

Change of some Physicochemical Characteristics in the Carbonaceous Uranium Ore using Oxidizing Roast

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Abstract We considered the change of the physicochemical characteristics in the carbonaceous uranium ore using oxidizing roast. Oxidizing roasting of the ore at 600°C makes the physicochemical and leaching characteristics was improved.

Key words uranium ore, roast, leaching

Introduction

The great leader Comrade **Kim Il Sung** said as follows.

“To put the national economy on a Juche basis we should first find more satisfactory solutions to the raw materials, fuel and power problems with our domestic resources.

Exploiting our rich mineral resources to the full is an important way of solving these problems.”(“**KIM IL SUNG WORKS**” Vol. 35 P. 309)

Uranium leaching process from a uranium ore is a typical example of reactions between solid and liquid, and its leaching rate depends on the physicochemical characteristics on surface of the ore [3, 4].

Especially, with oxidizing roasting the carbonaceous uranium ore done, the hydrophobic surface of the ore is changed to the hydrophilic one. When leaching uranium out of the roasted ore, penetration rate of the leaching solution into the ore is high, then it is available to have uranium leaching ratio high and to have leaching time short.

Otherwise, when leaching uranium out of the raw ore by the sulphuric acid, the gases such as CO₂ and H₂S discharge and float up to the top of the solution with the carbonaceous substance and the humus, but, there are no such behavior in the leaching of the roasted ore and there are advantage in separating the solid and the liquid.

The data on oxidizing roast of the carbonaceous uranium ore from the mine in our country have not been published yet.

Experiment Method

The oxidizing roasting the ore was carried out in the seramic crucible in the quartz tube with a heater through which air was ventilated with flux of 30L/(h·g) at the various temperature (400 ~800°C) every 2 hours by using the ore with granulation size in the range of 0.65~0.80mm.

The pore distribution and the specific surface area of the ores were measured by the measure equipment on pore using the mercury compression method.

Hardness was measured by using the hardness microscaler “TIII-2” about a unit cube (1cm×1cm×1cm) of the ore abraded smoothly before and after roasting of it at 600°C, respectively.

We laid a weight with 5kg up on the hardness microscaler and made a trace by the diamond weight. And then we measured the length of diagonal in the trace by the microscope and calculated the absolute hardness by the following equation.

$$H = 2 \sin \frac{\alpha}{2} \cdot \frac{P}{d^2} (\text{kg/mm}^2) \quad (1)$$

where α — angle of the diamond weight (°), P — mass of the weight (kg) and d — diagonal length (mm).

On measuring density of the ore were used the raw ore with granulation size less than 0.1mm, the substance floated after leaching by 0.5mol/L H_2SO_4 and washing under the condition of S:L=1:1.5, 1:6, respectively, and the fraction of the ore with granulation size less than 0.1mm roasted at 600 and 800°C.

First, we weighed a density bottle, filled it with a solvent to the scale (in case of the raw and roasted ore-deionized water, in case of floated substance-dioxane) and weighed again.

Second, we weighed the ore, poured it into the density bottle, filled with the solvent up to the scale of the bottle and weighed. Density was calculated with these values and density ρ of the solvents by the following equation.

$$D_{\text{H}_2\text{O}} = \frac{A \rho_{\text{H}_2\text{O}}}{(B + A) - C}, \quad D_{\text{dioxane}} = \frac{A \cdot \rho_{\text{dioxane}}}{(B + A) - C} \quad (2)$$

where A - the weight of the ore, B - the weight when feeling the solvent up to the scale and C - the weight when the ore was poured into the density bottle and the solvent was filled up to the scale of it.

Physicochemical characteristics on surface of the ore were investigated by measuring the electric kinetic potential (ζ -potential) and the electric osmosis velocity (Q) in the raw ore and the roasted ore, respectively. Absorption speed and saturation amount of the water in the raw ore and the roasted ore were measured, respectively, and the method follows.

We poured the raw ore or the roasted ore of 5.00g (granulation size less than 0.1mm, the roasting of the raw ore of 5.00g for 2 hours at 600°C), made it hard and contacted it with the capillary (diameter - 1.8mm) filled with the water. Movement velocity of the surface of the water was measured, and then saturation amount of the water was determined.

Leaching of uranium from the raw ore and the roasted ore was carried out with and without the oxidation reagent, respectively, uranium concentration was determined by the spectrophotometry with arsenazo-III from the leaching solution of 1mL and leaching ratio of uranium was calculated by it.

Discussion

① Pore volume and specific surface area of the ores with the roast temperature

Pore volume and specific surface area of the ores roasted at temperature in the range between 400 and 800°C are shown in table 1.

As shown in table 1, specific surface area of the ore roasted at 400°C is the most great, but, it comes down with the roast temperature, and comes up a little at 800°C because moisture and volatile component adsorbed into the ore were escaped without any chemical reaction [1, 2].

Table 1. Pore volume and specific surface area of the ores with the roast temperature

Section	Raw ore	The roasted ore (roast temperature)/°C				
		400	500	600	700	800
Specific surface area /($\text{m}^2 \cdot \text{g}^{-1}$)	28.6	39.6	25.4	20.1	14.7	19.9
Pore volume /($\text{mm}^3 \cdot \text{g}^{-1}$)	211.3	299.1	352.5	388.2	475.5	439.6

In fact, color of the ore roasted at 400°C is the same as the one of the raw ore.

At temperature over 400°C the combustion of the carbonaceous material and the decomposition of the sulfide and the carbonate occur, it results in decreasing of micropore's ratio and increasing of macropore's ratio, therefore, whole pore volume increases while specific surface area decreases. But, at 800°C, the oxides in the ore form the double oxide and some sintering reactions occur, so micropores are formed while specific surface area increases a little again.

② Hardness and density of the roasted ores

Generally, hardness of an ore is important factor on which power consumption in crushing and grinding process depends, power consumption increases with hardness of ore.

Density of ore is also important thing in a process operation. Especially, precipitating rate increases and operating time decreases with density.

Diagonal length of the traces measured by using the hardness micrometer was presented in table 2.

Table 2. Diagonal length of the traces

Sort of the ores	1	2	3	4	5	Average
Raw ore/mm	0.413	0.427	0.440	0.387	—	0.417
Ore roasted at (600°C)/mm	1.32	1.38	1.38	1.14	1.14	1.27

With calculated from equation (1) with data of table 2, absolute hardness in the raw ore is 53.3kg/mm^2 , and the one in the ore roasted at 600°C is 5.71kg/mm^2 . That is, when roasting at 600°C, its hardness is almost 10 times smaller than that of the raw ore, so that grinding becomes easier.

In table 3 are shown density values in the samples calculated from equation (2).

Table 3. Density values in the raw and the roasted ores (g/cm^3)

Sort of the ores	1	2	3	Average
The raw ore	2.290	2.253	2.260	2.268
The floated substance	2.010	2.008	2.010	2.009
The ore roasted at 600°C	2.654	2.703	2.651	2.670
The ore roasted at 800°C	2.687	2.705	2.690	2.696

As shown in table 3, roasting the raw ore makes its density increased almost 1.18 times because the carbonaceous and the humic substance with low density are eliminated from the ore [5–7].

And density of the floated substance is 2 times higher than that of the water, however, it is floated because it contains the hydrophobic substance a lot and, therefore, such gas drops as CO_2 and H_2S being generated in the leaching process using the diluted sulphuric acid stick on the hydrophobic surface[8–15].

This result shows that the time for separation between solid and liquid is reduced because of rapid sedimentation of the roasted ore and, otherwise, the process management is favorable because of absence of the floated substance.

③ Electro-chemical characteristics on surface of the ore

Electric osmosis velocity (Q ($\text{m}^3 \cdot \text{s}^{-1} \cdot \text{A}^{-1}$)) and

ζ -potential (mV) taking account of electric conductivity on surface can be expressed as the following equations.

$$\zeta = \frac{\eta \cdot Q \cdot \chi_{\text{surface}}}{\varepsilon \cdot \varepsilon_0} \cdot 10^3 \quad (3)$$

$$k = \pi \cdot r^2 \cdot L = 1.37 \cdot 10^{-8} \text{ m}^3, \quad Q = \frac{k}{t \cdot I},$$

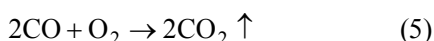
where η - viscosity of water at 15°C , ε - relative dielectric constant at 15°C , ε_0 - absolute dielectric constant of vacuum, χ_{surface} - specific electric conductivity on surface of the ore, I - current intensity, k - liquid volume in the measuring length unit (cm) and t - time.

Influence of the roasting temperature on Q and ζ -potential was shown in Fig. 1 and 2.

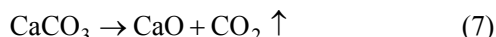
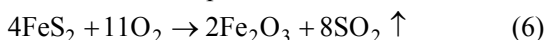
As seen in Fig. 1, Q are $1.32 \cdot 10^{-4}$ and $9 \cdot 10^{-5} \text{ mL/s}$ in the ores roasted at 500°C and at 600°C , respectively, so those are much grater than $8.98 \cdot 10^{-6} \text{ mL/s}$ in the raw ore, because wet ability of the ore was enhanced by elimination of the carbonaceous substance and etc.

As shown in Fig. 2, ζ -potential tends to Q for its change.

Oxidation reaction of carbon starts to take place at 450°C .



Otherwise, oxidation of the sulfides and decomposition of the carbonates occur at temperature of $500 \sim 700^\circ\text{C}$.



Among the uranium compounds contained in the ore, UO_2 and U_3O_8 soluble badly by the dilute acid are turned into UO_3 soluble well by the dilute acid.



Hence, when oxidizing roasting the ore, oxidation of the kind of sulfide and carbon occurs and the compounds in the ore react with the gases being produced as a result of roasting to form the oxides, the sulfites and the sulphates.

As shown in Fig. 2, the hydrophobic substance in the ore, the carbonaceous substance and some sulfide are removed at the temperature lower 500°C , so ζ -potential in the roasted ore is growing up, when roasting at $600 \sim 700^\circ\text{C}$ such chemical change is mainly completed, so that Fe^{2+} , Fe^{3+} , Mg^{2+} , Ca^{2+} and so on take part in formation of the electric double layer on interface between

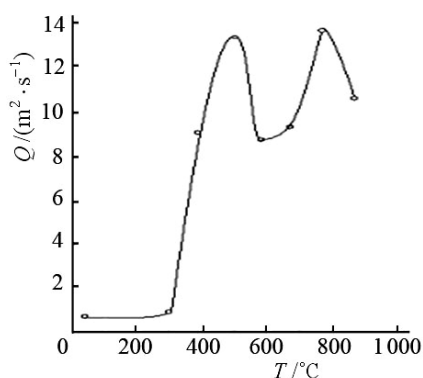


Fig. 1. Influence of roasting temperature on Q

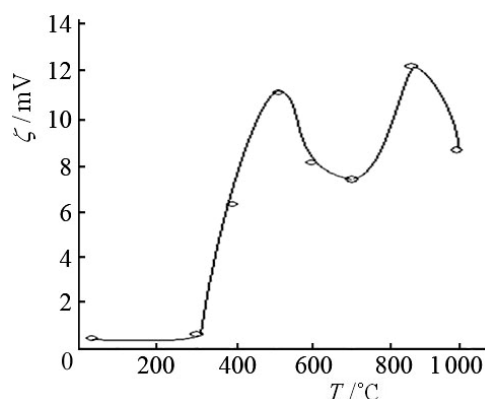


Fig. 2. Influence of roasting temperature on ζ -potential

carbonaceous uranium ore was shown in Fig. 3.

As shown in Fig. 3, water absorption velocity and water saturation amount increase almost lineally according to roasting temperature in the range of 300~700°C.

In the ore roasted at 600°C, these are 1.5 times more than those in the raw ore, because the hydrophobic components have been got rid from surface of the ore and pore ratio of the ore has increased as a result of the roasting (table 1).

Therefore, oxidizing roasting makes surface of the ore turned into the one favorable to chemical reaction between solid and liquid.

⑤ Uranium leaching from the roasted ore

We carried out leaching experiment under the condition of particle size of -0.1mm , 0.5mol/L sulphuric acid, $S:L$ of $1:1.5$, temperature of 60°C and leaching time of 6h for the roasted ore and the raw ore, respectively. At that time, was also considered the case that MnO_2 was added by 0.4% to the ore as an oxidant in order to check out the effect of oxidizing roasting.

The result is presented in table 4.

As shown in table 4, leaching ratio of uranium increased with the roasting temperature whether there was the oxidant or not, and it decreased at temperature over 600°C.

the ore and the solution. By strong electric attraction of such cations is compressed the diffusion layer of the electric double layer formed on surface of the ore which lies in a thermodynamic equilibrium state with the leaching dispersion, it results in decreasing of ζ -potential.

Otherwise, at temperature over 800°C , double oxides, FeO , Fe_2O_3 , Fe_2O_3 , MgO and etc., are formed, and, especially, at 900°C , even partial sintering in the ore occurs, so ζ -potential becomes to be small.

④ Absorption characteristics of water in the ores

Effect of the temperature on water absorption velocity and water saturation amount in the

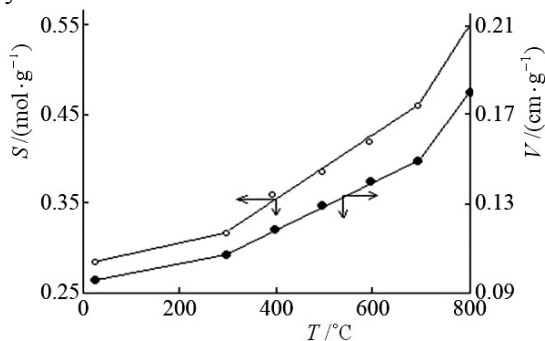


Fig. 3. Effect of roasting temperature on water absorption velocity(V) and water saturation amount (S)

Table 4. Leaching ratio of uranium with the roasting temperature

Oxidant	Roasting temperature/ $^\circ\text{C}$				
	Ore	500	600	700	800
Absence	88.0	90.8	93.5	91.4	88.0
Existence	91.4	95.0	98.0	96.3	89.6
Enhanced Leaching ratio	3.4	4.2	4.5	4.9	1.6

The most high leaching ratio obtained in the ore roasted at 600°C resulted from that the surface electric property has improved while, first of all, that temperature has being the most proper for oxidation of UO_2 to UO_3 . In case of the ore roasted at 600°C without the oxidant, its leaching ratio was more 2.1% high than that in case of the raw ore with the oxidant.

Otherwise, leaching ratio decreased because of reduction of UO_3 to UO_2 at temperature over 600°C and because of partial sintering of the ore at temperature around 800°C.

Conclusion

With the carbonaceous ore roasted at 600°C, pore ratio of it increased more 1.84 times, specific surface area decreased less 1.42 times, its hardness decreased almost less 10 times and its density increased more 1.18 times than that of the raw ore. Otherwise, electric osmosis velocity in the ore roasted at 600°C was higher 7.8 times than that in the raw ore, and water saturation amount and absorption velocity of water in the ore roasted at 600°C were approximately more 1.5 times than that in the raw ore, respectively. In case of the ore roasted at 600°C, leaching ratio was enhanced more 2.1% without the oxidant than that in case of the raw ore with the oxidant.

References

- [1] 김대연 등; 핵동력과 연료순환, 김일성종합대학출판사, 12~16, 주체96(2007).
- [2] 김대연 등; 핵동력의 리용과 전망, 김일성종합대학출판사, 48~53, 주체93(2004).
- [3] Y. A. El-Nadi; International Journal of Mineral Processing, 76, 1, 101, 2005.
- [4] L. I. Vodolazv; Atomic Energy, 90, 3, 193, 2001.
- [5] E. K. Potter; International Journal of Mass Spectrometry, 240, 1, 27, 2005.
- [6] Soundry David; Chemical Geology, 189, 3, 213, 2002.
- [7] F. B. Ribero; Applied Radiation and Isotopes, 54, 1, 153, 2001.
- [8] G. P. Curtis; Applied Geochemistry, 19, 10, 1643, 2004.
- [9] T. W. Marrer; Chemosphere, 54, 7, 873, 2004.
- [10] H. Ramebsck; J. Nuclear Materials, 277, 2, 288, 2000.
- [11] M. Amme; J. Nuclear Materials, 341, 3, 209, 2000.
- [12] Y. A. El-Nadi; International Journal of Mineral Processing, 76, 1, 101, 2005.
- [13] Yoshihiro Megur; J. Supercritical Fluids, 31, 141, 2004.
- [14] Harvinderpal Singh; Hydrometallurgy, 59, 69, 2001.
- [15] T. V. Molchanova; Atomic Energy, 90, 2, 2001.