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Clark University

Department of Chemistry

AEC Progress Report

January 1, 1971 - December 31, 1971

Nuclear Chemistry

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Daeg S. Brenner

Principal Investigator

DISCLAIMER

I. General

A. Introduction

The major portion of experimental measurements is carried out at Clark University, Worcester, Massachusetts. Radioactive sources are prepared at the Yale University heavy-ion accelerator and in some instances at the Cyclotron Institute of Texas A & M University and the M.I.T. Research Reactor. Computer facilities of the Worcester Area Colleges Computation Center located at Worcester Polytechnic Institute were used in data analysis. We are grateful for the cooperation of many individuals at these institutions for making these studies possible.

This report is concerned with research done during the year January 1, 1971 - December 31, 1971.

B. Personnel

Dr. Daeg S. Brenner, Associate Professor, Chemistry Department

Mr. David L. Anderson, Graduate Student

Mr. James O. Pilotte, Graduate Student

Mr. Thomas J. Ruth, Graduate Student

Mr. John L. Wood, Graduate Student

Mr. Wood completed the requirements for the Ph.D. as of June, 1971 and has joined the staff of the Institute for Experimental Nuclear Physics, Karlsruhe, Germany as a Research Associate. Mr. Pilotte is expected to complete his work towards a masters degree in early 1972. Mr. Anderson, a recent graduate of Allegheny College and Mr. Ruth, a staff member on leave of absence from Thomas More College, joined our group this fall. Both are working toward the doctorate.

C. Publication and Other Activities

1. Articles

"Decay of ^{162m}Ho to Levels in ^{162}Dy", J.L. Wood and D.S. Brenner, Nucl. Phys. A174 (1971) 353.

"Subshell Conversion-Line Intensity Ratios for Some Pure Transitions", D.S. Brenner and M.L. Perlman (Brookhaven National Laboratory), Nucl. Phys. (1971) in press.

"The Decay of ^{161}Er to Levels in ^{161}Ho", J.L. Wood and D.S. Brenner, Nucl. Phys. (1971) in press.

"Levels in ^{186}Os as Populated by the Decay of ^{186}Ir", K.J. Hofstetter (University of Kentucky), T.T. Sugihara (Texas A & M University), and D.S. Brenner, Nucl. Phys. (1971) submitted.

"Levels in ^{173}Lu as Populated from Decay of ^{173}Hf", R. Kishore and D.S. Brenner, Nucl. Phys., manuscript in preparation.

2. Contributed Papers

"The Decay of ^{173}Hf", R. Kishore and D.S. Brenner, 161st ACS National Meeting, Los Angeles, March, 1971.

"Energy Levels in ^{161}Ho", J.L. Wood and D.S. Brenner, 161st ACS National Meeting, Los Angeles, March, 1971.

3. Professional Activities

Daeg S. Brenner --

Member: American Chemical Society, American Physical Society, Sigma Xi, Phi Lambda Upsilon, Yale HILAC User's Group, Berkeley Super-HILAC User's Group, Research Collaborator - Brookhaven National Laboratory, Chairman-Spectroscopy Symposium for the 164th National ACS Meeting, New York, August, 1972.

II. Research Program

A. Nuclear Spectroscopy

The main thrust of our research program has been to characterize in detail the level structure of nuclides with permanently deformed ground states. In particular, our effort has been concentrated on neutron-deficient nuclides in the rare-earth region.

During this year we completed studies of the decay schemes of ^{161}Er and ^{173}Hf. We are particularly pleased with the results of the ^{161}Er→^{161}Ho experiments where our analysis has led to the identification of a number of Nilsson proton states which were previously unknown. As a follow-up to this work we have begun to study the decay schemes of ^{163}Er and ^{159}Er in order to evaluate the effect of changing deformation on the energy levels of the 67^{th} proton.

In other work, the collaborative study of the decay scheme of ^{186}Ir has been completed and submitted for publication and an experimental investigation of subshell-line intensity ratios done with M.L. Perlman of Brookhaven National Laboratory was finished.

1. <u>The Decay of ^{162m}Ho to Levels in ^{162}Dy</u> (J.L. Wood and D.S. Brenner)

A study of the decay scheme of 63-min ^{162m}Ho completed last year has been published in Nuclear Physics. A reprint is found in Appendix A. The salient result of this work was the identification of a two quasiproton state {p[411↑]; p[523↓]} 5- at 1390 keV, a state which had been predicted to occur but had not been previously identified.

2. <u>The Decay of ^{161}Er to Levels in ^{161}Ho</u> (J.L. Wood and D.S. Brenner)

An extensive investigation of the level scheme of ^{161}Ho as populated by decay of ^{161}Er was completed this year. The detailed

results of this work are contained in a preprint which has been accepted by Nuclear Physics for publication. A copy of the preprint is found in Appendix B1. Thirty-one new energy levels in ^{161}Ho were identified (only 5 were known previously) and all the Nilsson single-proton states expected to occur below 1 MeV in excitation energy have been characterized. Combination of our data with that obtained from in-beam reaction studies of other groups has enabled us to locate all the members of the $1/2^+[411]$ rotational band up to spin 23/2. The decoupling parameter extracted from a fit of the rotational formula to the experimental level spacings proved to be anomalous, as is the case for the same band in ^{165}Ho. There remains no satisfactory theoretical explanation for the level spacings in this rotational band. Finally, the de-excitation of the γ-vibrational band built on the $7/2^-[523]$ ground state of ^{161}Ho to the $1/2^+[411]$ and $3/2^+[411]$ rotational bands, a phenomenon not permitted by the pure hydrodynamical model, was found to be consistent with the predictions for microscopic structure of the γ-vibrational levels.

3. Levels in ^{173}Lu as Populated in Decay of ^{173}Hf (R. Kishore and D. S. Brenner)

The experimental results of this study were reported in detail in a previous Report (NYO-3950-3). During this year we have been refining the data and carrying out a theoretical analysis in order to understand the energy level structure below 1 MeV. A manuscript is currently being prepared and will be submitted for publication early in 1972.

4. Levels in ^{186}Os as Populated by the Decay of ^{186}Ir (K. J. Hofstetter (University of Kentucky), T. T. Sugihara (Texas A & M University), and D. S. Brenner)

The study of the very complex γ-ray spectrum of ^{186}Ir was completed this year and a manuscript has been submitted to Nuclear Physics for publication. A preprint is found in the Appendix B2. A number of new energy levels in ^{186}Os are proposed and an analysis of the interband transition intensities between members of the ground- and γ-bands shows agreement between the data and the first-order band-mixing model. The behavior of ^{186}Os and other Os transition nuclei differs significantly from those of the transition nuclei near N=90 where even inclusion of β-band mixing in the theory does not give complete agreement with the experimental results.

5. The Decay of ^{163}Er to Levels in ^{163}Ho (J.O. Pilotte and D.S. Brenner)

A study of the decay scheme of ^{163}Er was begun this year in an effort to extend our knowledge of the energy level structure of the 67^{th} proton as a function of nuclear deformation. The low-energy level structure of ^{163}Ho should be particularly interesting since it is expected (from interpolation between the well-known level schemes of ^{161}Ho and ^{165}Ho; see Appendix B1) that the $1/2^+[411]$ and $3/2^+[411]$ band heads should occur very close in energy, leading to a large amount of Coriolis coupling between the rotational bands. Unfortunately, one encounters a great deal of difficulty in studying the radioactive decay scheme of ^{163}Er since only 0.1% of the ^{163}Er nuclei decay to excited states in ^{163}Ho, with the result that it has been difficult for us to make sources of sufficient strength for coincidence spectro-

metry. At present, we are analyzing singles data of good quality and coincidence data of marginal quality in order to evaluate the feasibility of bringing this study to a successful conclusion.

6. The Decay of 36-min ^{159}Er (T. Ruth and D. S. Brenner)

A preliminary investigation of the γ-ray spectrum arising from decay of ^{159}Er was done in an attempt to evaluate the feasibility for producing and studying this nuclide at the Yale HILAC. Because of beam-energy limitations at the HILAC it was necessary to produce ^{159}Er by the ^{158}Dy (α,3n) reaction. Since ^{158}Dy is a low-abundance isotope (20% was the highest enrichment available from ORNL), there are numerous radioactive impurities produced by reactions on the other Er isotopes present in the target which obscure to a large extent radiations from ^{159}Er made in this way. At present, it seems likely that a successful investigation of the ^{159}Er decay scheme can only be pursued at a variable energy cyclotron of higher beam energy than available at Yale where reactions on higher abundance Er isotopes such as ^{161}Dy (α,6n) or ^{161}Dy (^{3}He,5n) can be exploited. We are currently considering carrying out such experiments in cooperation with personnel at the Cyclotron Institute of Texas A & M University.

7. The Level Scheme of ^{169}Tm from Decay of ^{169}Yb (D. Anderson, T. Ruth and D. S. Brenner)

An investigation of the decay scheme of 30-day ^{169}Yb was begun in an attempt to find evidence for several Nilsson states of the 69th proton which are predicted to exist at low energy in ^{169}Tm but as yet are not identified. These levels have not been seen presumably because they are weakly populated in ^{169}Yb decay and

would necessarily be connected to the known level structure by very weak γ-transitions. It is our intention to search for these very weak transitions using the high resolution Ge(Li) and Si(Li) detectors in our laboratory which are capable of providing a greater degree of discrimination than has been the case for the published studies of ^{169}Yb decay.

8. Subshell Conversion-Line Intensity Ratios For Some Pure Transitions (D. S. Brenner and M. L. Perlman (Brookhaven National Laboratory))

During this year the final analysis of experimental data and the interpretation of the results of L- and M- subshell conversion-line intensity ratios for some pure-multiple transitions was completed. A preprint of this work is found in Appendix B3. Experimental work on this problem was completed several years ago at Brookhaven National Laboratory. Subsequent analysis of our data and selected data from the literature was carried out at Clark University and at Brookhaven. The essential conclusion of the study is that there is no real disagreement between theory and experiment for subshell conversion ratios other than the well-known discrepancies for L-subshell ratios of E2 transitions in the rare-earth region. An explanation for these discrepancies is suggested and an accurate procedure for interpolation of tabular conversion coefficients is presented.

IV. Appendicies

A. Reprint

"Decay of ^{162m}Ho to Levels in ^{162}Dy", J.L. Wood and D.S. Brenner, Nucl. Phys. A174 (1971) 353.

B. Preprints

1. "The Decay of ^{161}Er to Levels in ^{161}Ho", J.L. Wood and D.S. Brenner, Nucl. Phys. (1971) in press.

2. "Levels in ^{186}Os as Populated by the Decay of ^{186}Ir", K.J. Hofstetter, T.T. Sugihara and D.S. Brenner, Nucl. Phys. (1971) submitted.

3. "Subshell Conversion-Line Intensity Ratios for some Pure Transitions", D.S. Brenner and M.L. Perlman, Nucl. Phys. (1971) in press. Removed