



Recovery Rhenium from roasted dust through super Para-magnetic Nano-particles



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ARTICLE INFO

Article history:

Received 15 October 2015

Received in revised form 5 July 2016

Accepted 19 July 2016

Available online 20 July 2016

Keywords:

Rhenium

Super Para-magnetic Nano-particles

Molybdenum

Heat roasting

ABSTRACT

Rhenium, a valuable and rare metal, is a byproduct of Molybdenum. It is usually produced through the dust and smoke of roasting Molybdenum concentration. Heat roasting is the traditional method of producing Molybdenum from sulphuric resources (Molybdenum), which not only creates environmental problems but also wastes some of the existing Rhenium.

To produce Rhenium, in this research, a Nano-technology-based solution is presented which is modern, fast, and economical. Rhenium, classified among the external mediator elements, is in group 7 of the periodic table. Regarding the arrangement of Rhenium's electron layer capacity, i.e. $5d^5$, its d orbital is completely sub-saturated and therefore, equipped with magnetic characteristic. As such, Rhenium can also be considered as a Para-magnetic metal. In this research, after providing metal ions solution, the absorption of Rhenium ions is examined under different operational conditions through the super Para-magnetic Nano-particles of Fe_3O_4 , which helped to determine the best conditions for absorption to occur. Washing the Nano-absorbent after recovering Rhenium ions from Nano-particles makes it prepared for further operations.

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1. Introduction

Rhenium, having atomic weight 186 and atomic number 75, usually exists in forms of either gray-to-black powder or a silver-to-white solid.

Compared to other elements, Rhenium owns the highest melting point after Tungsten and stands in the fourth rank concerning its special weight. Its special electric resistance is relatively four times more than Tungsten and Molybdenum. Besides being more stable and flexible than Tungsten and Molybdenum, Rhenium is equipped with magnetic and super-conducting characteristics [1–3].

Rhenium, among its diverse applications, is mainly utilized in electronic, aviation, shipbuilding as well as oil refinery industries [4,5].

Nowadays, the required Rhenium for industrial applications is supplied from the following resources: 1-Molybdenum concentration, 2-Copper concentration, 3-byproducts of lead, zinc and cadmium factories, 4-Rhenium-containing metal wastes and 5-petrochemical industries catalysts wastes.

In general, the main resource of Rhenium exists in sulfide form near its similar element, i.e. Molybdenum. That is why Rhenium and Molybdenum are usually found in Porphyry Copper supplies [6].

Iran has not only innumerable Copper sources but also Molybdenum as well as Rhenium mines. Out of the production of 2900 tons of Molybdenum concentration in each year, 2 tons of Rhenium is produced in Iran which, as the result of roasting Molybdenum concentration, is wasted in form of gas-containing dust.

Converting Molybdenum to Molybdenum oxide, on condition of recovering at least 90% of Rhenium, is quite beneficial from an economic angle. Hence, it is necessary to find a proper solution to recover Rhenium from Molybdenum concentration [7].

Rhenium, in mineral Molybdenum, is more often than not in form of sulfide Rhenium. Molybdenum, which is separated from Copper ore during the floatation operation, is often considered as a byproduct produced in Copper industry [8].

In all Rhenium-containing minerals, Rhenium is structured in a sulfide form. Processing operations so as to produce metals are often accompanied with roasting operations, which converts Rhenium to Rhenium heptoxide. In dust catchers, Rhenium heptoxide is finally collected in company of unroasted oxides and sulfide. In order to process Rhenium, it is respectively necessary to convert Rhenium oxide to solution, to conduct absorption operations and Rhenium separation [8].

Concerning the negligible amount of Rhenium in its raw forms, Hydrometallurgy-oriented methods are suggested to extract it. These methods include liquidation, concentration and crystallization processes respectively. The most significant methods for separating Rhenium from

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solution include chlorination [9], solvent extraction [9], activated Charcoal [10,11] and ion interchange [12,13].

Nevertheless, separating Rhenium from environment through the above-mentioned physical and chemical methods is often both ineffective and expensive and causes many environmental problems [14].

Magnetic field, given its low cost, simplicity, high speed as well as fair efficiency, has recently been utilized in wide scopes in separating Rhenium process as the result of which several absorbents are introduced. For instance, magnetic Nano-particles can be used to absorb heavy metals from liquid environments [15].

Magnetic Nano-particles, among other identified Nano-particles, are mainly used as absorbents to clean off impurities. This method has several advantages: producing high quality Nano-particles through simple methods. Magnetic Nano-particles also have high absorption capacity and super-magnetic characteristics; that is to say that these Nano-absorbents, after absorbing impurities, can be easily absorbed from solution through an external magnetic field [16].

In this research, after providing solutions of metal ions, the magnetic Nano-particles of Fe_3O_4 , which are super-magnetic, are transferred to the solution. Subsequently, the existent Rhenium is absorbed and then collected from the solution surface through a magnetic field. Finally, through a chemical process, the produced Rhenium solution is separated from Nano-particles.

2. Theoretical framework

Rhenium, classified among the external mediator elements, is in group 7 of the periodic table. Regarding the arrangement of Rhenium's electron layer capacity, i.e. $5d^5$, its d orbital is completely sub-saturated and therefore, equipped with magnetic characteristic. According to these characteristics, Rhenium is a Para-magnetic element, which implies that Para magnetic particles can be used to absorb Rhenium. In this study, heavy metal absorption in room temperature is done through taking advantage of formerly-prepared absorbents. To do so, a certain amount of absorbents is added to a certain volume of solution which contains heavy metals characterized with certain density and pH. After the stirring process, a magnetic field is passed upon the absorbent-containing solutions. As the result of this process, heavy-metals-containing absorbent is separated from the solution. Also, desorption or separating identified metals from Nano-absorbents takes place in the washing stage. The final density of the solution is afterwards calculated with regard to the concerned metal's special method. Having the initial and final density paves the way for calculating the removed heavy metal through following formula:

$$R = 100 \frac{C_0 - C_e}{C_0}$$

In this formula C_0 denotes the initial density of a heavy metal while C_e denotes the balanced or final density of the solution [17].

3. Experimental section

Liquidation, absorption, and desorption constitute the experimental structure of the paper. In each of these stages, in order to achieve optimum conditions, several parameters were studied in discrete examinations. In liquidation stage, parameters like density, alcohol efficacy, stirring speed, temperature, and time are examined while in the second stage parameters like PH, absorption, absorbent value, contact time, density of metal solution and temperature are studied. In this stage, also, optimum conditions for absorbent activity are provided. Finally, in desorption stage, several solutions were employed to separate certain elements from absorbent. Afterwards, absorbent was restored through washing operations so that it can be used for further operations.

3.1. Nano-particles

Iron oxide Nano-particles (Fe_3O_4), coated with active carbon, are used in conducting this research. To measure and examine the characteristics of these synthesized magnetic Nano-particles and Nano-composites, a number of techniques have been used; X-ray diffraction (XRD), transmission electron microscopy (TEM) and vibrating sample magnetometer (VSM). While the vibrating sample magnetometer helps to determine magnetic attributes, the X-ray diffraction helps to determine X-ray diffraction model and the purity of the generated Nano-particles.

Fig. 1 shows the XRD spectrum of iron oxide which is respectively modified and synthesized with activated carbon and co-sedimentation method. The peaks correspond to the standard XRD spectrum of iron oxide modified with activated carbon. The network parameters equate to $a = b = c = 8.374 \text{ \AA}$ and $\alpha = \beta = \gamma = 90$, which guarantees iron oxide's reverse cubic spinal structure. In diffraction pattern, also, different peaks corresponding to the miller plates are determined at 2θ which are compatible with the standard miller plates of iron oxide's reverse cubic spinal structure. Accordingly we can conclude that the concerned synthesis, characterized with a co-sedimentation technique, is a successful one.

$$D = k\lambda/\beta \cos\theta$$

Accordingly, the approximate size of iron oxide Nano-crystallites, which are synthesized employing co-sedimentation method, is around 50 nm.

We also use transmission electron microscope (TEM) to both examine the structural form and determine the approximate size of particles as well as their distribution in samples of Nano-particles of iron oxide modified with activated carbon.

Fig. 2 shows an image of carbon-activated modified iron oxide Nano-particles provided by TEM. As it can be discerned, most of the particles have almost a cubic shape and a size corresponding to 131 nm. In the X-ray diffraction, according to Scherrer equation, the average size of Nano-crystallites is around 50 nm. Correspondingly, according to the drawn histogram on TEM image, the size of grains is around 131 nm. As a result, in the synthesized Nano-particles each grain consists of several micro-crystallites.

Fig. 3 presents the magnetization curve based on magnetic field of iron oxide samples modified with activated carbon. The modified iron oxide's magnetic saturation corresponds to 87.44 emu/g.

3.2. Liquidation, dust, and roast

In this section, we aim to examine the liquidation of roasted Molybdenum concentration in Sarcheshmeh Copper mine (Kerman Province of Iran) to recover the existing Rhenium.

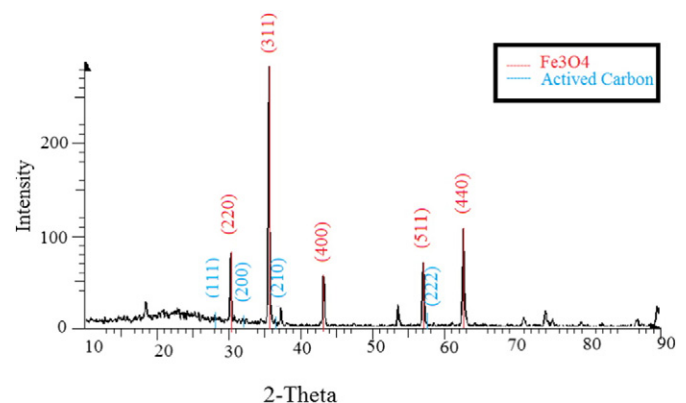


Fig. 1. X-ray diffraction of iron oxide Nano-particles coated with activated carbon.

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