Phil
326
11-1-66

IN-1024
August 1966

MASTER

NEUTRON ACTIVATION CROSS SECTIONS FOR
THE Co^{60} ISOMERS

C. H. Hogg and L. D. Weber

RELEASED FOR ANNOUNCEMENT
IN NUCLEAR SCIENCE ABSTRACTS

IDAHO NUCLEAR CORPORATION
NATIONAL REACTOR TESTING STATION
IDAHO FALLS, IDAHO

U. S. ATOMIC ENERGY COMMISSION

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

PRINTED IN USA. PRICE \$1.00. AVAILABLE FROM THE CLEARINGHOUSE FOR FEDERAL
SCIENTIFIC AND TECHNICAL INFORMATION, NATIONAL BUREAU OF STANDARDS,
U. S. DEPARTMENT OF COMMERCE, SPRINGFIELD, VIRGINIA 22151

LEGAL NOTICE

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:

A. Makes any warranty or representation, express or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or

B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.

As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission, or employee of such contractor, to the extent that such employee or contractor of the Commission, or employee of such contractor prepares, disseminates, or provides access to, any information pursuant to his employment or contract with the Commission, or his employment with such contractor.

IN-1024
Issued: August 1966
Physics
TID-4500

NEUTRON ACTIVATION CROSS SECTIONS FOR
THE Co^{60} ISOMERS

by

C. H. Hogg
L. D. Weber

RELEASED FOR ANNOUNCEMENT
IN NUCLEAR SCIENCE ABSTRACTS

LEGAL NOTICE

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:

A. Makes any warranty or representation, expressed or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or

B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.

As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission, or employee of such contractor, to the extent that such employee or contractor of the Commission, or employee of such contractor prepares, disseminates, or provides access to, any information pursuant to his employment or contract with the Commission, or his employment with such contractor.

IDAHO NUCLEAR CORPORATION

A JOINTLY OWNED SUBSIDIARY OF
AEROJET ALLIED
GENERAL CHEMICAL
CORPORATION CORPORATION

U. S. Atomic Energy Commission Research and Development Report
Issued Under Contract AT(10-1)-1230
Idaho Operations Office

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

NEUTRON ACTIVATION CROSS SECTIONS FOR
THE Co^{60} ISOMERS

A B S T R A C T

The neutron activation cross sections of the two Co^{60} isomers have been measured relative to that of Co^{59} with reactor neutrons. The thermal-neutron activation cross section for the 5.27-yr Co^{60} was measured to be 2.0 ± 0.2 barns relative to 37 b for Co^{59} . The resonance integral is estimated to be 4.3 barns relative to 74 b for Co^{59} .

The 10.4-min Co^{60m} thermal-neutron cross section and the resonance integral are 58 ± 8 b and 230 ± 50 b, respectively, relative to the Co^{59} values of 37 b and 74 b.

The effect of these cross sections on the production of Co^{60} is small, i.e., 10% during a 3-year irradiation period.

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

NEUTRON ACTIVATION CROSS SECTIONS FOR THE Co^{60} ISOMERS

TABLE OF CONTENTS

	<u>Page</u>
Abstract	iii
I. Introduction	1
II. Experimental Procedure and Results	1
A. Measurement of the 5.27-yr Co^{60} Neutron Cross Sections	1
B. Measurement of the 10.4-min Co^{60m} Neutron Cross Sections	3
C. Counting Techniques	5
III. The Determination of the Co^{61} Gamma-ray Yield	6
IV. The Effect on Co^{60} Production	6
References	9

LIST OF FIGURES

Fig. 1 - $\text{Co}^{59} \rightarrow \text{Co}^{61}$ neutron reaction scheme	2
Fig. 2 - The relative amounts of Co^{61} atoms present in an irradiated Co^{59} sample induced from the 5.27-yr Co^{60} and from the 10.4-min Co^{60m} as a function of irradiation time	4
Fig. 3 - Co^{61} decay scheme	7
Fig. 4 - Ratio of the number of Co^{60} atoms present assuming no burnout to that present with burnout, using the new cross-section values, plotted against irradiation time	8

I. INTRODUCTION

The reaction $\text{Co}^{59}(\text{n}, \gamma)\text{Co}^{60}$ is used extensively to measure thermal-neutron fluxes in nuclear reactors (Fig. 1) and to produce Co^{60} which is useful as a gamma-ray source. Co^{60} has a long half-life and emits high energy gamma rays. Although the Co^{60} cross sections had been measured⁽²⁾, it seemed advisable to confirm the relatively low values reported, since the Co^{58} thermal-neutron cross sections have been found to be high⁽¹⁾.

II. EXPERIMENTAL PROCEDURE AND RESULTS

A. Measurement of the 5.27-yr Co^{60} Neutron Cross Sections

The thermal-neutron cross section of 5.27-yr Co^{60} was determined from the amount of Co^{61} induced in a sample of Co^{60} irradiated for 4 hours in the neutron flux of the VH-2 experimental facility of the Materials Testing Reactor. The thermal-neutron flux in VH-2 is about 2.1×10^{14} n/sec/cm², as measured for each irradiation with Co^{59} . The cadmium ratio in VH-2, using 40 mil Cd, is 10 for "thin" Co^{59} .

The Co^{60} sample was taken from a section of 0.5% Co-Al alloy that had been irradiated for about 100 days in a thermal-neutron flux greater than 2×10^{14} n/sec/cm². The Co^{61} generated in the sample from the Co^{59} - Co^{61} sequence (Fig. 1) during the experimental irradiation was negligible, i.e., < 0.3% of the total. Co^{60} samples were irradiated both shielded with 40 mil Cd and unshielded. The measured Co^{60} cadmium ratio averaged 9.4. The thermal-neutron activation cross section for Co^{60} , averaged from six irradiations, is 2.0 ± 0.2 barns relative to 37 b for Co^{59} . The resonance integral is estimated to be 4.3 barns relative to 74 b for Co^{59} . The other published value for the Co^{60}

PPCo-A-4972

Fig. 1 - $\text{Co}^{59} \rightarrow \text{Co}^{61}$ neutron reaction scheme.

thermal-neutron cross section is $6 \pm 2 \text{ b}^{(2)}$. All calculations assume that the cross sections of the Co^{60} isomers are $1/v$ dependent in the thermal-neutron energy range and that the reactor neutron spectrum is " $1/E$ " in the resonance-neutron energy range. It has also been assumed that the neutron cross section of Co^{61} was not large enough to cause serious burnup of Co^{61} during irradiation (a 10% burnup would have required a value of $3 \times 10^4 \text{ b}$).

B. Measurement of the 10.4-min Co^{60m} Neutron Cross Sections

The thermal-neutron activation cross section and resonance integral for the 10.4-min Co^{60m} were determined from the Co^{61} activities induced in samples of Co^{59} irradiated from 10 to 60 minutes in each of two reactor positions, VH-2 and VH-4 of the MTR. The thermal-neutron flux in VH-4 was 1.8×10^{14} and the cadmium ratio was 33 for "thin" Co^{59} using 40 mil Cd. Since the Cd ratio of the Co^{60m} could not be measured directly, the resonance integral was calculated from data taken in irradiations made in two experimental positions having different thermal to resonance flux ratios. The amount of Co^{61} in the samples produced from the 10.4-min Co^{60m} isomer during these short irradiations is large compared to that produced from the 5.27-yr Co^{60} isomer. Refer to Fig. 2.

An "effective" neutron activation cross section for Co^{60m} was calculated from the Co^{61} produced in the transformation sequence shown in Fig. 1. A computer program described in Ref. 3 was utilized. The "effective" cross section, σ_{eff} , is that calculated from the total Co^{61} activity generated by both thermal and resonance neutrons, i.e., the reaction rate is $\phi_{\text{th}} \sigma_{\text{eff}} = \phi_{\text{th}} \sigma_{\text{th}} + \phi_{\text{R}} \sigma_{\text{R}}$ where ϕ_{th} is the thermal-neutron flux (2200 m/sec) measured in the facility, ϕ_{R} is the resonance flux per

PPCo-C-5169

Fig. 2 - The relative amounts of Co^{61} atoms present in an irradiated Co^{59} sample induced from the 5.27-yr Co^{60} and from the 10.4-min Co^{60m} as a function of irradiation time.

In the energy interval, σ_{th} is the 2200 m/sec cross section, and σ_R is the resonance integral. Adjustments were made to the Co^{59} and Co^{60} thermal-neutron cross sections entering into the calculations to account for the resonance contribution to the respective activities. The Co^{60m} "effective" cross section values are independent of irradiation times but were different for the two irradiation facilities, VH-2 and VH-4, and it is assumed that the difference is due to variation in the neutron spectra. Values obtained for the effective cross sections were 71 ± 7 b and 62 ± 6 b for VH-2 and VH-4, respectively. It can be shown from the equations for $\phi_{th} \sigma_{eff}$ in the two facilities that the Co^{60m} thermal-neutron cross section and the resonance integral are 58 ± 8 b and 230 ± 50 b, respectively, relative to the Co^{59} values of 37 b and 74 b.

C. Counting Techniques

Experimentally, each sample was counted several times over a 4 to 5 hour period beginning 3 to 5 hours after irradiation. Each composite spectrum was recorded on a punched-tape readout. A 1/8" thick x 2" diameter NaI scintillation detector was used. The thin detector absorbs most of the Co^{61} gamma rays intercepted while a large fraction of the Co^{60} gamma rays pass through without detection thus minimizing the problem of counting the Co^{61} 68-keV gamma rays in the presence of high 5.27-yr Co^{60} background. The Co^{60} gamma-ray spectra were recorded after the Co^{61} had decayed and then subtracted from each of the composite counts. Since the 10.4-min Co^{60m} isomer decays with the emission of a 59-keV gamma ray which interferes with the counting of the 68-keV gamma ray from Co^{61} , the irradiated Co^{59} sample activities were counted after the 10.4-min activity had decayed. The half-life of each corrected activity

used in the calculation followed the 99-min half-life⁽⁴⁾ of Co^{61} .

Corrections for the self-shielding of neutrons in sample during irradiation and absorption of the 89-keV gamma ray by the sample while counting were made.

III. THE DETERMINATION OF THE Co^{61} GAMMA-RAY YIELD

The determination of the Co^{61} decay rate was made by counting a 68-keV gamma ray. Essentially 100% of the Co^{61} disintegrations feed a 68-keV transition^(4,5,6) (Fig. 3). Since no information on the internal conversion of the 68-keV gamma ray could be found in the literature, it was necessary to determine the gamma-ray yield for this transition. The disintegration rate was determined by a 4π β - γ coincidence counting technique and the gamma-ray emission rate from the sample was measured with a gamma-ray scintillation spectrometer.

IV. THE EFFECT ON Co^{60} PRODUCTION

The effect of the above cross sections on the production of Co^{60} was calculated and is shown in Fig. 4. No appreciable burnup of Co^{60} occurs during long irradiations.

Fig. 3 - Co^{61} decay scheme.

Fig. 4 - Ratio of the number of Co^{60} atoms present assuming no burnout to that present with burnout, using the new cross-section values, plotted against irradiation time.

REFERENCES

1. C. H. Hogg, L. D. Weber, and E. C. Yates, Thermal Neutron Cross Sections of Co⁵⁸ Isomers and the Effect on Fast Flux Measurements Using Nickel, IDO-16744 (1962).
2. F. Brown, J. L. Wolfson, and L. Yaffe, "Pile Neutron Capture Cross Sections of Co⁶⁰ (10.5 min) and Co⁶⁰ (5.25 yr)," Can. J. Phys. 31, 903-10 (1953).
3. A. V. Grimaud, IBM 650 Radioactive Decay Utility Program (PPCo-00.053) IDO-16740.
4. Nuclear Data Sheets, National Academy of Sciences - National Research Council, Washington, D.C.
5. P. Erdos, P. Jordan, D. Maeder, and P. Stoll, "Untersuchung des Zerfalls von Co⁶¹ im Szintillationspektrometer," Helvetica Physica Acta, Vol. 28, P. 323 (1955).
6. R. H. Nussbaum, A. H. Wapstra, W. A. Bruil, M. J. Steck, G. J. Nijgh, and N. Grobбен, "Decay of Co⁶¹ and Cu⁶¹," Phys. Rev. 101, 905-6 (1956).