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INDUCED RADIOACTIVITY IN RECOVERED SKYLAB MATERIALS

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16. ABSTRACT

Four radioactive isotopes have been found in aluminum and stainless steel samples from Skylab debris recovered in Australia. The low-level activity was induced by high-energy protons and neutrons in the space environment. Measurements of the specific activities are given.

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INDUCED RADIOACTIVITY IN RECOVERED SKYLAB MATERIALS

INTRODUCTION

All materials become slightly radioactive when exposed to the high-energy nuclear radiation found in the space environment. The dominant source of particles capable of inducing radioactivity are protons from solar and galactic cosmic rays. At low orbital altitudes and medium inclinations, characteristic of the Skylab orbit, the Earth's magnetic field effectively screens the low-energy galactic and solar cosmic rays. Geomagnetically trapped protons with energies greater than approximately 30 MeV are also a source of activation in these orbits. In addition, high-energy secondary neutrons and protons from the Earth's atmosphere, or produced in the spacecraft itself, may also contribute to the activation process.

Quantitative calculations of the induced radioactivity (or activation) in spacecraft materials are difficult to make because of uncertainties in the secondary fluxes and the transport of activating particles through complex structures. Measurements of induced radioactivity from Skylab provide the opportunity for studying the effects of a massive, complex structure on the production of secondary particles. An experiment to measure activation in materials deployed on the Skylab 3 mission was designed to measure the relative contributions of neutrons and protons to the activation process [1] and to estimate the fluxes of these particles in various energy bands. The recovered Skylab debris data presented in this report are significant in that: (1) they allow a measure of long-lived radioisotopes otherwise unavailable for study, (2) they provide a measure of the induced radioactivity environment at a lower altitude than the original experiment. The long exposure time of Skylab allowed many longer-lived isotopes to build up to their saturation values. Furthermore, the measurement of induced radioactivity in suspected spacecraft samples provides a unique and unambiguous determination that the samples were, in fact, from Skylab.

DESCRIPTION OF SAMPLES

Skylab was launched on 14 May 1973 and reentered on 11 July 1979. A large fraction of the spacecraft which survived reentry impacted in remote areas of western Australia, with no reported injuries to persons or property. A Skylab reentry team from NASA's Marshall Space Flight Center (MSFC) visited the reentry area and borrowed several samples of reentry debris for study. "The NASA group had emphasized—that the rule of 'finders-keepers' prevailed and that there was no desire to take debris from citizens and that any small portions voluntarily surrendered for further scientific study would be returned to the finder with certification of authority as appropriate and with expression of appreciation from NASA" [2]. Accordingly, care was taken not to alter or damage the samples and to return them in a timely manner to their Australian finders.

Table 1 describes the samples that were measured. The sample numbers are those used in a preliminary list and may not correspond to those used in later lists. All samples except 16 were brought from Australia by the NASA/MSFC team and were measured during August 1979. Sample 16 was found at a later date and sent to MSFC for authentication and measurements in December 1979.

MEASUREMENTS

Measurements of induced radioactivity were made in the low-level counting facility of the Space Sciences Laboratory, NASA/MSFC. The Ge(Li) gamma-ray detector has a nominal active volume of 80 cm^3 and an efficiency of 16 percent at 1.33 MeV. The measured resolution of the detector is 2.4 keV at 1.33 MeV. The detector head is shielded by a minimum of 15 cm of low activity lead and 18 cm of low-background steel fabricated from old battleship armor plate, uncontaminated by Co^{60} found in modern steel. Samples were placed directly on the detector head in a sample counting volume of approximately 8 × 8 × 3 cm.

Background measurements were made for 60,000 sec (overnight) before and after each sample measurement. The average background counting rate was 0.92 counts/sec in the energy range from 0.2 to 3.0 MeV. Fourteen gamma-ray lines detected in the background were identified from K^{40} and from the thorium, radium and uranium decay series. Spectra were accumulated with a channel width between 1 and 2 keV.

The measured activities of induced radioactivity in the recovered Skylab samples are given in Table 2. There were no interfering background lines at any of the energies listed in Table 2. Figure 1 shows portions of two gamma-ray spectra from stainless steel samples 11 and 7. The gamma-ray lines from the isotopes Co^{58}, Mn^{54}, and Co^{56} are evident. Figure 2 shows the activation processes responsible for producing these isotopes from the stable isotopes in the samples. Self-absorption and scattering are small for the sample size and energies of the isotopes measured.

The derivation of absolute specific activities from the samples was difficult to obtain, due mainly to the unusual and nonstandard geometry of the samples. The estimated systematic errors for the specific activities are approximately 30 percent. This error is larger than any measured differences between various samples, so that only typical values for the specific activities are given in Table 3.

CONCLUSIONS

Activation measurements have been made in recovered Skylab materials with masses greater than 100 gm. These measurements provide direct and definite proof that the materials have been exposed to the space environment. The activities measured are consistent with earlier results from an activation experiment on Skylab 3 [1]. However, the Na^{22} activation produced in aluminum was measured for the first time from Skylab. The specific activity of Na^{22} in aluminum appears to be about twice as great as that from materials recovered from Surveyor 3 on the lunar surface [3].

For several months prior to reentry, Skylab was at a low altitude which excluded most trapped protons. The presence of short-lived isotopes such as Co^{56} ($t_{1/2}$= 77 days) and Co^{58} ($t_{1/2}$= 71 days) indicates that galactic cosmic rays produced most of the activation for these isotopes in these particular samples. The relative contributions of trapped radiation and cosmic radiation to induced radioactivity are very dependent on the effective shielding of the target samples, their composition, and the number of nucleons that are removed from the target nucleus in order to make it radioactive.

Finally, it should be noted that the measured induced radioactivity levels (Table 3) are very low and nonharmful, being less than the natural radioactivity of many common rocks and even the human body. (The specific activity of the human body due to K^{40} is approximately 70 disintegrations/sec/kg.)

TABLE 1. SKYLAB DEBRIS SAMPLES

Sample No.	Material	Identification	Finder	Mass (grams)
6	Aluminum	Alloy #356 casting from orbital workshop	P. Arlidge	∿150
7	Stainless Steel	HY-100 alloy, oxygen tank on airlock module	W. Norton	367
11	Stainless Steel	SS-321 alloy, water tank in orbital workshop	J. Lay	175
15	Silicon Diode	From shunt regulator in airlock module	C. Aither	117
16	Stainless Steel	HY-100 alloy, oxygen tank support ring	unknown	281

TABLE 2. MEASURED INDUCED RADIOACTIVITY

Sample	Isotope	Energy (keV)	Half-Life	Net Counts/ 1000 sec
6	Na^{22}	1278	2.6 yr	0.50 ± .15
7	Co^{58}	811	71d	0.49 ± .13
7	Mn^{54}	835	303d	4.32 ± .24
7	Co^{56}	847	77d	0.90 ± .16
11	Co^{58}	811	71d	0.41 ± .15
11	Mn^{54}	835	303d	2.83 ± .28
11	Co^{56}	847	77d	0.91 ± .18
15	Mn^{54}	835	303d	4.14 ± .30
16	Co^{56}	847	77d	0.60 ± .26
16	Mn^{54}	835	303d	2.41 ± .35

TABLE 3. TYPICAL SPECIFIC ACTIVITIES OF SKYLAB SAMPLES

Sample Material	Isotope	Specific Activity* (at re-entry)
Aluminum	Na^{22}	1.1 disintegrations/sec/kg
Stainless Steel	Co^{58}	0.8 disintegrations/sec/kg
Stainless Steel	Mn^{54}	3.0 disintegrations/sec/kg
Stainless Steel	Co^{56}	1.5 disintegrations/sec/kg

*Estimated accuracy: ±30 percent

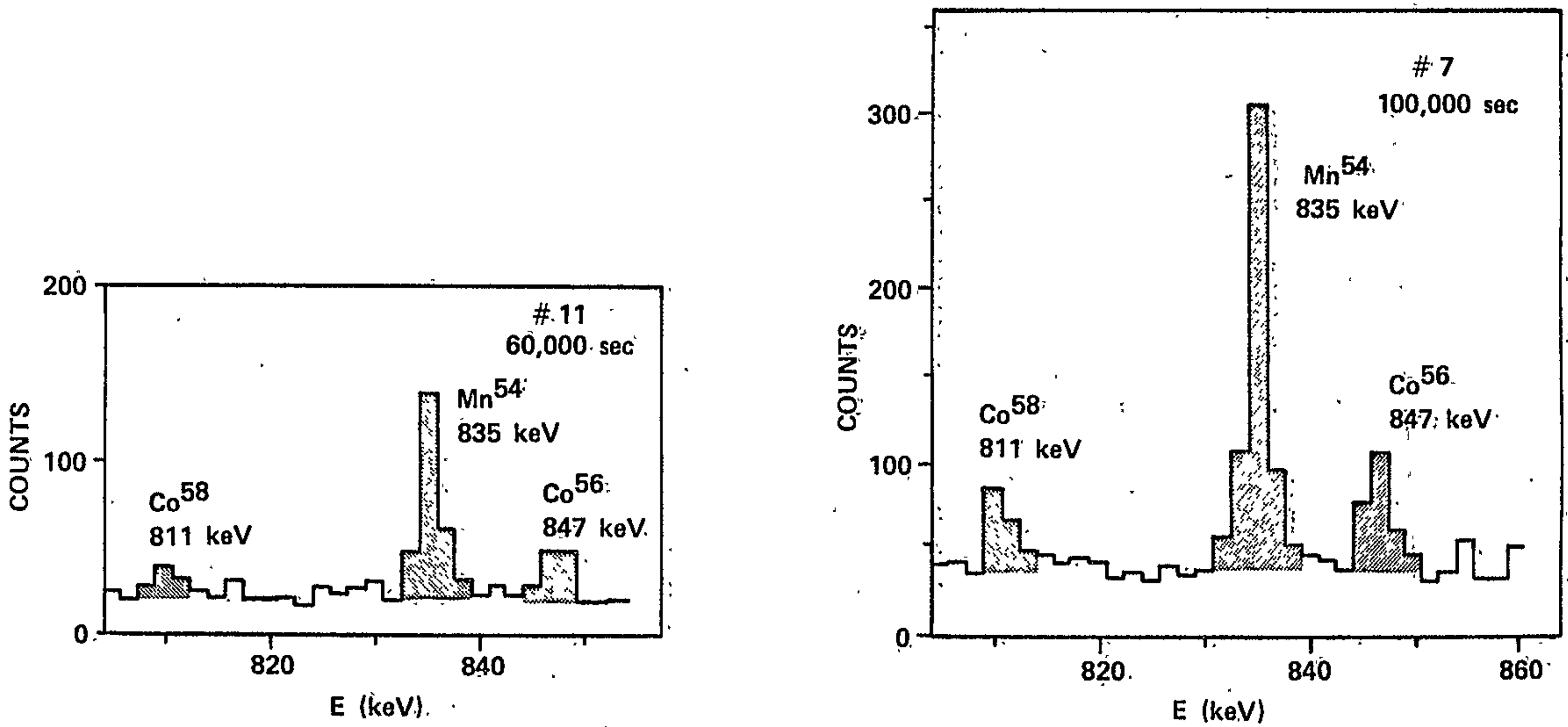

Figure 1. Two portions of spectra from stainless steel samples. The net activation counts are shaded for each of the three isotopes identified. There were no lines at these energies in the background.

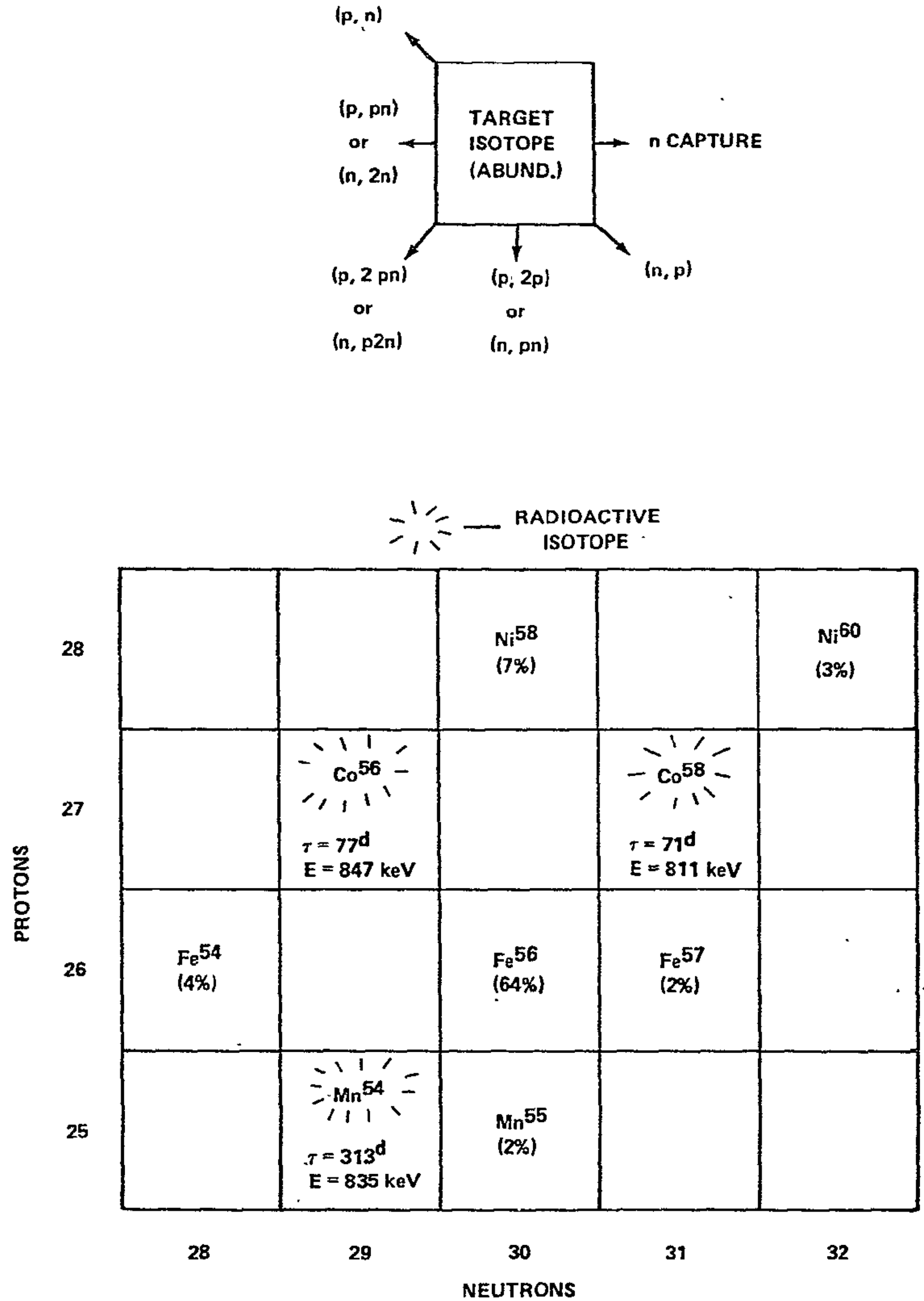

Figure 2. The stable and radioactive isotopes in the stainless steel samples.

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APPROVAL

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The information in this report has been reviewed for technical content. Review of any information concerning Department of Defense or nuclear energy activities or programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

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