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PROGRESS REPORT ON NUCLEAR DATA IN BRASIL

JUNE 1973 - MAY 1974

JULY 1974

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(June 1973 - May 1974)

1. INTRODUCTION

This Progress Report has been written on the basis of:

a) abstracts which have been sent to the INDC Liasion Officer upon request to individuals who might represent groups doing research in nuclear physics, reactor physics, nuclear chemistry, and nuclear engineering;

b) abstracts of papers published by Brazilian scientists in the "Revista Brasileira de Física", and other international journals;

c) abstracts of papers presented at the Annual Meeting of the Brazilian Society for the Advancement of Science, 1974.

The material has been selected having in mind the eventual interest to nuclear data compilers and evaluators. Although it was tried not to miss any appropriate institution or individual there have been some oversight.

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

S.B.Herdade
Liasion Officer for Brazil,
International Nuclear Data Committee

2. MAIN EXPERIMENTAL FACILITIES FOR NUCLEAR PHYSICS RESEARCH

2.1 - 22 MeV Herb Pelletron Accelerator (Instituto de Física - Universidade de São Paulo)

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

Present status: in operation

Utilization: fast neutron physics (time-of-flight spectrometer), heavy ion reactions, nuclear spectroscopy, and charged particle reactions.

2.2 - PUC- RJ Van de Graaff Accelerator (Pontificia Universidade Catolica - Rio de Janeiro)

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 current; electrons: 1.5 to 3.0 MeV 20 KeV resolution, 900 μA current.

Present status: in operation

Utilization: atomic and nuclear physics research (nuclear spectroscopy).

2.3 - University of São Paulo Electrostatic (Van de Graaff Accelerator (Instituto de Física-Universidade de São Paulo)

Characteristics: 3.5 MeV protons or deuterons; 7 MeV alphas. Beam currents: 10 μA for protons or deuterons, and alphas up to 3.5 MeV. Above 3.5 MeV the alpha current is approximately 0.1 μA.

Status: presently not in operation

2.4 - University of São Paulo Electron LINAC (Instituto de Física - Universidade de São Paulo).

Characteristics: Electron linear accelerator composed by two SLAC type section, three meter long each. Electron beam is supplied by a 100 kV pulsed electron gun at a repetition rate of 60, 120, 180, 240, 300 and 360 H_z. Maximum nominal energy: 75 MeV. Analysed (0.5% resolution) current approximately 100 nA at 60 H_z.

Status: in operation in the energy range 8 to 45 MeV, with currents up to 200 nA; the vacuum system will be replaced by one using ion pumps so that the nominal energy could be reached in a near future.
Utilization: electrodesintegration studies, electron and bremsstrahlung induced fission; delayed neutron studies, and nuclear spectroscopy.

2.5 - CBPF Electron LINAC - (Centro Brasileiro de Pesquisas Físicas - Rio de Janeiro).

Characteristics: This machine was designed and built by the CBPF Accelerator Development Group. Energy: 28 MeV; 60 μA mean current; pulsed beam with pulses from 500 ns to 3 μs.
Status: in operation
Utilization: nuclear spectroscopy and neutron time-of-flight experiments.

2.6 - Variable Energy Cyclotron (Instituto de Engenharia Nuclear - Rio de Janeiro)

Characteristics: Cyclotron Corporation Model CV-28; will deliver over 50 μA of external beams of 2 to 24 MeV protons 3 to 14 MeV deuterons, 5 to 38 MeV $^{3}He^{++}$, and 6 to 28 MeV $^{4}He^{++}$. Heavier ions can also be accelerated.
Status: the accelerator and chemistry laboratoires building will be finished in July 1974; operation of the machine estimated to start in October 1974.
Utilization: production of neutron deficient radionuclides for medical uses; activation analysis; nuclear chemistry; radiation damage; nuclear reactions; neutron cross-section measurements.

2.7 - IEA - RI Swimming Pool Research Reactor (Instituto de Energia Atomica - São Paulo).

Characteristics: Built by Babcock and Wilcox Co. Nominal power: 5Mw. Has been operated during 17 years at 2 Mw. Facilities for experiments and irradiation include: 8 radial beam-holes, 2 tangential beam-holes, 2 pneumatic "rabbit" stations, and 22 irradiation rigs in the core.
Status: shut down for Power upgrade to 10 Mw.
Utilization: radioisotope production; activation analysis; nuclear, neutron, and solid state physics experiments.

2.8 - IPR Triga Reactor (Instituto de Pesquisas Radioativas Belo Horizonte

Characteristics: Designer and builder - General Atomic. Nominal reactor power: 30 Kw (upgraded to 250 Kw).

Status: in operation.

Utilization: radioisotope production; activation analysis ; solid state physics; radiation and nuclear chemistry.

2.9 - Brazilian Argonauta Research Reactor (Instituto de Engenharia Nuclear - Rio de Janeiro)

Characteristics: Designed in ANL, USA, and built by Mecânica CBV Ltda., Rio de Janeiro, Brazil.

Argonauta type (H_2O - graphite; 20% enriched uranium).

Power: 10 Kw (maximum). Fuel: VO_2-Al pressed powder mixture with clodding, fabricated by the Metallurgy Division of IEA, São Paulo, Brazil.

Experimental facilities: neutron beams (horizontal-vertical); isotope production (holes, cavities, channels); short time irradiation ("rabbit" system); thermal column (internal and external); shield test removable.

Utilization: neutron and reactor physics, solid state physics, engineering tests, radiochemistry, isotope production, graduate education.

3. NUCLEAR SPECTROSCOPY

3.1 - Spectroscopic Factors of Negative - Parity Multiplet States in Odd Sn Isotopes

S. de Barros[+], M.J.Bechara[+], T.Borello-Lewin[+] and V. Paar[++] (International Centre for Theoretical Physics, Trieste, Italy).

The spectroscopic factors of the negative-parity multiplet states $7/2^-_1$, $9/2^-_1$, $11/2^-_2$, $13/2^-_1$ and $15/2^-_1$ in odd Sn isotopes are calculated by including leading order scattering and ground-state correlation process. It is shown that ground-state correlations play an important role for the spectroscopic factors of the $7/2^-_1$ and $11/2^-_2$ states. The theoretical results are in good agreement with the available experimental data.

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3.2 - Effective Magnetic Dipole Operators and the Lifetime of the $^{3}/_{2}^{-}$ State in ^{207}Pb.

M.Dost[+] and J.D.Rogers[++]

A lifetime of $\tau = (0.15 \pm 0.03)$ psec for the 897 KeV $^{3}/_{2}^{-}$ state in ^{207}Pb is determined by the Doppler shift attemation method in thick target Coulomb excitation by 68 and 61 MeV ^{16}O ions on ^{207}Pb. The analysis uses the Monte Carlo method to treat the slowing down of recoiling Pb nuclei in Pb, and takes into account the effects of particle - γ angular correlations, finite detector size, and the slowing down of the projectiles in the target. The derived value of $B(M1, {}^{3}/_{2}^{-} \rightarrow {}^{1}/_{2}^{-}) = (0.52 \pm 0.10) \left(\frac{e\hbar}{2mc}\right)^2$ can be described with the same effective magnetic moment operator as describes the magnetic dipole moment in nuclei around ... ^{208}Pb.

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3.3 - g-Factors of the 264 KeV and 632 KeV States in ^{77}As.

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(Instituto de Física, UFRGS, Porto Alegre) and
J.M.Gualda and R.N.Saxena
(Instituto de Energia Atomica, São Paulo)

The integral perturbed angular correlation technique has been used to measure g-factors of the 264 KeV and 632 KeV states in ^{77}As. The measurement of the 264 KeV level was performed in an external magnetic field of 30 KO_e. The 632 KeV states, having a shorter lifetime was studied with help of the large hyperfine magnetic field at As nuclei in Fe matrix.

The g-factor of the 264 KeV($^{5}/_{2}^{-}$) state was measured using the 367-264 KeV gamma cascade while the 558-417 KeV gamma cascade was used to determine the g-factor of the 632 KeV ($^{5}/_{2}^{+}$) state. The results are: $g_{5/2^-} = + 0.33 \pm 0.05$ and $g_{5/2^+} = + 1.42 \pm 0.32$. The magnetic moments calculated from

these results are compared with the values obtained from the models available for the nuclei in this mass region.

3.4 - Half-Lives if Excited States in ^{77}As and ^{81}Br

R.N.Saxena and A.Bairrio Nuevo Jr.
(Instituto de Energia Atomica, São Paulo)and
R.P.Livi and F.C.Zawislak
(Instituto de Física, UFRGS, Porto Alegre)

The odd proton nuclei in the mass region $71 \leq A \leq 85$ have a very similar low energy level structure. In particular the state with spin of $^{5}/_{2}^{-}$ has been identified in most nuclei of this mass region. As a part of our systematic study of nuclear properties in this region, we have measured the half-lives of the excited states in ^{77}As (264 KeV $^{5}/_{2}^{-}$) and ^{81}Br (276 KeV $^{5}/_{2}^{-}$). The delayed gamma - gamma coincidence technique using Pb loaded plastic scintilators coupled to the RCA-8275 and -8850 photomultipliers tubes and conventional electronics was utilized. For the measurement of the 264 KeV state of ^{77}As the 367-264 KeV gamma cascade was used while the 276 KeV state of ^{81}Br was measured through the 290-276 KeV gamma - cascade. The half-lives were determined from the slope of the delayed coincidence curves. The results ate $T_{1/2}$(264 KeV) = 280$^{\pm}$ 20 psec and $T_{1/2}$ (276KeV) = 236$^{\pm}$ 15 psec.

3.5 - Directional Correlations of Gamma Transitions in ^{134}Xe.

J.M.Gualda and R.N. Saxena
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F.C.Zawislak
(Instituto de Física, UFRJ, Porto Alegre)

The directional correlation of coincident γ-transitions in ^{134}Xe have been measured using a Ge(Li)-NaI(Tℓ)spectrometer . The measurements have been carried out for the - 405-884-847, 433-(1072)-847, 540-884-847, 595-(540)-884-847, 621-884-847, 677-884-847, 766-847, 857-884-847, 884-847, 948-(1072)-847, 1072-847, and 1136-884-847 KeV gamma cascades. Spin assignments have been made for the levels at 1920 KeV (3^{+}), 2136 KeV (5^{+}), 2272 KeV (4^{+}), 2352 KeV (4^{+}), 2408 KeV ($5^{\pm}$), 2588 KeV (4^{+}) and 2867 KeV (4^{+}). In addition previous spin assingments of levels at 1613 KeV

(2^+) and 1731 KeV (4^+) have also been confirmed. The multipole mixing ratios (E2/M1) obtained from the present data are: (405)= 0.80 $\pm \begin{smallmatrix}0.7\\0.4\end{smallmatrix}$, (433)= 0.08 ± 0.06, (540)=-1.92±0.10, (595)= -0.32 ± 0.20, (621)= - 0.76 ± 0.05, (677)=-0.32±0.02, (766)= - 2.4 ± 0.2, (857)= - 0.64 ± 0.1, (948)= - 0.40±0.1, (1072)= - 0.16 ± 0.02, and (1136)= 0.48 ± 0.02.

3.6 - High Resolution Spectroscopy for the s-d Shell.

J.A.Guillaumon Fo. and I.D.Goldman
(Instituto de Física - Universidade de São Paulo)

The decays of the nuclides ^{24}Ne, ^{25}Na, ^{29}Al and ^{35}P, produced by "bremmstrahlung" irradiation at the University of São Paulo Electron LINAC, are being studied using a Ge(Li) detector with 2.5 KeV resolution at 1332 KeV, and a X-ray detector with 600 V resolution.
In the decay of ^{29}Al, the transition of 1153 KeV with a measured intensity of (0.93 ± 0.12)% has been detected, besides the higher intensity transitions 1273 (89.3%), 2028 KeV (3.8%), and 2426 KeV (6%).

3.7 - Measurement of the Transition $3^+ \rightarrow 1^+$ in the decay of ^{164m}Ho.

V.R.Vanin and I.D.Goldman
(Instituto de Física - Universidade de São Paulo)

The nuclide ^{164}Ho has been obtained by "bremmstrahlung" irradiation of Ho_2O_3 powder at the University of São Paulo Electron LINAC. Thin targets have been utilized due to the high self-absorption coefficient in Ho. A Ge(Li) X-ray detector, associated to a 2048-channel analyser have been used, with a resolution of 0.6 KeV at 80 KeV, sufficient to separate completely the line of 94.0 KeV atrributed to the decay of ^{164m}Ho from the line of 91.4 KeV, produced by the decay of ^{164g}Ho.
The measurement of the ratio of the cross-over intensity $3^+ \rightarrow 1^+$, of 94.0 KeV, and the intensity of the transition $3^+ \rightarrow 2^+$, of 56.6 KeV, resulted in the value 0.006 ± 0.001.

4. PHOTONUCLEAR REACTIONS

4.1 - Cross-section for the Reaction $^{232}Th(\gamma,n)^{231}Th$ near threshold.

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J.Goldemberg
(Instituto de Física - Universidade de São Paulo)

The (γ,n) cross-section of ^{232}Th has been measured by the activation method, using neutron capture monochromatic gamma-rays from 5.43 to 10.83 MeV, at the IEA-R1 research reactor. The ^{231}Th activity is measured by the area under the 84 KeV peak measured with a Ge(Li) spectrometer.
Irradiations have been carried out near the gamma-ray sources, with the samples surrounded by cadmium and paraffin to minimize (n,f) and (n,2n) reactions.
The measured cross-section presented the same structure previously observed for the (γ,f) reaction, with agreement with the values obtained through the measurement of the total number of neutrons emitted in the (γ,n) process.

4.2 - Formation of ^{178}Ta Isomeric States.

O.A.M.Helene and I.D.Goldman
(Instituto de Física - Universidade de São Paulo)

The experimentally determined isomeric states formation ratios for ^{178}Ta have been compared with the calculated ones on the basis of the statistical model. The experimental results have been obtained by irradiating ^{181}Ta samples with bremmstrahlung produced by the University of São Paulo Electron LINAC. A Ge(Li) detector, with a resolution better than 3 KeV at 1.33 MeV, was utilized to measure the residual activities.
The experimentally determined formation ratio between the states 1^+ and 7^-, 8^-, or 9^- was approximately 1, for electron beams with energies between 30 and 40 MeV. By irradiating ^{181}Ta near the threshold of the reaction $(\gamma,3n)$, a value significantly greater than 1 has been obtained for the formation ratio between the mentioned states. This result seems to indicate that the 1^+ state is the ground state of ^{178}Ta.

4.3 - Isomeric State Formation by $(\gamma,3n)$ Reaction in ^{141}Pr.

S.A.S.Vitiello and I.D.Goldman
(Instituto de Física - Universidade de São Paulo)

Sources of ^{138m}Pr and ^{138g}Pr were produced by the bremmstrahlung beam of the Linear Accelerator of the Instituto de Física da Universidade de São Paulo, at the energy of 43.5 MeV. The isomeric state $(7,8,9)^-$, T = 2.02h, and the ground state (1^+), T = 1.4min., were indetified by the half lives and the

transition of 788.8 Kev, respectively. In order to obtain sufficient statistics, the analyzed spectra was the result of 10 runs. The obtained experimental branching ratio, was 0.32, and the comparison with the statistical theory is presented in Table I.

Table I

N_γ	σ	Square Well	Parabolic	Exp.
4	2	.038		
4	3	.324	.336	.32
4	4	.755		

4.4 - Isomeric State Formation by $(\gamma,3n)$ reaction in ^{107}Ag.

S.A.S.Vitiello and I.D.Goldman
(Instituto de Física - Universidade de São Paulo)

Natural silver targets were bombarded by the bremsstrahlung beam of the Linear Accelerator of the Instituto de Física da Universidade de São Paulo.

Gamma-ray spectra following the decay were measured, and the isomeric $^{(2+)}$ and ground state $^{(5+)}$ are determined by the transition of 555.8 Kev and separation of the half-lives, 33.5 min and 66.5 min, respectively.

The experimental deduced ratio in energies from 33 to 46 MeV, are presented in Table I.

Following Huizenga and Vandenbosch (Phys.Rev. 120(1960)1305 and 1313), a comparison of data was done with statistical theory. The transmission coefficients have been calculated using a square well and a parabolic potential. The gamma-ray cascades with a 10% quadrupole admisctures give to the spin cut-off parameter a value greater than 5.

Table I

Energy(MeV)	33	36	38	40	42	44	46
Ratio	.35	.28	.26	.28	.26	.17	.18

4.5 - The $^{55}Mn\ (\gamma,3n)^{52}Mn$ Reaction.

M.Nielsen and I.D.Goldman
(Instituto de Física - Universidade de São Paulo)

We have irradiated powder samples of metallic Mn in the Linear Accelerator of the Instituto de Física da Universidade de São

Paulo. The bremsstrahlung was obtained using a $2g/cm^2$ thantalum irradiator.

The measurement was made using a Ge-Li detector and the interference of the 2.6h activity of ^{56}Mn produced by neutron capture was avoided by waiting the convenient time.

The measurement of the ^{52g}Mn, 5.7 d activity was made following the transitions 744, 935 and 1434 KeV. The yield was calculated in reference to the ^{54}Mn, 300 d activity, 835 KeV transition.

The cross section ratio of the ^{52}Mn to ^{54}Mn, at energies from 32.5 up to 44 MeV, have been determined and the results presented on Table I.

To determine the $(\gamma,3n)$ cross section, we shall use the experimental results from $^{55}Mn\ (\gamma,n)^{54}Mn$ reaction published by P.A.Fournay, R.S.Tickle and W.D.Whitehead, Phys.Rev. 120,1424 (1960) and R. Nathans and J.Halpern, Phys. Rev. 93, 437 (1954) and the thick target bremsstrahlung calculations recently published by M.J.Berger and S.M.Seltzer, Phys.Rev. C2, 621(1970).

Table I

Energy (KeV)	32,5	33,5	35,0	36,5	37,5	38,0	38,2	40	42	42,5	44
Ratio ($\times 10^{-4}$)	0,053	0,065	0,30	0,92	1,92	2,22	3,30	5,27	8,21	7,97	12,30

4.6 - Formation Ratio of the ^{117}In Isomeric States by (γ,α) Reaction.

E.A.Finotti and I.D.Goldman

(Instituto de Física - Universidade de São Paulo)

Measurements of ^{117g}In and ^{117m}In, formed in the $^{121}Sb(\gamma,\alpha)$ reaction, are very difficult when natural antimony is used as target, due to the formation of ^{122}Sn. Even though the ^{122}Sn half-life is 2.8 d, treater than the 40 min and 117 min half-lives for ^{117g}In and ^{117m}In, respectively, the measurements of the residual activities are disturbed by the presence of that antimony isotope. In order to measure easily the characteristic lines of 552.9 KeV from ^{117g}In and 315.3 KeV from ^{117m}In, a chemical separation of indium from antimony has been carried out. A result 0.30 ± 0.15 has been obtained for the isomeric state formation ratio Rm/Rg relative to the nuclide ^{117}In.

4.7 - The (γ,n) Reaction in ^{19}F and ^{23}Na in the Energy Range 0.3 - 1.0 GeV.

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H.G. de Carvalho and J.B.Martins
(Centro Brasileiro de Pesquisas Físicas, Rio de Janeiro)

Cross-section per equivalent quantum has been measured for the reactions $^{19}F(\gamma,n)^{18}F$ and $^{23}Na(\gamma,n)^{22}Na$ in the energy range 0.3 - 1.0 GeV. The targets were plates of analytical grade sodium oxalate (34% ^{23}Na) and lithium fluoride (73% ^{19}F) in powder form. The powders were packed uniformly between two lucite discs (5cm diameter and 0.05 cm thickness).
Average absolute cross sections of (1.30 ± 0.10) mb and (1.60± 0.20) mb have been calculated for the two reactions, respectively, over the whole energy range considered, by means of the photon difference method.

4.8 - The Monte Carlo Method for Photonuclear Reactions.

M.Foshina and J.B.Martins
(Centro Brasileiro de Pesquisas Físicas, Rio de Janeiro)

There are many published papers on the utilization of the Monte Carlo method in the study of intranuclear cascades iniciated by protons. Nevertheless, in the case of intranuclear cascades iniciated by photons there is only the work done by Gabriel and Alssmiler (Phys. Rev. 182 (1969)1035), that allows the determination of important parameters in photonuclear reactions up to 0.4 GeV.
For the estimate of values for the cross-section of photo production of neutrons in the energy range 200 MeV to 1000 MeV we have applied the Monte Carlo method, taking into consideration primary interactions carried out through quasi-deuteron" or "photo mesonic" processes. 10000stories have been followed and the probabilities for the photo production of neutrons in the nuclei ^{12}C, ^{19}F, ^{23}Na, ^{55}Mn, ^{103}Rh, ^{197}Au and ^{238}U have been determined.

4.9 - Photoproduction of Neutrons in Complex Nuclei.

H.G. de Carvalho, J.B.Martins, M.Foshina
(Centro Brasileiro de Pesquisas Físicas, Rio de Janeiro)

V. di Napoli and M.L. Terranova
(Instituto di Chimica Generale ed Inorganica dell' Universitá, Roma)

The estimates of cross-sections for the photoproduction of neutrons using the Monte Carlo method have been compared with previously obtained experimental results, in the energy range 300 MeV to 1000 MeV, using the bremsstrahlung beam of the Frascati accelerator. Estimates of the cross-sections have also been obtained thourgh simple expressions from the nu - cleons.

The following results have been obtained for the average values of the cross-sections in the energy range 300 MeV to 1000 MeV: $^{12}C(\gamma,n)^{11}C$ - 0.7 ± 0.03; $^{19}F(\gamma,n)^{18}F$ - 1.06 ± 0.05; $^{23}Na(\gamma,n)^{22}Na$ - 1.27 ± 0.06; $^{55}Mn(\gamma,n)^{54}Mn$ - 2.6 ± 0.13 ; $^{103}Rh(\gamma,n)^{102}Rh$ - 4.36 ± 0.21; $^{197}Au(\gamma,n)^{196}Au$ - 8.03 ± 0.40 and $^{238}U(\gamma,n)^{237}U$ - 9.37 ± 0.45, in milibarns.

4.10- A New Method for the Analysis of Electroexcitation Reactions.

I.C.Nascimento and S.B. Herdade
(Instituto de Física - Universidade de São Paulo)

In the study of photonuclear reactions the nuclei are irradiated with photons produced by an external source and, in this case, they are plane waves where all the angular momenta enter in equal proportion. In electrodisintegration reactions the nuclei are irradiated by photons produced in the electron scattering process in these same nuclei. The virtual photons produced and absorbed are not plane waves. The analysis of these reactions used to be carried out by Plane Wave Born Approximation (PWBA) which, for heavy nuclei may lead to contradictory conclusions as far as the multipolarities of the nuclear transitions are concerned. Gargaro and Onley (Phys. Rev. C4 (1971) 1032) have been calculated the virtual photon spectra using a Distorted Wave Born Approximation (DWBA). This method is being checked in this work by comparing the experimental results for the electrofission of ^{238}U and for the ratio σ^-/σ^+, where σ^- and σ^+ are the cross-sections for the reactions (e,e'n) for electrons and positrons respectively, with the calculated ones. This work is being carried out with the collaboration of Prof. D.S.Onley, Ohio University, Athens,Ohio, USA.

4.11 - El Virtual Photon Spectrum for the use in Electrodisintegration Reactions.

E. Wolynec
(Instituto de Física - Universidade de São Paulo)

The nuclear electroexcitation process is intimately related to the corresponding photoexcitation process. In both cases the nucleus receives the excitation energy through the interaction of an electromagnetic field with the nuclear charges and currents. By relating the two processes it is possible to define a virtual photon spectrum $N(\lambda,L,E_o,\omega)$ and write the total electron inelastic cross-section σ_e, in a form analogous to the one for the bremsstrahlung yield:

$$\sigma_e(E_o) = \int_0^{E_o-m_0} \sum_{\lambda,L} \sigma_\gamma^\lambda (L,\omega) N(\lambda,L,E_o,\omega) \frac{d\omega}{\omega} \quad , \quad \text{where } E_o =$$

= total energy of the incident electron, m_o = electron rest energy, ω = photon energy, λ = E or M for electric or magnetic transitions of multipolarity 2^L and $\sigma_\gamma^\lambda (L,\omega)$ = cross-section for photoexcitation. Recently, $N(\lambda,L,E_o,\omega)$ has been calculated using DWBA (Gargaro and Onley, Phys. Rev. C4 (1971) 1032). Nevertheless the calculation results is a non-analytic expression for the virtual photon spectrum. The calculation of a particular virtual photon spectrum using DWBA, which involves the sum of many partial waves, takes a lot of computer time, which makes prohibitive its use for the analysis of electrodisintegration reactions.

Using the computer code VIRFO- I developed by Onley for the spectrum calculations, we generated 50 points of the El virtual photon spectrum for different values of Z and E_o (Z = = atomic number of the target nucleus). From these points an analytical expression has been adjusted to the DWBA calculated spectrum for El. This expression is :

$$N(El, E_o, \omega, Z) = NP(El, E_o, \omega) + \left[1.29\times10^{-5}\exp(1.245\, Z^{1/3} - 0.052\omega)\right] \cdot \left[(E_f - m_o)/(\omega + m_o)\right]\omega \quad ,$$

where : Z = atomic number of the target nucleus, $NP(El, E_o, \omega)$ = expression for the virtual photon spectrum in PWBA, and $E_f = E_o - \omega$.

4.12 - An Analysis of Electrodisintegration of Nuclei using El Virtual Radiation Spectra Evaluated with Coulomb Distorted Waves.

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Data on the ratio of photo and electrodisintegration of several nuclei (^{12}C, ^{64}Cu, ^{64}Zn, ^{109}Ag, ^{181}Ta and ^{197}Au) are compared with theoretical ratios predicted by plane and distorted waves calculations. The analysis with distorted waves shows that all data are compatible with photoabsorption through El transitions, as can be explained by the electric dipole sum rule. This outcome does not agree with published conclusions for high Z nuclei using plane wave approximation.

5. NUCLEAR FISSION

5.1 - On the Photofission Cross Sections of ^{209}Bi, ^{232}Th and ^{238}U at Intermediate Energies.

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Photofission cross sections have been estimated for ^{209}Bi, ^{232}Th and ^{238}U, in the energy range from 0.15 GeV up to 2 GeV, using fissibility values computed with the Monte Carlo Method. For the calculation of the fissibilities, use has been made of some already known results of proton-induced intranuclear cascade calculations, in order to obtain information about mass number, atomic number and excitation energy distributions of the post-cascade nucleus. The calculation has been carried out as a fission-evaporation competition, using an energy dependence of the ratio of the neutron evaporation width to fission width. The results have been compared with experimental data, showing that the photofission cross sections are consistend with the photomeson mechanism of nuclear excitation.

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5.2 - High Energy Photofission Cross Sections of Uranium, Thorium and Bismuth.

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Bremsstrahlung beams produced in a thin tungsten radiator by incident electrons accelerated in the "Deutsches Elektronen Synchrotron" (Hamburg) at energies ranging from 1 GeV to 5.5 GeV, and in an aluminum radiator by electrons accelerated at 16 GeV in the "Two Mile Stanford Linear Accelerator" (SLAC), were used in our experiments. The nuclear emulsion technique has been employed for fission fragment detection. Using a special development process carried out previously in our laboratory, discrimination between fission fragments tracks and alpha particles tracks was possible for nuclear emulsion pellicles loaded with uranium and thorium. The photofission cross sections were obtained from measurements of the cross sections per equivalent quantum by using 1/k bremsstrahlung spectrum approximation (k is the photon energy) in energy ranges L GeV- - 5.5 GeV and 5.5 GeV - 16 GeV. The results show a decrease in the cross sections with energy, which is in good agreement , within experimental errors, with the results of other authors who used not only this technique but mica and glass detectors as well. For photon energies higher than 1 GeV, the photofission cross sections decrease asymptotically by about fifty times their value at 300 MeV in the case of ^{238}U and ^{232}Th, and twelve times in the case of ^{209}Bi.

5.2 - Photofission Cross Section of ^{238}U in the Energy Range 5.43 MeV - 10.83 MeV measured with Polycarbonate Foils (Makrofol).

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The cross section for the reaction $^{238}U(\gamma,f)$ near threshold has been previously measured in this laboratory by utilizing a fission chamber, as well as by other authors. Although a structure had been always observed in the cross section curve for energies from 5 to 9 MeV, there are certain discrepancies in the data obtained by different research groups. In order to check our results, the photofission cross section of ^{238}U for neutron-capture gamma-rays in the energy range 5.43 to 10.83

MeV has been measured again by means of a different technique, using polycarbonate (Makrofol) foils as fission fragment detectors. The behaviour of the experimental curve obtained was the same one observed in the previous measurements, using a fission chamber and electronic counting.

5.4 - Angular Distribution of Fragments in the Electron Induced Fission of ^{232}Th.

J.H. Vuolo, S.B.Herdade and I.C.Nascimento
(Instituto de Física - Universidade de São Paulo)

Angular distributions of fragments in the electron-induced fission of even-even nuclei can be calculated provided the virtual photon spectrum in the magnetic substates M, and the rotation matrix $d^{J}_{M,K}(\theta)$ are known (Huizenga, Nucl. Tech. 13, April 1972, pg. 20). The distribution for electrofission differs from the one for photofission because it includes also the substate M=0 and a different distribution of multipoles.

The angular distributions of the fragments in the electrofission of ^{232}Th have been obtained in the energies 8 and 9 MeV. A thorium thin target is irradiated in the electron beam of the University of São Paulo LINAC and the fission fragments are detected by polycarbonate foils (Makrofol) 10μm thick in the angular range from - 30° to 132° with the beam direction.

The results of this work are being campared with the theoretically calculated distributions, using a Distorted Wave Born Approximation formalism, as well as with experimental results previously obtained for ^{238}U. On the basis of these studies, informations on the shapes of the fission barriers of ^{232}Th and ^{238}U may be obtained. The absolute values of the cross-section for the electrofission of ^{232}Th will also be obtained in the energy range 8 - 50 MeV.

5.5 - Electron-Induced Fission of ^{209}Bi.

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(Instituto de Física - Universidade de São Paulo)

The electron-induced fission of ^{209}Bi is being studied in the energy range 40 - 60 MeV at the University of São Paulo Electron LINAC. Polycarbonate (Makrofol) sheets 10μm thick are utilized as fission fragment detectors. Preliminary results for the $^{209}Bi(e,e'f)$ cross-section have been obtained using a

bismuth target 2.2 mg/cm^2 thick; for an electron energy of (42.0 ± 0.4) MeV it was obtained the value (1.5 ± 0.4)x10^{-5}mb. Results with better statistical accuracy will be obtained with a better geometrical efficiency of fission fragment detection. The photofission cross sections will be obtained by an unfolding procedure using a virtual photon spectrum calculated by a DWBA formalism (Gargaro and Onley, Phys. Rev. C4 (1971) 1032). Our experimental results in the energy range 40 - 60 MeV, together with previously obtained results by other authors in different energy ranges (Moretto et al, Phys. Rev. 179 (1969) 1176; TUrck et al, Phys. Lett. 49B (1974) 335; Ranjuk et al, Ukrainsky Fizicnyj Zurnal 14 (1969) 408) will be utilized to make a better estimate of the value of the fission barrier fo: ^{209}Bi.

5.6 - Yields of Lanthanide Isotopes and Yttrium in the Fission of ^{238}U Induced by 14 MeV Protons.

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Radiochemical measurement of fission yields for many mass numbers greater than about 140 has until recently been difficult because the great chemical similarity of the lanthanide elements effectively precludes rapid chemical purification. As a result, mass chain yields have only been determined for those masses where the longest lived member has a half life more than about a few hours.

However in recent years, the advent of high resolution Ge-Li gamma detectors has made possible the identification and measurement of radioisotopes even in very complex mistures since the accurate gamma energies and the half lives of the peaks usually enable unambiguous assignnments to particular radioisotopes to be made. In these work, a lanthanide fraction was separated from the irradiated uranium target within about 15 minutes and 90 minutes of the end of irradiation. This fraction contained isotopes of yttrium, lanthanum and the lanthanides. Half lives as short as 10 mins (eg. ^{95}Y) could be readily detected and measured.

To calculated the fission yield of each isotope, it is necessary to know the abundance of the gamma ray in the nuclear decay scheme, and the efficiency of the Ge-Li detector at that

energy. The detector was calibrated in the usual way using IAEA standard sources. Abundances of the various gamma rays, however, presented a more difficult problem since literature values often show large discrepancies, particularly for some of the shorter-lived isotopes. To overcome this, abundances were calculated by calibrating with the system ^{235}U (thermal n, fission), for which the mass yields have been well esta - blished.

Preliminary results have been obtained for the relative yields of 10 mass chains (93, 94, 95 Yttrium), 142, 143, 146, 147, 149, 151, 155 La + lanthanides). These have been converted to absolute yields by normalisation with mass yields already published in the literature.

6. CHARGED PARTICLE REACTIONS

6.1 - Analog Spectroscopy with Proton Inelastic Scattering.

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(Instituto de Física - Universidade de São Paulo)

Proton inelastic scattering through isobaric resonances is analysed in the regions of tin, and of the isotones N = 50 and N = 82. The scattered wave in the interaction region is decomposed in harmonic oscillator wave functions. The parent states are treated in the BCS + RPA scheme. The single-proton escape amplitudes are calculated with the 2 body coulomb charge ex - change force. The partial widths for 2^+ and 3^- states in (p,p') reactions are then determined. The results are compared with the ones obtained using the coupled equations method and with calculations utilizing the unified model.

6.2 - The Total Width of Isobaric States in ^{123}Sb.

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(Instituto de Física - Universidade de São Paulo)

Excitation functions for the proton inelastic scattering on ^{123}Sb, corresponding to excitations of collective 2^+ and 3^- states, have been fitted by a formula containing five parameters, representing a resonant amplitude and an energy independent background amplitude. The energy range of the incident protons corresponds to the region where the isobaric analog

resonances of the stated with independent particle configurations $d_{5/2}$ and $f_{7/2}$ in ^{123}Sb are situated. The fact that the non - resonant cross section for inelastic scattering is low, compared with the resonant cross section, resulting in small interference effects, allowed us a better determination of the total widths as compared with previous results from the analysis of the elastic scattering cross section by other authors. An iterative process for the data fit with expressions containing one, two and three resonances, has been utilized. The energies and total widths obtained in the analysis of the 2^+ state excitation functions are, respectively: $d_{5/2}$ (E = 8.95 MeV, Γ = 52 $\pm$ 3 KeV), $d_{5/2}$(E = 9.26 MeV, 145 $\pm$ 3 KeV), $f_{7/2}$(E=10.464 MeV, Γ = 97 KeV). The 3^- state presents only one resonance : $f_{7/2}$(E = 10.426 MeV, Γ = 112 KeV).

6.3 - Direct-Compound Contribution to (p,2p) Reactions.

M.S.Hussein
(Instituto de Física - Universidade de São Paulo)

The term corresponding to the formation of a residual compund nucleus (R.C.N.) following the knocking out of a proton would contribute coherently to the direct term in (p,2p) reactions. This, we argue, modifies the angular distribution if one treats the residual compound nucleus statistically (isotropic angular distribution of emitted particles). It is possible to isolate the contribution of this new component of the ampli - tude using simple Hauser-Feschback analysis on the final nu - clear decay. This is a very important program for the better study of hole states in nuclei. Any structure found in the decay amplitude of the R.C.N. would then be understood as intermediate structure in the exit channel. Investigations are in progress to assess the importance of the compound-compound contribution at lower bombarding energies.

6.4 - The Excitation of "Gauge Analog States" (GAS) by Heavy Ion Reactions.

M.S.Hussein and H-T. Chen
(Instituto de Física, Universidade de São Paulo)

A new method for the investigation of the transfer of 4 particles in heavy nuclei reactions is proposed. The "Gauge Spin"

concept is introduced to label the different nuclear states reached by the transfer of an even number of neutrons. This leads naturally to consider the possibility of exciting the "Gauge Analogue State (GAS)of the target nucleus by means of stripping or pick-up reactions between heavy nuclei. Reactions with ^{206}Pb or ^{210}Pb as projectiles and other lighter or heavier Pb isotopes as targets are suggested. A theory of two coupled equations is constructed to treat these reactions.

6.5 - Measurements of the $^{27}Al(p,n)^{27}Si$ and $^{12}C(\alpha,n)^{15}O$ Reaction Thresholds.

D. Pereira
(Instituto de Física - Universidade de São Paulo)

The "counter ratio" technique of Bonner et al (Phys. Rev. 96 (1954)122) has been utilized in the measurements of the thresholds for the reactions $^{27}Al(p,n)^{27}Si$ (E_{th}=5.7969 MeV) and $^{12}C(\alpha,n)^{15}O$ (E_{th}=11.3408 MeV) as part of the program for calibration of the University of São Paulo Pelletron accelerator. The calibration constant of the analysing magnet obtained from these measurements, are in excellent agreement with the one obtained by oserving the analog resonance T = 3/2 (E_{res}=14.231 MeV), through the $^{12}C(p,p)^{12}C$ reaction.

6.6. - Measurement of the $^{19}F(p,n)^{19}Ne$ Reaction Threshold.

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(Instituto de Física - Universidade de São Paulo)

The threshold of the reaction $^{19}F(p,n)^{19}Ne$ at 4.233 MeV has been observed by the used of two BF_3 counters in an arrangement similar to the "Bonner system" (Rickards et al, Nucl.Phys. 86 (1966) 167), in order to obtain a calibration for the University of São Paulo Pelletron accelerator. The calibration constant obtained for the 90° analysing magnet from this measurement is in excellent agreement with results from other similar experiments carried out in the Pelletron laboratory.

7. NEUTRON PHYSICS

7.1 - A Formula for the Fluctuation Cross-Section of Nuclear Reactions at Low Energies.

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An expression is derived for the total fluctuation cross-section valid for the general case of any number of directly coupled open channels. In the limit when this number is very large one recovers the familiar Hauser-Feshbach result for inelastic scattering. A different result emerges for the elastic case. Generally, for many overlapping resonances:

$$\frac{\sigma_{cc'}}{(2\ell+1)\,\pi\,\lambda_c} = \left(\frac{N-1}{N+1}\,\delta_{cc'} + 1\right)\frac{P_c\,P_{c'}}{\sum_{c''} P_{c''}}$$

7.2 - Resonance interference in ^{232}Th - ^{233}Pa Systems .

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The validity of the hypothesis for the separability of resonances in the solution of the Boltzmann equation for the calculation of neutron slowing-down in an absorbing medium depends upon the importance of the form term due to the resonance interference effect. This effect is related to the Placzek oscillations in the neutron flux and collision density due to the negative source of neutrons represented by an absorption resonance.

By utilizing previous results on the effect of resonance interference in practical homogeneous infinite ^{232}Th - ^{232}Pa systems with a carbon moderator (Ballariny and Marable, Trans. Amer. Nucl. Soc. 13 (1970) 714), the interference effect terms have been separated and its relative and absolute variations as a function of the C/Th ratios and of the resonance spacing have been studied, leading to the following conclusions:

The form interference between the ^{232}Th doublet resonances is always negative (constructive) and its variation with the system degree of moderation presents a maximum.
The total form effect term is greater for well thermalized systems.
The total interference of the ^{232}Th doublet on the ^{233}Pa resonance of lower energy, in well thermalized systems, oscillates around the value of the assymptotic term, with the increase of the resonance spacing in the two nuclides, so that the form term assumes positive and negative values that can be neglected.

7.3 - Neutron Transmission Study of the Rotational Freedom of Methyl Groups in Polydimethylsiloxane.

L.Q.Amaral[+], L.A.Vinhas and S.B.Herdade[+]
(Instituto de Energia Atômica, São Paulo)
I.E.A. - Technical Report nº 320

The total neutron cross section of polydimethylsiloxane has been measured as a function of neutron wavelength in the range 4 Å to 10 Å at room temperature, using a slow-neutron chopper and time-of-flight spectrometer. Scattering cross sections per hydrogen atom were obtained and the slope (12.2 ± 0.2) barns/Å has been derived.
Comparison with calculated neutron cross sections using the Krieger-Nelkin formalism for different dynamical situations as well as comparison with calibration curves relating the slope to the barrier hindering internal rotation indicates the existence of practically free rotation of CH_3 groups about their C_3 axis.

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7.4 - Molecular dynamics of tert-butanol studied by neutron transmission

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I.E.A. - Technical Report nº 328

Neutron transmission of the globular compound tert-butanol $(CH_3)_3COH$ have been measured in the temperature interval - 0ºC to 40ºC for 6.13 Å neutrons and in the neutron wave - length range 4 to 7.5 Å in the liquid and solid states. Results show that the cross-section difference at the state transition in 24ºC is 13%, while it is only ~1% at the first order phase transition in 14ºC. Evidence of existence of a third crystalline phase with the lowest cross section has been found. The barrier to internal methyl rotation in the solid state is estimated as (3.8 ± 0.5) kcal/mol and does not change much over the phase and state transitions. The observed dynamical changes must be due to movements of the whole molecule and evidence that tert-butanol is not in the strict sense a plastic crystal; correlation with heat capacity results is discussed.

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