

INVESTIGATION OF NICKEL CONTAINED FROM SULFIDE ORE DEPOSIT SAMPLES IN NAMTU MINE AREA BY MEASURING HALF-LIFE OF COBALT-58

Khin Su Su Han¹, Kay Thi Thin²

Abstract

The half-life of nickel in sulfide ore samples was determined by using neutron activation analysis. In NAA method, the samples were activated by Am-Be (α, n) isotopic neutron source. Its strength is 550 mCi, average neutron energy is about 3 MeV and half-life is 432 years. After irradiation, the gamma radiation of the samples were collected and calculated by using GM (ST-360) counter. Since, the resulting half-life of the sample is 70 days, the possible reaction of nickel is confirmed as

$^{58}_{28}\text{Ni} (n, p) ^{58}_{27}\text{Co}$. The best choice is this nuclear reaction for ore sample. This reaction is confirmed by calculating the half-life of this reaction.

$^{58}_{28}\text{Ni} (n, p) ^{58}_{27}\text{Co}$ is the best reaction because it has suitable energy and half-life.

Keywords: Rare Earth Metals, GM (ST-360) counter, Sulfide Ore Deposit Mine, NAA method

Introduction

Bawdwin Mine is the biggest Pb, Zn and Ag producer of Myanmar. The ore body is one of the largest and richest ever found. The geologic setting, ore type, metal zoning, alteration and geochemical characteristics all point out that the Bawdwin deposit is one of those of the well known massive sulfide deposits associated with felsic volcanism formed. The major Bawdwin ore body is that of the stratabound massive sulfide type, emplaced within the volcanoclastic rocks. The ore occurs as solid masses of sulfides, in places practically void of gangue minerals, as veins.

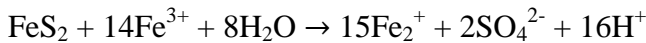
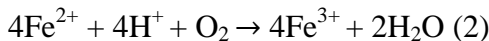
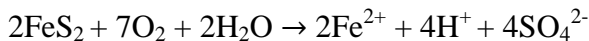
Here, the vertical metal zoning of Cu-Zn-Pb in the massive stratiform ore body and high Ni-Co-Cu in the underlying and cross-cutting loads of lower part of Mingtha and Chin are visualized.

¹ Lecturer, Department of Physics, Mandalay University of Distance Education, Mandalay, Myanmar.

² Pro-Rector, Meiktila University, Meiktila, Myanmar.

These sulphides, including galena (lead sulfide), sphalerite (zinc) and chalcopyrite (copper), accumulate at and just below the seafloor, where they form massive deposits that can range from several thousands to about 100 million tones. High concentrations of base metals (copper, zinc, lead) and especially precious metals (gold, silver) in some of these massive sulfide deposits have recently attracted the interest of the international mining industry. Many polymetallic sulfide deposits are also found at sites that are no longer volcanically active.

Massive sulphides formed in basaltic to and esitic environments of back-arc spreading centres (573 samples) are characterized by high average concentrations of zinc (17%), lead (0.4%) and barium (13%), but little iron. Polymetallic sulphides at back-arc rifts in continental crust (40 samples) also have low iron content but are commonly rich in zinc (20%) and lead (12%), and have high concentrations of silver (1.1%, or 2.304 g/s).



These ore deposits have been formed during submarine volcanic-exhalative processes while needed condition like pH - Eh is suitable for sea water, depth of topography and chemical composition of the water. Some of characteristics of type of ore deposits are:

- 1 Paragenesis of massive ore deposits, contain after 60 - 90% of sulfas, for example pyrite and pyrotite.
- 2 Type of these ore deposits, with increasing oxide ore deposits. likes iron ore deposits in central Iran and ore kiruna iron ore deposits in Sweden.
- 3 This type or deposits are divided into three groups:
 - a- Ore deposits with paragenesis of zinc-lead-copper
 - b- Ore deposits with paragenesis of zinc- copper
 - c- zinc- copper

Experimental Procedure

Sample Location (Sampling Site), Selection reaction and Preparation

Bawdwin Mines area (approximately about 12 square miles) lies at Namtu, Northern Shan State, Myanmar. Bawdwin mine is situated at longitude 97°23'24" E and latitude 23°05'24" N. The mining town of Bawdwin is situated in a narrow valley among a mountainous country rising up to 4600 feet above sea level and with V-shaped valleys. Bawdwin Mine is the biggest Pb, Zn and Ag producer of Myanmar. The ore body is one of the largest and richest ever found.

Bawdwin ore body with Pb, Zn, Ag is once one of the largest and richest ever found. It occurs in a NW-SE trending zone of about 8000 feet long and 400-500 feet in width mostly along the eastern side of the Taungpeng-Hsenwi fault system. The ore body itself is about 3000 feet long and is well-defined. In the center of the ore shoot the ore was almost sulfides for a width of about 140 feet.

Each sample was weighed carefully by digital balance. A 40g of this ore granules from encapsulated in a polyethylene container was used in this work. This container was chosen due to its low background. Then all samples were put in a plastic bag in very close to the neutron source for one week irradiation time.

Threshold reactions of the types (n, p) , (n, n') , (n, α) and $(n, 2n)$ induced by the fast component of the fast neutron spectrum as well as the (n, γ) capture reactions produced by thermal and epithermal neutrons are well recognized.

Activation analysis with fast neutrons (fast neutron activation analysis , FNAA), using threshold reactions is not widely used, because of the low-flux density of fast neutrons in Am-Be neutron source, the small cross sections of many threshold reactions and the relatively high-threshold energy of neutrons.

Threshold reactions provide useful alternative reactions for the determination of certain elements by NAA if the (n, γ) reaction products are formed with unfavourable radioactive properties. As an example, determining

Ni using the $^{58}\text{Ni} (n,p) ^{58}\text{Co}$ reaction ($T_{1/2}$ of ^{58}Co is 70.82 days) is favoured instead of using neutron capture reactions ($^{64}\text{Ni} (n,\gamma) ^{65}\text{Ni}$), which need pneumatic irradiation rabbit system due to the short half life time of ^{65}Ni .

Fe and Ni were determined in blue-green algae using the reactions $^{54}\text{Fe} (n, p) ^{54}\text{Mn}$ and $^{58}\text{Ni} (n, p) ^{58}\text{Co}$. The iron isotopic abundances were determined in iron materials using threshold reactions. Fast determination of Fe by instrumental neutron activation analysis through the formation of ^{56}Mn from both $^{55}\text{Mn} (n,\gamma) ^{56}\text{Mn}$ and $^{56}\text{Fe}(n, p)^{56}\text{Mn}$ using both reactor neutrons and epithermal neutron irradiation was described and evaluated. ^{58}Co production from natural nickel in nuclear reactor was described with particular consideration of interfering nuclear reaction.

The most abundant isotope of nickel is mass 58, and it is the most useful for the activation analysis with 14 MeV and 3 MeV neutrons. The best nuclear reaction for the identification of the isotope of interest should be chosen. Sometimes there is more than one reaction available for the same isotope. The possible induced nuclear reactions in Nickel ^{58}Ni together with the reaction characteristics are shown in Table (1).

$^{58}\text{Ni} (n, p) ^{58}\text{Co}$ is the best reaction because it has suitable energy and half-life. Moreover, the absorption reaction cross-section and target isotope abundance of the $^{58}\text{Ni} (n, p) ^{58}\text{Co}$ are relatively high Gamma emission probability (99%) from first peak energy (810.76keV) of this reaction is very high. It is also the endothermic reaction (Q-Value is negative) and threshold energy is lower than other reaction. Therefore, $^{58}\text{Ni} (n, p) ^{58}\text{Co}$ reaction is selected from four reactions. The decay scheme was shown in Figure (1). The best choice is this nuclear reaction for iron sample. (^{58}Ni about 99%) This reaction is confirmed by calculating the half-life of this reaction.

Table 1: Nuclear data for some threshold reaction

Reaction	Gamma -energy (keV)	Half-life (days)	Gamma emission probability (%)	Threshold energy (MeV)	Isotopic abundance %
$^{58}\text{Ni} (n, p) ^{58}\text{Co}$	810.77	70.86	99.00	2.6	68.077
$^{54}\text{Fe} (n, p) ^{54}\text{Mn}$	834.85	312.12	99.97	2.8	5.845
$^{92}\text{Mo} (n, p) ^{92m}\text{Nb}$	934.44	2.576	99.07	6	14.48
$^{95}\text{Mo} (n, p) ^{95}\text{Nb}$	765.9	10.15	99.808	-	15.92

Half-Life Measurement of Irradiated Samples

The sample material is irradiated with neutrons from a neutron source. In this process, isotopes are converted into radioactive isotopes. While these isotopes decay, with half-life varying from seconds to years, they emit β -decay half-life and for detecting trace amounts of elements present in materials. These methods and data analysis techniques for making high precision measurements of nuclear beta decay half-lives. The change in the electron captures half-life of ^{58}Ni in pure Nickel. In addition, the beta-minus decay half-life of ^{58}Co is measured to changes the electron capture. Figure (1) shows the decay scheme of ^{58}Co .

Americium also alloys with Beryllium to form Am-Be which produces neutrons via the $^9\text{Be} (\alpha, n) ^{12}\text{C}$ reaction was used. ^{241}Am has a half-life of about 432 years. Although this isotopic decays by emitting alpha particles of about 5.4 MeV, these particles are following by gamma rays in the 40 to 60 keV region in the majority of the disintegrations. This gamma-ray emission make Americium appear less satisfactory than Plutonium for the preparation of neutron sources. For the Am-Be source in Physics lab, University of Mandalay, total neutron capture from the neutron source $N=1.04 \times 10^6$

neutrons/cm²s. Figure (2) shows the experimental set-up of the 550mCi ²⁴¹Am-Be neutron source irradiation facility.

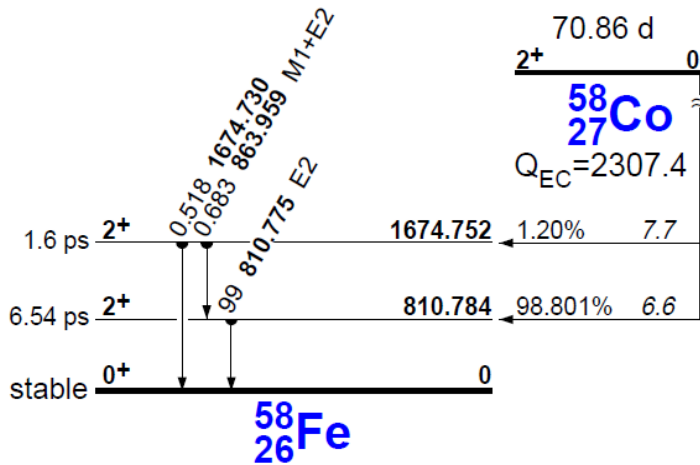


Figure 1: The decay scheme of ⁵⁸Co



Figure 2: The experimental set-up of the 550mCi ²⁴¹Am-Be neutron source irradiation facility.

Experimental Set-up for Radiation Measurement

After irradiation, the gamma ray spectra of the radioactive ore samples were detected and analyzed by GM Counter. The experimental set-up for GM-ST360 counter is shown in Figure (3). Irradiate the sample for about 2 weeks by placing it in appropriate position in the $^{241}\text{Am-Be}$ Neutron (normally at the center of the coloum). Apply the operating voltage (1000V) for the GM Tube. Place the irradiated samples under the window of GM tube at a convenient distance (2cm) in order to get a good number of counts per second. Determine the background count rate (N) for each interval of 300 seconds (5minutes).



Figure 3: Expiration arrangement for GM-ST360 counter

To measure the half-life of Nickel-58

$$N(t) = N - \lambda N \Delta t, \quad (1)$$

where $N(t)$ is the number of atoms that will be present at time t , N is the number of atoms present currently, λ is the decay constant, and Δt is the elapsed time. If the number of radioactive atoms remaining is plotted against time, curve can be obtained. The decay constant can be obtained from the slope of these curves (discussed more below).

A more common way of expressing the decay of radioactive atoms is the half-life. The half-life of a radioactive isotope is the time required for the disintegration of one-half of the atoms in the original sample.

$$\text{activity, since activity} = \frac{N}{\text{time}}$$

(N= Each count of a GM tube represents one atom decaying and releasing one particle or ray of radiation.)

This is a separable differential equation that becomes

$$\int_{N_0}^N \frac{dN'}{N'} = -\lambda \int_0^t dt' \quad (2)$$

Thus, if we plot the natural log of the number of atoms (or activity) versus time, we will get a straight line with slope = dy/dx. This would allow us to find the decay constant. We will need the decay constant in the next step, which is to find the half-life of the radioactive isotope we are studying. Starting from Equation and applying a simple logarithmic identity,

Finally, we can solve for the half-time

$$t_{1/2} = \frac{\ln(2)}{\lambda} \quad (3)$$

Results and Discussions

The experimental work was performed at the Nuclear Research Laboratory, Department of Physics, and Mandalay University. In NAA experiment, ore samples were irradiated by using Am-Be (α, n) isotopic neutron source and then the induced gamma radiation were detected by using GM- ST360 Radiation Counter with windows and Macintosh software. Moreover, the absorption reaction cross-section and target isotope abundance of the ^{58}Ni (n, p) ^{58}Co are relatively high Gamma emission probability (99%) from first peak energy (810.76keV) of this reaction is very high. It is also the endothermic reaction (Q-Value is negative) and threshold energy is lower than other reaction. Therefore, ^{58}Ni (n, p) ^{58}Co reaction is selected from four

reactions. Note down the back ground count rate, before and after the experiment in order to subtract from the observed counts and record observations as shown in the Table (2). plot graph of log of the count rate (log N) versus time (second). The decay constant can be obtained from the slope of these curves (discussed more below). It was be a straight line as shown in figure (4). The slope of the straight line graph using the least square fit methods (use the formula)

$$m = (n \sum xy - \sum xy) / (\sum nx^2 - (\sum x)^2) \tag{4}$$

to determine the slope of the graph which gives the value of the decay constant.

Where n = number of observations

x = time interval

y = Log N

Table 2: Irradiation Measured data and Counting Conditions

Sr. No.	Time (min)	Counts	Net counts rate	Log N
1	5	1738	253.67	5.54
2	10	3257	231.77	5.45
3	15	4658	216.6	5.38
4	20	6082	210.17	5.24
5	25	7702	214.15	5.37
6	30	9248	214.33	5.37
7	35	10227	198.27	5.29
8	40	11039	182.05	5.20
9	45	11738	166.90	5.11
10	50	12334	152.75	5.03
11	55	13000	142.43	4.90
12	60	14360	145.4	4.90

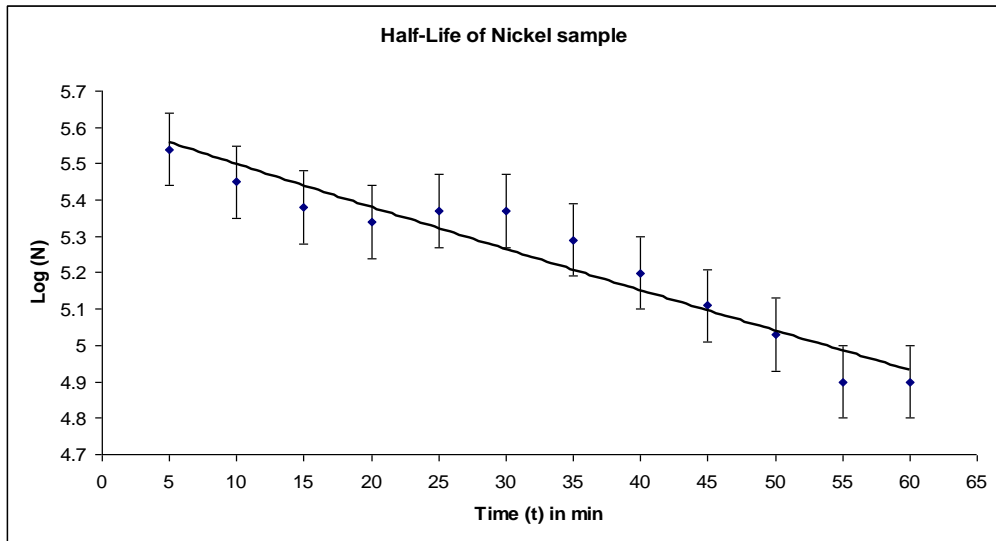


Figure 4: Linear decay curve

Conclusion

Neutron activation of materials followed by using GM counter is an effective method for making measurements of nuclear beta decay half-lives and for detecting trace amounts of elements present in materials. In addition, the beta decay half-life of ^{58}Co is measured and compared with table of isotope library. Since, the resulting half-life of the sample is 70 days, the possible reaction of nickel is confirmed as $^{58}\text{Ni} (n, p) ^{58}\text{Co}$. The best choice is this nuclear reaction for ore sample. This reaction is confirmed by calculating the half-life of this reaction. $^{58}\text{Ni} (n, p) ^{58}\text{Co}$ is the best reaction because it has suitable energy and half-life.

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