EXPERIMENT 18

Neutron Activation Analysis (Fast Neutrons)

EQUIPMENT NEEDED FROM EG&G ORTEC

- 113 Scintillation Preamplifier
- 266 Photomultiplier Tube Base
- Bin and Power Supply
- 556 High Voltage Power Supply
- 480 Pulser
- 575A Amplifier
- Source Kit SK-1G (see Appendix)
- 905-3 NaL(Tl) 2- x 2-in. Detector and PM Tube
- ACE-2K MCA System including suitable IBM PC (other EG&G ORTEC MCAs may be used)
- Oscilloscope
- 1- to 3-Ci Am-Be neutron source
- Sample Set No. 318
- ORC-18 Cable Set

Purpose

This experiment will demonstrate the principles of element identification using the technique of fast neutron activation.

Introduction

In this experiment the same isotopic neutron source that was used in Experiment 17 will be used after it has been removed from the howitzer. The target samples will be irradiated by being placed in almost direct contact with the neutron source.

The spectrum of neutrons that results from an Am-Be isotopic neutron source is shown in Fig. 16.2. From this figure it is evident that the neutron energies are distributed from 2 to 11 MeV for the unmoderated source (with no paraffin or water moderator). The reaction that produces the neutrons in the source is

$$^{9}\text{Be} + \alpha \rightarrow \text{n} + {}^{12}\text{C} + 5.704 \text{ MeV} . \qquad (1)$$

In Eq. (1) the 5.704-MeV energy is the Q value for the reaction. It is the effective mass, (Δm), that is converted into energy, where Δm is given by

$$\Delta m = (m_9 + m_\alpha) - (m_n + m_{12}) , \qquad (2)$$

and where m_9 is the mass of ^{9}Be, etc. Hence, $Q = \Delta mc^2$. Most of the alpha-emitting isotopes have alpha energies of ~5.5 MeV. Conservation of energy for Eq. (1) would be

$$E_\alpha + Q = E_n + E_{12_C} . \qquad (3)$$

From conservation of momentum the neutrons would get ~12 to 13 MeV (~92.5%) of the available energy (E_α + Q) for the reaction in the forward direction. Of course, the neutron energy would change as a function of its angle of departure relative to the direction of the incident alpha particle. It is therefore possible to produce neutrons with an upper energy value of ~11 MeV. The neutron energies in Fig. 16.2 are distributed as shown for the following reasons:

1. Alpha energy is lost in the source before a reaction is produced.
2. ^{12}C can be left in one of its excited states.
3. Neutron energies vary with the angles involved.

The activation in Experiment 17 was produced by slow neutrons. The spectrum of the neutrons from the isotopic source was thermalized by a paraffin moderator; the moderation could also have been produced by water. Slow neutron reactions are usually of the type

$$\text{A(n,}\gamma\text{)*B}, \qquad (4)$$

where *B usually decays by β^- emission followed by gamma radiation (see examples in Fig. 17.2).

For fast neutrons there are three types of reactions that predominate:

$$\text{A(n,p)B}, \qquad (5)$$

$$\text{A(n,}\alpha\text{)B}, \qquad (6)$$

$$\text{A(n,2n)B}. \qquad (7)$$

The reactions produced by Eq. (5) generally have neutron thresholds in the range of 1 to 3 MeV and therefore cannot be produced with thermal neutrons. The thresholds for Eqs. (6) and (7) are even higher and are usually in the range of 10 to 20 MeV.

An unmoderated isotopic neutron source can be used to produce only (n,p) reactions effectively.

WARNING

Do not physically contact the isotopic source at any time.

For the experiment the neutron source is usually removed from its container with tongs or by a string that will prevent the handler from getting any part of his body within 2 ft of the source. The neutron source is then placed in the center of a table that has been roped off and identified as a radiation hazard to ensure personnel isolation. Then the sample to be activated can be moved to the chamber. Use tongs to place the sample in its position.

As in Experiment 17, each sample is normally activated for one half-life or longer.

EXPERIMENT 18.1

Gammas and Half-Lives from (n,p) Reactions

Procedure

1. Set up the electronics as shown in Fig. 18.1. Calibrate the MCA with gamma sources from SK-1G for an analyzer full scale of 2 MeV.

2. Place the aluminum target from Sample Set. No. 318 in contact with the Am-Be source for ~30 min. The reaction produced is $^{27}Al(n,p)\,^{27}Mg$ and the $T_{1/2}$ of the product will be 9.5 min (Fig. 18.2).

3. Transfer the sample to the NaI(Tl) detector and count for a period of time long enough to define the gamma groups for the reaction.

EXERCISE

a. Measure the gamma energies. Do they agree with those shown for this reaction in Fig. 18.2?

4. Set the ROI of the MCA so that it brackets the 1.013-MeV gamma for the reaction. Preset for a counting time of 40 s. Take a 40-s count every 2 min until enough data have been obtained to plot a half-life curve. What is the measured $T_{1/2}$?

5. Figure 18.2 shows that ~70% of the gammas are 0.842 MeV and that ~30% are 1.013 MeV. Irradiate a second aluminum sample for ~30 min to obtain a sample that will be used to check this ratio.

6. Use the ROI of the MCA to set two regions of interest, one for 0.842 MeV and the other for 1.013 MeV. Transfer the sample to a counting position that is 9.3 cm from the face of the detector. Accumulate a spectrum in the MCA for a period of time long enough to have ~1500 counts under the 1.013-MeV peak.

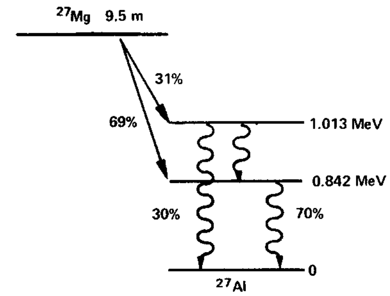

Fig. 18.2. Decay Scheme for Product of $^{27}Al(n,p)^{27}Mg$ Reaction.

EXERCISE

b. Correct each of these sums by

$$\Sigma(\text{corrected}) = \frac{\Sigma}{\epsilon_p}\,, \qquad (8)$$

where ϵ_p is the intrinsic peak efficiency of the detector at that energy level (Fig. 3.6). The corrected sums should be in the ratio of 70% to 30% as stated above. Are they?

EXPERIMENT 18.2

Optional (n,p) Reactions that can be Studied

Procedure

Table 18.1 lists six (n,p) reactions from Sample Set No. 318 to be studied in the same manner as the $^{27}Al(n,p)\,^{27}Mg$ reaction of Experiment 18.1. All of the samples needed for the experiments outlined in Table 18.1 are contained in Sample Set No. 318.

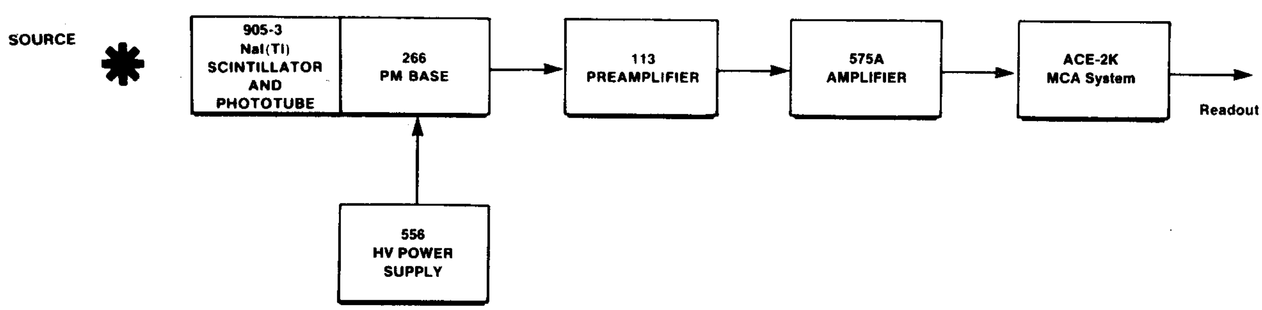

Fig. 18.1. Interconnection of Equipment for Experiment 18.

Table 18.1. Fast Neutron Activation Parameters for the Samples in Sample Set No. 318.

Element	Reaction	σ_{barns}	$T_{1/2}$	Measured γ (keV)	Activation Time	Counting Time (s)
Magnesium	$^{24}Mg(n,p)^{24}Na$	0.180	14.9 h	1370	4 h	1000
Sodium	$^{23}Na(n,p)^{23}Ne$	0.034	40.2 s	440	3 min	100
Silicon	$^{28}Si(n,p)^{28}Al$	0.220	2.3 min	1780	5 min	100
Vanadium	$^{51}V(n,p)^{51}Ti$	0.027	5.8 min	320,605	10 min	200
Iron	$^{56}Fe(n,p)^{56}Mn$	0.110	2.56 h	845,1810	4 h	1000
Chromium	$^{52}Cr(n,p)^{52}V$	0.080	3.76 min	1440	10 min	200

References

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