MULTI-ELEMENT ANALYSIS OF GOLD ORE MILL HEADS BY INSTRUMENTAL NEUTRON ACTIVATION TECHNIQUE

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ABSTRACT

Instrumental neutron activation analysis by Americium-Beryllium radioisotope neutron source has been employed for the multi-element analysis of gold ore mill heads from five different sites of the State Gold Mine at Prestea in Ghana. Gold was identified in ppm levels. The major elements identified were Al, Na and K. These were found to be common to all the five sites. The minor elements found were Cu, As, Mn, Ca, Sb, Mg, V and Br. Some of the minor elements were however absent at some of the sites. The following elements, Fe, Rb, Sr and Zr were also identified but could not be qualified.

KEYWORDS: *Multi-element analysis, Instrumental neutron activation, thermal neutrons, Americium-Beryllium neutron source, Gold ore mill heads.*

INTRODUCTION

The mining industry in Ghana constitutes the second major economic activity apart from agriculture. The most important minerals with significant output are gold, diamond, manganese and bauxite. Gold mining is however, the most dominant industry in the mining sector of the country [1].

Presently, with the opening of two new mines, there are seven major mines in operation in Ghana. Four of these mines located at Prestea, Tarkwa, Dunkwa-on-Offin and Konongo are managed by the State Gold Mining Corporation of Ghana.

In view of the variation of gold concentration of the ore body of mining sites, it is very necessary to routinely analyse the ore mill heads to ensure that gold production from the mines is cost effective. In this regard, it is important to employ analytical methods which are fast and reliable for such routine analysis. Besides, the gold ore in Ghana has been found to contain some other important minerals including silver [2].

The objective of this work was to employ neutron activation analysis, using thermal neutrons from a low flux Am-Be radioisotope for such analysis. Neutron activation analysis was chosen because it has been established as a powerful nuclear analytical technique for multi-element analysis when a high flux is employed. The other advantages of this method are that it is fast, reliable, and with modern High Purity Germanium (HPGe) detector system being employed, very high energy resolution is achieved. Thus a single measurement is capable of producing a spectrum with well resolved energy peaks corresponding to the elements in the sample that have undergone the (n,γ) reaction. Above all, this method is non-destructive indicating that the original sample may be retrieved with negligible chemical changes.

THEORY

Suppose a sample of gold ore mill heads is exposed to a thermal neutron flux for a period of time T and then allowed a "cooling" (delay) time T_d followed by a counting time T_c. If a gamma detector system with a photo-peak efficiency of $\varepsilon(E_i)$ for a gamma energy E_i is used to count the gamma radiations, then the mass of the i-th element present in the sample may be expressed [3] by

$$m_i = C_i \lambda_i M_i / \{f\sigma_i\theta_if_i\varepsilon(E_i) GN_{av}K_i\} \qquad (1)$$

$$K_i = \{1-\exp(-\lambda_i T_i)\}(1-\exp(-\lambda_i T_c))\exp(-\lambda_iT_d) \qquad (2)$$

where

$C_i =$ counts under the photo-peak of nuclide i with energy E_i

$\sigma =$ activation cross-section of the (n,γ) reaction,

$\lambda_i =$ the decay constant ($\lambda_i = 0.693/T_{1/2}$, where $T_{1/2}$ is the half-life)

$\theta_i =$ isotopic abundance of the target nuclide

$N_{av} =$ Avogadro's number (6.022×10^{23} atoms per mole)

$M_i =$ chemical atomic weight of the i-th element

$G =$ sample-detector geometric factor

$f_i =$ gamma yield (number of gammas per decay)

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The nuclear constants $T_{1/2}$, M_i, σ_i, θ_i, and f_i may be obtained from Handbook on Nuclear Activation Data [4]. The measurable parameters in the equation (2) are C_i, f, G and $\varepsilon(E_i)$. Thus, taking a known weight of the gold ore mill heads for irradiation, the amount of the various elements identified may be determined, and hence their percentage abundance in the sample calculated.

EXPERIMENTAL

Irradiation Source

The irradiation source is a 20 Curie Am-Be radioactive neutron source. It is cylindrically shaped and is fixed in a holder at the center of a fiber-glass tank, filled with de-ionized water. The de-ionized water serves a dual purpose of moderator and also absorber of neutrons. Extra shielding is provided by concrete blocks arranged round the tank. Tranfer of sample to and from the neutron source is by means of a flexo-rabbit pneumatic transfer system operating under a pressure of 15 psi, giving a sample transfer time of 1.3 seconds [5]. The thermal neutron flux at the irradiation site is $1.124 \times 10^5 ns^{-1}cm^{-2}$ [6].

Sample Preparation and Irradiation

Forty gold ore mill head samples, each weighing about 200 grams from various sites, were supplied by the State Gold Mines at Prestea. These were already milled into powder form. Of the five mining sites selected, duplicate samples, each weighing between 17 and 18 grams were loaded into the rabbit plastic containers for irradiation. Each of the samples was sent by the pneumatic transfer system into the Am-Be source for irradiation. This is because the system allows only one sample irradiation at a time. The irradiation schemes were chosen so as to take into account the half-lives of the radionuclides. In this regard, the following irradiation times were chosen, 10 minutes, 3 hours, 1 day, 3 days, and more than 10 days. At the end of each irradiation the sample was returned for counting, with the appropriate delay (cooling) time allowed where necessary.

Data Processing

The detector type used for the counting of signals was an ENERTEC High Purity Germanium (HPGe) detector of 3000 (+ve) bias and a resolution of 2.55 KeV for 1332 KeV photo peak of Co-60. The associated electronics are: high voltage supply (Canberra model 3105), spectroscopy amplifier (Canberra model 2010) and Canberra Multi-Channel Analyzer (MCA) Series 35-Plus.

The signals from the detector were passed through the spectroscopy amplifier, and then accumulated by the MCA for a present time. The spectra from the MCA were transferred to a DEC 350 microcomputer for analysis, using a Gamma Spectrum Analysis software PRO/CEBAS supplied by the IAEA. This software identifies the various photopeaks and works out

the areas under them. Figure 1 shows a block diagram of the PC based Gamma spectrometry system for data acquisition and analysis.

By means of equation (1) the mass of each of the identified elements was calculated, and hence its abundance in the sample determined. The validation of the analytical procedure was undertaken by irradiating a standard reference material (SRM) Black Fly Ash [7], and counting under identical experimental conditions.
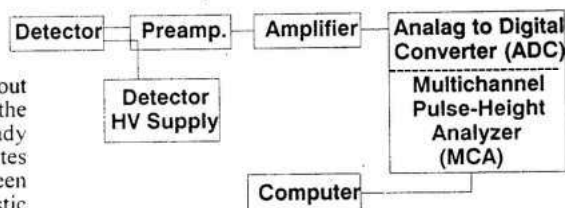

Fig. 1: A block diagram of the electronics setup of the PC based Gamma Spectrometry System for Data Acquisition and Amalysis.

RESULTS AND ANALYSIS

Figure 2 is a display of a typical spectrum of the gold ore mill heads showing some identified radionuclides. Table 1 also shows the results of measurements for five sites. Gold was found in three of the five sites, and this varies from 8-16 ppm. It could not however be detected for two sites N/S 27 and N/S 25.

The major elements Na, Al and K were found at all the five sites. Of these, Al was found to be by far the most abundant. This is not surprising because Prestea is near Awaso, which is one of the main Bauxite deposits in Ghana. The minor elements which were found common to all the sites are Cu, As and Mn. The presence of As is also expected, since the geology of the area indicates that the ore body is Arsenopyrite [2]. The presence of Ag is also expected, in view of the fact that it is reported [8] that there is up to 10% is silver associated with the gold, and this helps to pay for the cost of refining the gold from the ore.

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CONCLUSION

From the results of the analysis it is clearly seen that despite the low neutron flux, the neutron activation techniques is sensitve for the determination of gold in mill heads even at the ppm level. Three major elements, Na, Al and K, together with ten other minor elements were qualified. Also Fe, Zr and Zn were identified but could not be quantified. The major drawback of the low neutron flux from the Am-Be source is that to obtain accurate results, the longer-lived isotopes required longer irradiation times to obtain statistically significant counts. This then meant a slow turn round time per sample analysis.

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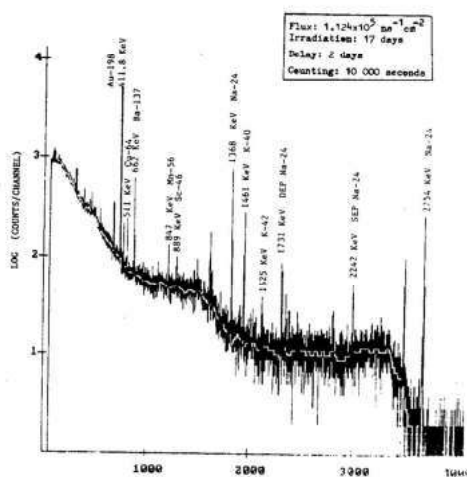3. OSAE, E.K. The Principle of Neutron Activation Analysis, Technical Report, NNRI/GAEC, 1988.

Fig. 2: A typical gamma-ray spectrum of the gold ore mill head showing the fitted photopeaks and some identified radionuclides.

TABLE 1

Element	SAMPLE CODE				
	NS/27	AS/25	NS/29	DS/27	NS/25
	CONCENTRATION (ppm)				
Cu	360 ± 37	330 ± 60	316 ± 16	345 ± 23	332 ± 74
As	818 ± 48	982 ± 39	1219 ± 42	1336 ± 25	591 ± 39
Mn	819 ± 65	804 ± 19	780 ± 74	707 ± 17	643 ± 48
Na$^+$	1.565 ± 0.114	1.656 ± 0.280	1.492 ± 0.014	1.419 ± 0.057	1.231 ± 0.029
K$^+$	1.267 ± 0.289	0.925 ± 0.068	1.222 ± 0.158	1.673 ± 0.044	1.683 ± 0.145
Al$^+$	7.80 ± 0.54	7.50 ± 0.47	8.66 ± 0.43	7.25 ± 0.69	4.82 ± 0.92
Au	—	12 ± 5	7.7 ± 0.4	16 ± 4	—
Ag	156 ± 30	185 ± 22	—	—	—
Mg	1540 ± 330	4720 ± 800	—	—	—
V	233 ± 29	—	—	—	—
Sb	57 ± 10	—	407 ± 56	—	—
W	222 ± 11	—	—	128 ± 10	—
Ca$^+$	0.865 ± 0.11	*	*	*	—
Br	1800 ± 180	141 ± 17	—	—	*
I	—	—	1100 ± 121	—	—

+ Percentage   * Identified but not qualified

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