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Abstract

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APPLICATION OF THE NUCLEAR REACTION (α, n, γ) TO THE DETERMINATION OF BERYLLIUM IN BENEFICIATION PRODUCTS

The use of nuclear reactions makes it possible to determine certain elements by their specific nuclear properties. To determine beryllium in ores and beneficiation products, the nuclear reactions (γ, n) (^{1}-^{3}) and (α, n) (^{4}) are used. The use of the nuclear reaction (γ, n) gives exceptional selectivity, since under the action of γ-quanta with energies in the range from 1.63 MeV to 2.23 MeV, neutrons are emitted, by the photonuclear effect, only from beryllium. The inconvenience of using this reaction for the determination of beryllium is the need to employ high activities of hard γ-emitters, for example Sb^{124}, requiring substantial shielding. In addition, relatively large amounts of the material being analyzed are required for determining beryllium by the photonuclear reaction (γ, n). From this point of view, the use of the nuclear reaction (α, n) is more convenient. In this case, neutrons are formed as a result of a nuclear reaction with low-penetrating α-particles, which does not require bulky shielding.

However, the drawback of this nuclear reaction in determining beryllium is the lack of selectivity, since when the sample being analyzed is bombarded with α-particles, neutrons may be emitted not only from beryllium, but also from boron, fluorine, and lithium, which are often present in the analyzed samples in appreciable amounts (especially fluorine in the form of fluorite). When beneficiation products contain a large amount of fluorite in a certain constant quantity, this leads to a shift of the calibration curve (^{5}); but if the amount of fluorite in the beryllium concentrate changes, this will lead to significant errors in determining beryllium. When using the nuclear reaction (α, n) to determine beryllium in beneficiation products, it is possible to record not the neutrons, but the γ-radiation accompanying this reaction. In the nuclear reaction $Be^9 + He^4 \rightarrow C^{12} + n^1$, an excited C^{12} nucleus is formed. As a result of de-excitation of the excited C^{12} nucleus, hard γ-quanta with energies of 4.45 and 7.65 MeV arise (^{6}).

The excited nuclei of elements formed as a result of the interaction of α-particles with the nuclei of boron, fluorine, and lithium, which have the greatest neutron

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yields in the (α, n) reaction, do not give γ-quanta of such energies (^{6}). This makes it possible to determine beryllium in beneficiation products in the presence of boron, fluorine, and lithium, independently of their amount in the sample being analyzed. The γ-quanta arising as a result of the nuclear reaction (α, n) on beryllium were previously used (^{7}) to determine beryllium in aerosols; in that work an α-source of Po^{210} with an activity of 2.6 Ci was used.

The convenience of using α-sources of Po^{210} for determining beryllium by the nuclear reaction $(\alpha, n\gamma)$ lies in the fact that, in the region above 150 keV, the γ-radiation spectrum of Po^{210} contains only γ-quanta with an energy of 0.8 MeV. The intensity of the 0.8 MeV γ-radiation is 1.2 γ-quanta for every 10^5 α-particles (^{8}). This circumstance makes it convenient to determine beryllium from γ-quanta with an energy of 4.45 MeV; moreover, an experimenter working with a Po^{210} α-source of high activity does not need protection from

such weak γ-radiation, which makes the device for irradiating the analyzed concentration products very light and compact. The only protective device is merely a thin foil of heavy metal, protecting surrounding objects from contamination by Po^{210} due to recoil. It is still more convenient to deposit a thin layer of heavy metal, protecting against recoil, directly on the surface of the α-source. The high energy of the γ-quanta emitted by the products of the nuclear reaction (α, n) on beryllium (excited C^{12} nuclei) makes it possible to use, for discriminating γ-quanta of lower energies arising from the interaction of α-particles with nuclei of other elements, instead of the amplitude analyzers usually used for γ-spectroscopy, a broadband amplifier—discriminator of the USh-2 type.

Registration of the γ-quanta arising as a result of the nuclear reaction $(\alpha, n\gamma)$ on beryllium was carried out by us with the aid of a scintillation spectrometric NaI(Tl) crystal (diameter 30 mm, height 40 mm) and a universal scintillation detector USD-1. The counting of pulses after the amplifier-discriminator was carried out with a counting device of the PS-10000 type.

Fig. 1. γ-spectrum obtained upon irradiation of beryllium oxide with α-particles: N—count of γ-quanta, D—discrimination level

In Fig. 1 is shown the γ-spectrum obtained by us upon irradiation with α-particles of chemically pure beryllium oxide. To record the spectrum, an FEU-13A photomultiplier was used. The α-radiation source with the analyzed sample was placed on the detector crystal, set in a protective housing. In the spectrum it was possible to obtain peaks characteristic of the Po—Be source. A certain blurring of the spectrum, compared with known results (^{6}), is explained by the forced placement, owing to the low activity of the α-source, of the sample

Fig. 2. γ-spectrum obtained upon irradiation of fluorite with α-particles

Figure 2: Fig. 2. γ-spectrum obtained upon irradiation of fluorite with α-particles

Fig. 3. Dependence of the count of γ-quanta with energy above 4 MeV on the content of beryllium oxide

Figure 3: Fig. 3. Dependence of the count of γ-quanta with energy above 4 MeV on the content of beryllium oxide

directly on the crystal and by the absence of collimation of the γ-quantum beam. However, this is not an obstacle for analysis, since, owing to the high energies of the γ-quanta of the products of the reaction (α, n) on beryllium, there is no need to determine the BeO content from the characteristic peak of the spectrum; it is sufficient only to discriminate γ-quanta of lower energy. Figure 2 shows the spectrum obtained upon irradiation of fluorite with α-particles. The count of γ-quanta emitted by the products of the nuclear reaction (α, n) on fluorine ceases completely at a discrimination of 15 V. The use of an integral discriminator is convenient because of the greater availability and simplicity of the device in comparison with an amplitude analyzer.

Fig. 2. γ-spectrum obtained upon irradiation of fluorite with α-particles

The determination of the beryllium content was carried out by us in mixtures prepared from pure beryl ($Be_3Al_2(Si_6O_{18})$) and fluorite (CaF_2) of flotation size ($-200 + 350$ mesh), which represent the worst case for determining beryllium by means of the nuclear reaction (α, n), since determination of beryllium in the presence of large amounts of fluorine by the nuclear reaction (α, n) from the neutron count is altogether impossible. In Fig. 3 is given a calibration graph for determining beryllium oxide at various contents of beryl and fluorite. The straight-line character of the calibration graph shows that fluorine, in this method of determination, is not an interfering element. Similar results are also obtained in

in the presence of other light elements having a large yield of the nuclear reaction (α, n). The influence on the determination of beryllium of the presence of a large amount of aluminum in the analyzed samples was not detected.

The use of the nuclear reaction $(\alpha, n\gamma)$, occurring in a thin surface layer of the substance being analyzed (of the order of 20 μ), makes it possible to use very small weighed samples, prepared, for example, by dusting the substance being analyzed onto the appropriate backing; for this purpose a sample of the order of 50-100 mg is quite sufficient.

Fig. 3. Dependence of the count of γ-quanta with energy above 4 MeV on the content of beryllium oxide

The relatively high content of beryllium in flotation concentrates made it possible for us to carry out the determination using a 5 mCi α-source.

At a BeO content of 1% and a counting time of 30 min, the relative error of the determination does not exceed 15%.

An increase in the BeO content leads to an increase in the number of recorded γ-quanta and thus gives greater accuracy of determination. Greater accuracy of determination can be obtained by using α-sources of higher activity, which will also lead to a reduction in the determination time.

With the use of an α-source with an activity of the order of one curie, rapid determination of BeO will be possible at contents of hundredths of a percent.

Just as the nuclear reaction (α, n), the reaction $(\alpha, n\gamma)$ can be used for the determination of beryllium in solutions (^{9}), as well as in alloys.

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CITED LITERATURE

1. A. M. Gaudin, J. H. Pannel, *Anal. Chem.*, **23**, 1261 (1951).
2. B. S. Aidarkin et al., *Trudy Radievogo inst. AN SSSR*, **5**, no. 2 (1957).
3. Kh. B. Mezhiborskaya, *Photoneutron Method for Determining Beryllium*, Moscow, 1961.
4. I. N. Plaksin, V. N. Smirnov, L. P. Starchik, *DAN*, **127**, no. 3, 618 (1959).
5. I. N. Plaksin, V. N. Smirnov, L. P. Starchik, *Atomnaya energiya*, **9**, no. 5, 361 (1960).
6. Yu. A. Nemilov, A. I. Pisarevskii, *Trudy Radievogo inst. AN SSSR*, **9** (1959).
7. R. Gold, *Nucleonics*, **15**, 11, 114 (1957).
8. N. S. Shimanskaya, *ZhETF*, **31**, no. 2, 174 (1956).
9. I. N. Plaksin, M. A. Belyakov et al., *DAN*, **139**, no. 2 (1961).

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