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PROGRESS REPORT ON NUCLEAR DATA IN BRAZIL

(June 1971 – May 1972)

edited by
S. B. Herdade

– I.F. U.S.P. –

UNIVERSIDADE DE SÃO PAULO
Instituto de Física

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Comissão Nacional de
Energia Nuclear

P R E F A C E

This Progress Report covers the period: June 1971 - May 1972. It is a collection of abstracts which have been submitted to the INDC Liaison Officer upon request. The request was addressed to individuals who might represent groups doing research in nuclear physics, reactor physics and nuclear engineering, whose results could be of interest to nuclear data compilers and evaluators. Although the editor tried not to miss any appropriate institution or individual, there might have been some oversight.

A part of the work outlined in this report has been prepared to be presented at the Annual Meeting of the Brazilian Physical Society, in July 1972.

The information herein contained must be considered as private communications; they should not be quoted without author's permission.

São Paulo, SP
Brazil, May 1972

S. B. Herdade
Liaison Officer for Brazil
International Nuclear Data Committee

A. INSTITUTO DE ENERGIA ATÔMICA

Caixa Postal 11049 - Pinheiros
São Paulo, Brasil

1. IEA-R1 5 Mw Swimming Pool Research Reactor

Built by Babcock and Wilcox Co., became critical for the first time in September 1957. It is operated normally at 2 Mw, 8 hours a day, 5 days a week. Low-Power operation and maintenance is carried out one day each fortnight. The facilities for experiments and irradiation includes: 8 radial beam-holes, 2 tangential beam-holes, 2 pneumatic "rabit" stations, and 22 irradiation rigs in the core.

The reactor is utilized mainly for nuclear, neutron and solid state physics experiments, radioisotope production, and activation analysis.

Reactor power is being upgraded to 10 Mw.

2. Resonant Nuclear Scattering of Gamma-Rays in the Energy Range (5-10 MeV).

G.G. Bianchini

Monochromatic photons obtained from thermal neutron capture reactions in the IEA-R1 reactor are utilized for the excitation of nuclear levels in the energy range 5-10 MeV, by means of the resonant nuclear scattering of gamma-rays.

Resonant events are obtained when one of the gamma lines of the incident spectrum coincides with a nuclear level in one of the nuclides contained in the target under study.

This method of exciting nuclear levels gives information on the following properties of nuclear levels: energy, spin, parity, total and partial level widths and statistical information on the widths and spacing of nuclear levels.

By utilizing photons produced in the thermal neutron capture in iron, targets of lead, nickel and cadmium

have been studied. Elastic resonant scattering has been observed at the energy 7.646 MeV for ^{62}Ni, and 7.632 MeV for ^{112}Cd. The lines emmitted in the excitation of these levels have been studied as well as the inelastic scattering for levels of lower energies.

For the elastic level of 7.279 MeV in ^{208}Pb, the following parameters have been determined from angular distribution experiments, self-absorption, and variation of the temperature of the target: spin (J), width (Γ), and spacing (ε) between the incident line and the resonant level. The following results have been obtained:
$J = 1$, $\Gamma = (0.4 \pm 0,1)$eV, and $\varepsilon = (7.8 \pm 0,5)$eV.

3. Measurement of the cross-sections for the reaction $^{238}U(\gamma,n)^{237}U$, in the energy range 6-10 MeV, by radiochemical techniques.

O.Y. Mafra, M.F. Cesar, C.Renner, S.Kuniyoshi and J. Goldemberg

The cross-sections for the reaction $^{238}U(\gamma,n)^{237}U$ are being measured, for monochromatic gamma-rays in the energy range 6-10 MeV, obtained from neutron capture in several materials at the IEA-R1 reactor, utilizing a method of radiochemical separation.

The activity of ^{237}U is determined by integrating the counts under one of its gamma lines measured with a Ge(Li) detector.

The irradiation is carried out close to the target used as source of monochromatic gamma-rays. The sample is protected with cadmium and parafin to avoid neutron induced reactions. The presence of ^{237}U has been identified by the spectrum and half-life (6.75h).

These cross-sections have been determined previously by indirect means, counting the total number of neutrons emmited by an uranium sample taking in account the known cross-sections for photofission. Uncertainties in the precision of this method lead us to the direct study of the reaction (γ,n) in ^{238}U.

4. Study of the de-excitation of ^{77}Se through the desintegration of (^{76}Ge + n).

M.A.N. de Abreu and J.M. Gualda

The analysis of the gamma radiation in the energy interval 10-2500 KeV emmitted in the de-excitation of ^{77}Se, resulting from the desintegration of ^{77}Ge: $^{77}Ge \xrightarrow[13h]{} {}^{77}As \xrightarrow[39h]{} {}^{77}Se$, has been carried out using a Ge(Li) detector with a resolution of 2.2 KeV. The nuclide ^{77}Ge was produced by thermal neutron capture in a sample of germanium enriched to 74% in the isotope of A = 76.

The existence of new low intensity lines: (62.4 KeV) in ^{77}Se, (60.0 KeV) in ^{77}As, and a doublet (51.4 KeV) in ^{77}Se is detected.

5. Influence of the finite thickness of the sources on the forms of the internal conversion lines observed in a beta-ray spectrometer.

Brigitte R.S. Pecequilo and A.A. Suarez

Using a magnetic sector type beta spectrometer built at the Instituto de Energia Atômica, measures have been carried out of ^{114}Cd internal conversion lines of several energies (K558, K651, K725, K805, K1134, K1209) for different target thicknesses (0.32 mg/cm^2, 0.8 mg/cm^2, 1.42 mg/cm^2, etc.).

The obtained conversion lines allowed us to obtain the functional dependence of the resolution and other parameters with respect to the energy and source thickness. By utilizing this result it is possible then, to calculate the intensities and energies experimentally obtained.

6. Experimental Reactor Physics

Facilities:

a) Pulsed neutron source, High Voltage Eng.Corp. Model

PN-400. Deuterons: energy 400 KeV, maximum current 150 μA. Neutron yield: 10^{10} n/s. Duty cycle: ~ 10%.

Equipment for utilization: 1024 channel and 256 channel analysers; Ge(Li) detector 40 cm^3, 2 KeV resolution; pneumatic transfer system for samples (transit time $\geq$ 1s).

b) Sealed neutron source Philips - SAMES.

c) Statistical chopper, to be installed in one of the neutron tubes of the IEA-R1 reactor. It is intended to be used at first for obtaining integral parameters for reactor physics and neutron transport theory.

B. INSTITUTO DE FÍSICA, UNIVERSIDADE DE SÃO PAULO

Cidade Universitária - Caixa Postal 20516
São Paulo, Brasil

1. 22 MeV Herb Pelletron Accelerator

1.1 Installation

The Pelletron system consists of a 4-MV injector and a tandem-type accelerator. It is capable of furnishing beams of 22 MeV protons, 27 MeV alphas and heavy ions of energy 50 MeV for oxygen to 80 MeV for sulphur.

The main accelerator and the injector have been installed and aligned together with the auxiliary beam handling equipment. Experimental arrangements are in various stages of development and some groups have practically completed the mounting of their chambers and detectors. Beam has been obtained in the target area.

1.2 Neutron Physics with a time-of-flight system

A time-of-flight system was designed to obtain 1 nanosecond beam pulse with a basic repetition rate of 5.5 MHz. This rate may be reduced by factors of two until 0.34 MHz. Pulses of approximately 30 n.s. are obtained by chopping, are compressed by a klystron type buncher and chopped after acceleration to give the desired pulse width.

1.3 Research Program in Neutron Physics

The research program will be initiated by studying $(^3He,n)$ reactions in ^{12}C and ^{16}O where yields are large and the characteristics of the system can be easily observed.

$(^3He,n)$ reactions will also be studied with nuclei in the f-p shell and compound with results on analogous $(^{16}O,^{14}C)$ reactions. The results will be interpreted in terms of current theories in pairing vibrations.

It is also planned to study the energy spectrum of neutrons obtained from heavy ion reactions and compare the results with current evaporation theories.

1.4 Research Program with heavy ions

Studies will be made of the one and two nucleon transfer reactions produced by heavy ions. Initially oxygen beams will be used.

A systematic study will be made of the elastic scattering of heavy ions by different isotopes of the same element in order to obtain information on the relative diffuseness and extension of the nuclear boundary.

2. Electrostatic Accelerator

2.1 Installation

This accelerator is capable of producing 3.5 MeV protons and deuterons and 7 MeV alphas. Beam currents obtained are 10 μ amp for protons and deuterons, and alphas up to 3.5 MeV. Above 3.5 MeV the alpha current is approximately 0.1 μ amp. The beam may be either continuous or pulsed at 5 MHz with about 5 nanosecond pulse widths for neutron time-of-flight experiments.

2.2 Fast Neutron Cross Section Measurements of Some Rare Earth Nuclei

(to be submitted to "Nuclear Physics")

Measurements of neutron radiative capture cross sections have been made using a Moxon-Rae Detector and time of flight techniques. Cross section ratios to In were determined for Sm, En, Gd, Tb, Dy, Ho, Er, Yb, Lu and Ta for 30, 65, 165 and 300 keV neutron energies.

3. Electron Linear Accelerator

3.1 Description and Characteristics

The University of São Paulo electron linear accelerator is composed by two SLAC type section three meters long. Electron beam is supplied by a 100 KV pulsed electron gun at a repetition rate of 60 cycles per second. After prebunching and focussing the beam is accelerated up to 50 MeV by the two sections. An analysing magnet allows a beam with a resolution of 0.5% in energy and a current of

0.1 μA.

Redesign of the gun power supply and of the Klystron modulator, as well as installation of a second Klystron will allow a higher repetition rate (180 cps) and higher energy (70 MeV).

Research programs include electrodisintegration studies, electron and bremsstrahlung induced fission, and nuclear spectroscopy.

3.2 Electrodisintegration measurements in ^{35}Cl and ^{19}F

J.R. Moreira, E.Wolynec and G. Moscati

An analysis of the relative contribution of the different electromagnetic field multipoles to the excitation of some nuclear levels can be made by electrodisintegration studies.

The electron beam of the University of São Paulo LINAC is being used to induce reactions of the type (e,e',n) in several nuclides.

Targets have been chosen in which the reaction product can be analysed by means of its β^+ activity. The positrons are identified through the annihilation radiation using two NaI(Tl) crystals in coincidence.

In order to distinguish the reaction (e,e',n) from the reaction (γ,n) caused by the electron bremsstrahlung in the target itself, a pair of samples is irradiated with a lead radiator between them.

Preliminary results for C coincide with results found in the literature. Measurements relative to ^{35}Cl and ^{19}F are in progress.

3.3 Electron and bremsstrahlung-induced fission of ^{238}U

S.B. Herdade, I.C. Nascimento, J.D.T. Arruda Neto and J. Goldemberg

The cross-section ratio $\sigma(\gamma,f)/\sigma(e,f)$ has been determined using the electron beam of the University of São Paulo LINAC in the energy range 15 to 45 MeV.

Preliminary results have shown that this ratio is

approximately constant in this energy range. With these first results it was not possible to conclude if the transitions are of an electric dipole or of a magnetic dipole nature.

With the accumulation of more measurements, it is hoped that the above cross-section ratio will be determined with better precision.

The method utilized for the measurements is the one of counting fission fragment tracks in mica sheets.

4. Nuclear Spectroscopy

4.1 Isomeric formation ratio by Bremsstrahlung gamma rays on ^{89}Y $(\gamma,2n)$ ^{87}Y, and ^{89}Y $(\gamma,3n)$ ^{86}Y reactions

J.S. de Goes, O.A.M. Helene, V.R. Vanin, S.A.S.Vitielb, C.M. Faria, J.A. Guillaumon Filho e I.D. Goldman

Yttrium was irradiated at the electron beam of the "Acelerador Linear do Instituto de Física da Universidade de São Paulo". The measurements have been taken with a GeLi detector with 3KeV resolution at 662KeV, associated with a 4096 Multi-channel.

We have measured the half-life and characteristic transition to identify the isotope and the isomer. See table I and table III.

The experimental results show for ^{87}Y a slight increase of the isomeric ratio on relation $\Sigma_{9/2}^{+}/\Sigma_{1/2}^{-}$. We present the results in table II.

To ^{86}Y, the increase of the isomeric ratio $\Sigma_{8}^{+}/\Sigma_{4}^{-}$ is more pronounced, and that is consistent with the proximity of the low energy results to the reaction threshold, table IV.

The statistical Model, proposed by Huizenga and Vandenbosch, gives to the spin cutoff parameter $\sigma<3$ for ^{87}Y and $\sigma\tilde{}$ 4 for ^{86}Y.

4.2 Isomeric Formation Ratio by Reactions (γ,xn) for ^{120}Sb, ^{104}Ag, ^{110}In and ^{178}Ta

J.S. de Goes, O.A.M. Helene, V.R. Vanin, S.A.S. Vitiello, C.M. Faria, J.A. Guillaumon Filho and I.D. Goldman

Antimony, silver, indium and tantalum were irradiated at the electron beam of the "Acelerador Linear do Instituto de Física da Universidade de São Paulo" with energies respectively of 38, 40, 39 and 40 MeV, producing the Bremsstrahlung in the sample.

The measurements have been taken with a GeLi detector with 3 KeV resolution associated with a 4096 Multichannel.

The isomeric state was determined by the half life and the characteristic transition (see Table V).

The isomeric formation ratio from high to low spin are shown in Table VI.

4.3 Energy Levels of ^{119}Sn

T. Borello, O. Dietzsch, E.W. Hamburger and C.O Orsini

The isotopes ^{111}Sn, ^{113}Sn, and ^{123}Sn have been studied in previous work. In this work the reaction $^{118}Sn(d,p)^{119}Sn$ has been studied with 17 MeV deuterons from the University of Pittsburgh Tandem. The protons analysed by a magnetic spectrometer, have been detected in nuclear emulsions. Fourteen spectra in scattering angles from 8^{o} to 69^{o} have been obtained. The analysis of these spectra allowed the identification of 47 energy levels up to an excitation of 4.5 MeV, and of their angular distributions. Nineteen of these energy levels have been observed for the first time. Comparisons of the angular distributions with the ones preview by the DWBA have furnished the values of ℓ. It is interesting to notice that a level with $\ell = 3$ appears at 1.056MeV, well bellow the energy one should expect on the basis of the shell model. Levels $\ell = 3$ at energies ~ 1 MeV appear also in the isotopes $^{113}S_n$, $^{121}S_n$ and $^{117}S_n$. Perhaps this level can be explained by the weak coupling of the phonon 2^+ with the quasi-particle $h_{11/2}$.

T A B L E I

$^{89}Y(\gamma,2n)\ ^{87}Y$

	Spin	half life	Measured Transitions
Ground State	$\frac{1^-}{2}$	80 h	388 KeV 483 KeV
Metastable State	$\frac{9^+}{2}$	14 h	381 KeV

T A B L E I I

Table of Isomeric Formation Ratio of ^{87}Y

Electrons energy	Ratio of high to low Spin	Previous results (a)
35,6 MeV	0,396	
38,0 MeV	0,426	
40,0 MeV	0,364	
42,0 MeV	0,485	
44,0 MeV	0,433	
46,0 MeV	0,473	
150 MeV*		0,42 ± 0.03
280 MeV*		0,42 ± 0.03

* bremsstrahlung

(a) W.B. Walters and J.P. Hummel - Phys. Rev. 150, 867 (1966)

T A B L E I I I

$^{89}Y(\gamma,3n)^{86}Y$

	Spin	half-life	measured transitions
Ground State	4^-	14.6h	1078 KeV
Metastable State	8^+	46 m	208 KeV

T A B L E I V

Table of isomeric Formation Ratio of ^{86}Y

Electron Energy	Ratio of High to Low Spin
35.6 MeV	0.0526
38.0 MeV	0.0789
40.0 MeV	0.0997
42.0 MeV	0.1380
44.0 MeV	0.1098
46.0 MeV	0.1190

T A B L E V

ISOTOPE	REACTION	SPIN	HALF LIFE	MEASURED TRANSITIONS
^{102}Sb	$^{121}Sb(\gamma,n)^{120}Sb$	8^-	5.8d	1030 KeV
		1+	15.9m	511 KeV
^{104}Ag	$^{107}Ag(\gamma,3n)^{104}Ag$	5^+ (ground-state)	30m	511 KeV. 555 KeV
		2^+	67m	556 KeV. 767 KeV e 938 KeV
^{110}In	$^{113}In(\gamma,3n)^{110}In$	7^+	4.9h	642 KeV, 658 KeV
		2^+	67m	658 KeV
^{178}Ta	$^{181}Ta(\gamma,3n)\ ^{178}Ta$	1^+	9.4m	511 KeV
		$(7,8,9)^-$	2.Ih	213 KeV, 326 KeV, 426 KeV

T A B L E V I

TABLE OF ISOMERIC FORMATION RATIO OF IRRADIATED ISOTOPES

ISOTOPE	HIGH SPIN	LOW SPIN	RATIO OF HIGH TO LOW SPIN
$^{120}_{Sb}$	8^-	1^+	0.080
$^{104}_{Ag}$	5^+	2^+	0.130
$^{110}_{In}$	7^+	2^+	1.035
$^{178}_{Ta}$	$(7,8,9)^-$	1^+	0.183

C. CENTRO BRASILEIRO DE PESQUISAS FÍSICAS

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1. Electron Linear Accelerator

Energy: 28 MeV; 60 μA mean current; pulsed beam with pulses from 500 n sec to 3 μsec. This accelerator was designed and built by the Centro Brasileiro de Pesquisas Físicas Accelerator Development Group. It is in operation since 1968 and has been utilized for radionuclide production in nuclear spectroscopy studies. An uranium target is used for the production of pulsed neutron beams. Flight paths of 5, 10, 15, 20 and 25 meters are in use for neutron time-of-flight experiments. Resonant neutron capture studies are in progress.

A pneumatic system (rabit), for irradiation of samples, is available. A high flux ^{235}U neutron source is planned for 1972.

2. Levels of ^{197}Pt and ^{197}Au populated by the decay of ^{197}Pt g.s and ^{197m}Pt.

S. de Barros, S. Calzavara and A. Tonati

The decays of ^{197}Pt and ^{197m}Pt have been studied by gamma-ray spectroscopy, using Ge(Li) detectors. Coincidences have been registered with the aid of a multiparameter analyser. The experimental results are compared with previous results obtained in decay and nuclear reaction experiments. The β branch, populating the 548.0 KeV [1], was not confirmed. A decay scheme coherent with our coincidence data is presented.

(1) E.Bashandy and M.Migahed, Annalen Physik, 7 (1967) 152.

3. Decay of ^{197}Ir

S.Calzavara, S. de Barros, A.M. Gonçalves

The ^{197}Pt transitions following the decay of ^{197}Ir have been investigated with a Ge(Li) detector. A new decay scheme for ^{197}Ir is presented, including four gamma-rays: (877.6 ± 0,3)KeV, (938.0 ± 0,3)KeV, (1049.6 ± 0,3)KeV, and (1341 ± 0,3)KeV, not previously detected.

Spin and parity assignements for excited levels of ^{197}Pt and for the ground state of ^{197}Ir have been proposed. The observed level structure has been compared with the ones obtained from nuclear models.

4. Neutron-Capture Gamma-Ray Spectroscopy in ^{76}As.

N.Lisbona, A.M. Gonçalves and S.de Barros

Gamma-rays from excited levels of ^{76}As have been detected in a time-of-flight spectrometer by single and coincidence counting. The detectors used were NaI(Tl) (8cm diameter x 8cm height) and (12x12 cm^2 area x 10cm height). 23 resonances have been analysed in the energy interval 20 to 1450 KeV. The 307.7 KeV and 578.8 KeV resonances correspond to new levels of ^{76}As, and the 498.0 KeV and 8720,0 KeV resonances confirm the levels that caused disagreement in previous measurements [1] [2]. An extension of the Coceva et al [3] method to odd-odd nuclei, allowed us to make several spin assignements in the resonance energy interval 0 to 1000 KeV. The consequences of the extension of this method are discussed. The indication of the variation with spin of the S-wave neutron density function, in the direction $S(I + \frac{1}{2}) > S(I - \frac{1}{2})$, is confirmed.

(1) J.B. Gard, et al, Phys.Rev. 136, B 177 (1964)
(2) J.Julien, et al, Phys.Lett. 10, 86 (1964)
(3) C.Coceva, et al, Nucl.Phys. A 117 (1968) 586-614

5. Transparencies of Complex Nuclei to Photoproduced Pions and Recoil Nucleons.

H.G. de Carvalho, J.B. Martins, O.A.P. Tavares and R.A.M.S. Nazareth (Centro Brasileiro de Pesquisas Físicas - Rio de Janeiro); V. di Napoli (Instituto di Chimica Generale ed Inorganica dell'Universitã - Roma).

Lettere Al Nuovo Cimento, Vol. 2, N.22 (1971)

In the high-energy photonuclear research it is very important to study the probability that a pion and/or a recoil nucleon produced by the interaction of a high-energy photon with a complex nucleus, escape from the nucleus without any interaction, i.e. the transparency of the nucleus to the photopions and recoil nucleons.

The present paper reports the calculation of transparencies for pions and recoil nucleons originated by interaction of high-energy photons with complex nuclei (energy range: 0.3 - 1.0 GeV).

6. Alpha Activity of ^{209}Bi

H.G. de Carvalho and M.de Araujo Penna
To be published in "Lettere al Nuovo Cimento"

The nuclide ^{209}Bi has a magic number of neutrons (126) and one proton more than magic (83). This particular shell structure imposes restrictions on the usual methods for calculation of the alpha-decay half-life. The alpha-decay of ^{209}Bi to the ground state of ^{205}Tl leads to a large spin and parity change, adding strong hindrance to the process. The extremely low activity is far out of the ordinary experimental methods for alpha-radioactivity measurements which have been unsuccessfuly used by many authors. The present paper reports the result of the alpha-decay half-life of ^{209}Bi obtained from theoretical considerations taking into account all hindering factors of ^{209}Bi decay, and establishes a new lower limit for the experimental half-life.

7. Nuclear Ground-State Structure and Beta-Decay

L. Tauhata, M. Binderly Gaspar and A. Marques

Nuclear ground state wave functions are generated through modern computational methods and used for calculations of relevant data in beta-decay. The results are checked against life-times and beta-ray energy

spectrum accurately measured with solid-state detectors and yield information either upon the wave functions or weak interaction coupling constants.

8. Compensation for the Gamma-Ray Energy Dependence in Delayed Coincidence Measurements with NaI(tl) Detectors

A. Marques

A method is developped for the accurate time balance of the two channels of a delayed coincidence device which can allow for time delays generated in the crystal detectors. Short life-time measurements ($< 10^{-10}$s) are envisaged.

9. Mass Formula for Super-Heavy Elements

T. Kodama

A theoretical mass formula for super-heavy elements is under development.

10. Quadrupole Moment of the First Excited 3/2-Level of Ru^{99}

D. Grienzburger, J. Danon in Collaboration with W. Potzel, F. Wegner and U. Zahn (Technische Höschule Munchen)

Electric field gradients are calculated in Rutenium molecular complexes whose quadrupole interaction has been measured by Mössbauer spectrometry method. The quadrupole moment for that state is derived.

D. PONTIFÍCIA UNIVERSIDADE CATÓLICA, DEPARTMENT OF PHYSICS

Rio de Janeiro ZC-20, Brasil

1. Van de Graaff Accelerator

High Voltage Eng. Model KN-4000 machine, with the following characteristics:

protons or deuterons: 0.5 to 4.0 MeV, 3 KeV resolution, 200 μA intensity.
electrons: 1.5 to 3.0 MeV, 20 KeV resolution, 900 μA intensity.
The accelerator is expected to be operational in September 1972.

2. The Level Spectra of Nuclei with $51 \leq Z \leq 61$ and the Intermediate-Coupling Model.

A.G. de Pinho, I.V. Goldstein and J.M.F. Jeronymo
Published in: An.Acad.Bras.Ciên. (1971), 43 (1)

The properties of the low-lying levels of many odd-mass nuclei with $51 \leq Z \leq 61$ were studied in the framework of the unified (intermediate-coupling) model. Energies, magnetic dipole and electric quadrupole moments, transition probabilities and spectroscopic factors were calculated and compared with the experimental values. Up to three phonons and four shell model orbits were considered in the calculation of the positive parity states. The A-dependence of the adjustable parameters of the model was examined.

3. Level Scheme of ^{211}Bi

E.F. da Silveira, A.G. de Pinho and C.V. de Barros Leite
Published in: An.Acad.Bras.Ciên. (1971), 43 (1)

The decay scheme of ^{211}Pb was reinvestigated by means of Ge(Li) singles and coincidence techniques giving rise to the addition of two new levels to the known level scheme of ^{211}Bi. A total of 31 transitions were observed following the decay of ^{211}Pb and its descendents and 21 of these

transitions were accomodated in the level scheme of ^{211}Bi. Energies and relative intensities of all the transitions were determined as well as some internal conversion coefficients. The resulting level scheme was compared with a calculation where only the $(\pi\ 1h\ 9/2)^1\ (\nu\ 2g\ 9/2)^2$ configuration was considered and the levels were calculated by using only experimental information about the interaction of two neutrons in 2g 9/2 neutron and a h 9/2 proton (from ^{210}Bi). No adjustable parameter was present and some impressive results were attained.

4. Experimental Determination of Relative Radiative Decay Rates of Vacancies in the K Shell.

A.G. de Pinho
Published in: Physical Review A, 3 (1971) 905

A high-resolution Ge(Li) X-ray spectrometer was used for measuring relative radiative decay rates of vacancies in the K shell of the following atoms: Au, Hg, Tl, Pb, Bi, Rn, Ra, Th, and U. In the most favorable cases, the X-rays following the filling of a K vacancy by L_{II}, L_{III}, M_{II}, M_{III}, M_{IV}, M_V, N_{II}, N_{IV-V} and O_{II-III} electrons were observed and measured. The results were compared with recent relativistic calculations carried out by Scofield.

5. $\frac{1+}{2}$ Ground States of Cs^{127} and Cs^{129}

I.V. Goldstein and A.G. de Pinho
Published in: Physical Review C, 4 (1971) 653

The nature of the $\frac{1}{2}^+$ ground states of the light isotopes of cesium is discussed in the framework of the unified model. These states are well reproduced by the Nilsson model for oblate shapes, as well as by the intermediate-coupling version of the unified model.

6. Enhanced Low-Energy E2 Transitions in the Odd-A Isotopes of Sb, I, Cs and Pr.

I.V. Goldstein and A.G. de Pinho
Published in: Canadian Journal of Physics, 49 (1971) 1794

The intermediate coupling version of the unified model was used to calculate E2 transition rates in some odd-mass isotopes of Sb, I, C_s, and Pr. The observed enhancement of these transitions is reproduced and regular variations of the transition probabilities in groups of neighboring isotopes are explained.

7. Levels of the Odd Mass Isotopes of Sb and I and the Unified Model

I.V. Goldstein and A.G. de Pinho

A description of the low-lying positive parity levels of the odd mass isotopes of Sb and I is presented on the basis of the intermediate coupling approach of the unified model. Such analysis helps to understand many properties of those levels since a rather satisfactory agreement with experimental data is reached.

8. Levels in the N=82 Nucleus ^{142}Nd

F.M. Smolka and A.G. de Pinho

Decays of both ^{142}Pr and ^{142}Pm to levels in the 82-neutron isotone ^{142}Nd were investigated with Ge(Li) detectors. The ^{142}Pm was not separated from the ^{142}Sm source and some ambiguity is present in the assignement of gamma-rays with energies up to 2.05 MeV. Spin and parity assignements were made for all levels. The resulting level scheme is compared with predictions of theoretical calculations.

E. INSTITUTO DE ENGENHARIA NUCLEAR

Cidade Universitária, Ilha do Fundão
Rio de Janeiro, Gb - Brasil

1. Reactor Engineering Division

1.1 Brazilian ARGONAUTA Research Reactor

Designer: Argone National Laboratory, USA
Built by: Mecânica CBV Ltda., Rio de Janeiro, Brasil
Owner and operator: Comissão Nacional de Energia Nuclear
Type: Argonauta (H_2O-graphite; enriched uranium 20% in ^{235}U)
Power: 10 Kw (maximum)
Fuel: UO_2-Al pressed powder mixture with cladding
Critical mass: 2.088 Kg ^{235}U (one slab loading)
Neutron flux: average thermal - $0,57 \times 10^{11}$ n/cm^2.s
peak thermal - $1,20 \times 10^{11}$ n/cm^2.s
peak fast - $0,65 \times 10^{11}$ n/cm^2.s

Experimental facilities: neutron beams (horizontal-vertical); isotope production (holes, cavities, channels); short time irradiation (rabbit pneumatic system); thermal column (internal and external); shield test removable.
Utilization: neutron and reactor physics, solid state physics, engineering test, radiochemistry, isotope production, graduate education.

1.2 Resonance scape probability for the Argonauta reactor

A sandwich made with uranium foils (depleted in ^{235}U) and representative sections of the fuel under study is irradiated in the reactor core, and the activity of ^{239}U or ^{239}Np is measured.

1.3 Neutron cross-section measurements in the energy range 0.001 eV - 1.0 eV, with a crystal spectrometer

The resolution function for the IEN crystal spectrometer has been calculated, as well as the effect of the 2nd order contamination for the planes (111) of an aluminum crystal. Initially, to evaluate the influence of these effects in resonance measurements, the Iridium

resonance at E_o = 0,654 eV has been considered, using a Tellurium resonant filter to eliminate the 2nd order contamination.

The theoretical curve for the resonance has been calculated by the Breit-Wigner formula, taking in account the Doppler broadening for room temperature. This curve has been affected by the estimated resolution function, and corrected for 2nd order contamination. The theoretical curve agrees with the experimental results.

The ^{176}Lu resonance in the thermal region has been measured, and the following parameters were obtained:

$$E_o = (0,141 \pm 0,002)\,eV$$

$$\sigma_o = (13550 \pm 70)\,b$$

$$2g\,\Gamma_n^o = (0,230 \pm 0,005)\,MeV$$

$$\Gamma\gamma = (59 \pm 1)\,MeV$$

1.4 Neutron generator

Model: Texas Nuclear 9905

Neutron production: $^3_1H(d,n)^4_2He$, $^2_1H(d,n)^3_2He$

Maximum neutron flux: ~ 10^9 n/cm^2.s

Pulsed operation: 1 to 5 pulses/s; pulse width: 0.1 μs to 10 ms.

Additional equipment: pneumatic system for sample transfer; 2 photomultipliers coupled at 180°; 400 channel analyser.

Data output: paper tape puncher, card puncher, graph recorder.

Utilization: activation analysis; study of diffusion and moderation parameters in several media; cross-section measurements; graduate education.

1.5 Measurement of the thermal neutron diffusion parameters in water spherical systems by the pulsed neutron source method.

The decay constants of the thermal neutron flux have been measured in 20 spheres, varying the buckling in the range $0.024 \leq B^2 \leq 1,37$. A careful analysis has been made of the problems that influence the measurements of

the decay constants and the determination of the diffusion parameters, namely: the presence of epithermal neutrons, the variation of background, the influence of shielding, the contamination by harmonics, the behaviour of the extrapolated distance, the influence of the detector utilized, the weights adopted in the analysis of the experimental curves, etc. The results have been normalized for 26.5°C.

The fits of the curve

$$\lambda = V\Sigma_a + D_o B^2 - CB^4 + FB^6 + \ldots$$

with 3 or 4 parameters gives, respectively:

$$V\Sigma_a = 4882 \pm 10 \ (s^{-1})$$
$$D_o = 36550 \pm 94 \ (cm^2 \ s^{-1})$$
$$C = 3930 \pm 130 \ (cm^4 \ s^{-1})$$

and

$$V\Sigma_a = 4879 \pm 12 \ (s^{-1})$$
$$D_o = 36620 \pm 185 \ (cm^2 \ s^{-1})$$
$$C = 4120 \pm 530 \ (cm^4 \ s^{-1})$$
$$F = 140 \pm 370 \ (cm^6 \ s^{-1})$$

1.6 Measurement of the diffusion parameters in "Dowtherm A"

The decay constants of the thermal neutron flux have been measured in 9 spherical systems of "Dowtherm A", in the buckling range $0{,}044 \leq B^2 \leq 0{,}468$.

The fit of the curve: $\lambda = V\Sigma_a + D_o B^2 - CB^4$, where the values have been normalized for 20°C, gave the results:

$$V\Sigma_o = 2896 \pm 66 \ (s^{-1})$$
$$D_o = 51657 \pm 769 \ (cm^{-2} \ s^{-1})$$
$$C = 23635 \pm 1823 \ (cm^{-4} \ s^{-1})$$

2. Nuclear Physics Division

2.1 Variable Energy Cyclotron

A CV-28 cyclotron from the Cyclotron Corporation is

scheduled to start operation in June 1973. This accelerator will deliver over 50μA of external beams of protons from 2 to 24 MeV, deuterons from 3 to 14 MeV, $^{3}He^{++}$ from 5 to 38 MeV and $^{4}He^{++}$ from 6 to 28 MeV. Heavier ions can also be accelerated. Production of neutron deficient radionuclei for medical uses will be a pratical application of the cyclotron. Research on nuclear spectroscopy, neutron physics, activation analysis, radiation damage, nuclear reactions, will be stimulated. The housing of the cyclotron will be a 1500 m^2 building with Physics and Chemistry laboratories, and a 400 m^2 experimental area.

With a view on future applications of the variable energy cyclotron of the Instituto de Engenharia Nuclear, data was compiled on the following items:

a) neutron deficient radioisotopes for medical uses
b) charged particle activation analysis
c) fast neutron production by charged particles

2.2 Search for New Transitions in the Decay of ^{164}HO

A search for transitions from the 1^+ ground state of ^{164}Ho to the $2'^+$ gamma-vibrational states of ^{164}Dy and ^{164}Er was undertaken. A transition to the 760 keV $2'^+$ level of ^{164}Dy with log ft = 8.0 was found. For the transition to the 860 keV ^{164}Er $2'^+$ level, only a lower limit was found (log ft = 7.6). The results are discussed in terms of the multiple quasi-particle-pair interpretation of the gamma vibrations.

2.3 The Decay of ^{58}Cu

The energies and relative intensities of the γ-rays and the relative intensity of the annihilation radiation from the decay of ^{58}Cu have been measured. Levels at 444.9 keV and 4538.3 keV in ^{58}Ni were found to be populated in this decay. The intensity of the β^+-feeding of the 3584.9 keV level was found to be < 0.1%.

2.4 Gamma-ray Spectroscopy of the Thorium Active Deposit

The decay schemes of ^{212}Pb, ^{212}Bi, ^{212}Po and ^{208}Tl

members of the Thorium Active Deposit, were studied. In the γ-ray spectra obtained with Ge-Li detectors, forty-four γ-ray transitions were observed of which six, with energies 145.9, 164.2, 205.4, 227.5, 290.4 and 493.3 keV, not seen before, and two, with energies 927.6 and 982.9 keV were found simultaneously with other workers. A systematic separation of ^{212}Pb, ^{212}Bi and ^{208}Tl nuclei using AMBERLITE IR-120 and IRA-401 ion exchange resins as well as using recoil methods, showed that the two last mentioned γ-rays belong to ^{208}Tl decay. The 227.5 keV line was attributed to the β-decay of ^{212}Bi, based on the separations and also considering the α -particles intensities feeding the ^{208}Tl levels. The 205.4 and 290.4 keV γ-rays belong to the decay of ^{208}Tl as deduced from difference in the energy of levels in ^{208}Pb.

2.5 Some Applications of Coincidence Methods in Nuclear Spectroscopy

After setting up and studying some characteristics of the coincidence system, coincidence measurement in ^{208}Pb (gamma-gamma) and in ^{212}Po and ^{208}Tl (alpha-gamma) were performed. Three new gamma-ray transitions with energies 657,2 keV, 668,2 keV and 836,0 keV were found to be in coincidence with 2614 keV line. A 598,5 keV gamma-ray coincident with the 8,78 MeV α particles was confirmed in the decay of ^{212}Po. These transitions do not fit in the known decay schemes. Gamma-rays of 146,1 keV, 165,6 keV, 493,3 keV and 620,0 keV were seen in coincidence with α particles from the decay of ^{212}Bi. The energy measurement of this last transition is more accurate than measured before.