: *Internet Engineering*. - 2003. – P. 464). (In Rus.).