TANDEM ACCELERATOR LABORATORY ANNUAL REPORT 1978



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NUCLEAR RESEARCH CENTER DEMOKRITOS

TANDEM ACCELERATOR LABORATORY

ANNUAL REPORT 1978

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INTRODUCTION

During 1978 the research of the laboratory progressed along the lines previously established, namely gamma ray spectroscopy, heavy ion reactions, theoretical nuclear physics and applied atomic and nuclear physics.

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In gamma ray spectroscopy light ions as well - as heavy ions were utilized for spectroscopic investigations in the A~90 mass region and the Ge, Ga region. The expanded interest in the A~90 mass region has been coupled to shell model calculations performed at the laboratory , which successfully reproduce the experimental results.

In heavy ion reactions, the problem of resonant structure in heavy ion reactions in the s-d shell continued to interest the laboratory and many systems were examined. A systematic study of ⁷Li induced reactions was also initiated. Some very interesting results were also obtained from the study of the competition between pn and d and p2n, dn, and t outgoing channels.

In theoretical nuclear physics, work continued in the applications of the shell model and the isomorphic model as well as the examination of collective phenomena.

In the applied atomic and nuclear physics research the use of the perturbed angular correlation method for study of biological systems has led into some important results of conformational changes in Bovine Serum Albumin. The investigation of the connection of trace elements with skin cancer continued as well as other applications of the PIXE and XRF methods. We were fortunate enough during 1978 to have very few problems associated with the accelerator itself This enabled us to divert our funds towards purchasing equipment such as detectors, and off-axis duoplasmatron source etc.

The influx of visitors from other countries for experiments with our Tandem as well as visits from our scientists to other laboratories , was found again to be very beneficial and rewarding.

We again take the opportunity to express our sincere thanks to all the technical personnel of the Tandem for their dedication and the quality of their work.

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George Vourvopoulos

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PDF created on April 4, 2012, by S. V. Harissopulos HEAVY ION REACTIONS

1) ¹²C+¹²C Resonances Studied Through Y Decay

Ι.

G. Andritsopoulos⁺, X. Aslanoglou, P. Bakoyeorgos and G. Vourvopoulos

Resonances in the ${}^{12}C+{}^{12}C$ system and in the energy range $E_{CM}=7-10$ MeV were studied through γ decay. Excitation functions of the γ decay of the first excited state of ${}^{20}Ne$, ${}^{23}Na$ and ${}^{23}Mg$ seen through the ${}^{12}C({}^{12}C,\alpha)$ ${}^{20}Ne$, ${}^{12}C({}^{12}C,p)$ ${}^{23}Na$ and ${}^{12}C({}^{12}C,n){}^{23}Mg$ reactions corroborated the existence of resonances observed through various particle reactions. With the help of the angular distributions from the ${}^{12}C({}^{12}C,\alpha){}^{20}Ne$ g.s reaction, two other resonances were established at $E_{CM}=7.26$ MeV and $E_{CM}=9.65$ MeV and $J^{\pi}=2^{+}$ and 3^{+} respectively

Fig. 1 shows the angular distribution of the $E_{CM}=9.6$ MeV resonance. The fit through the data points is via a p^2 (cos ϑ) function which clearly indicates that the resonance has $J^{\pi}=8^{+}$.

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2) Resonant Behaviour of the ${}^{9}Be + {}^{12}C$ System

X. Aslanoglou, G. Vourvopoulos, G. Andritsopoulos,⁺ E. Holub⁺⁺ and D. Pocanic⁺⁺.

The ${}^{9}\text{Be+}{}^{12}\text{C}$ system is a strong candidate for quasi-molecular resonant behaviour, because of the relatively low level density of ${}^{21}\text{Ne}$, a condition thought of as necessary for the observation of resonances.

An excitation function of the ${}^{12}C({}^{9}Be,\alpha){}^{17}O$ reaction was taken at the energy range of 8-20 MeV (Lab) in steps of 250 keV (Lab) detecting alpha particles at four angles simultaneously, $\Theta_{L} = 15^{\circ}$, 35° , 45° and 65° . The target was a 100 µg/cm² ${}^{12}C$ foil, corresponding to a 200 keV energy loss for a 15 MeV ${}^{9}Be$ beam.

Fig. 1. shows the excitation function for the 1st exc.state of ¹⁷O at three different angles. A strong indication that the anomalies seen in the excitation function are not statistical fluctuations is the correlation of the observed anomalies among different channels and different angles. For this reason, the correlation function $D=\sum_{i=1}^{N} \frac{(\sigma i - \langle \sigma i \rangle)}{\langle \sigma i \rangle}$ $i=1 \langle \sigma i \rangle$

was used where the index i runs over all states and angles measured and the averaged was defined in an energy interval of 3.5 MeV. Fig. 2 shows the results of the correlation analysis. Based on these results the peaks at $E_{CM}=7.7$, 9.7 and 11.3 are defined as resonances in the $^{9}\text{Be}+^{12}\text{C}$ system. An attempt is under way to determine the spins and parities of those resonances.

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3) <u>Search for Resonances in the</u> ⁹Be+¹³C System

X. Aslanoglou, G. Vourvopoulos, G. Andritsopoulos⁺, E. Holub⁺⁺ and D. Pocanic⁺⁺.

In the quest of resonances in systems of low level density in the region around the Coulomb barrier, the reaction ${}^{13}C({}^{9}Be, \alpha)$ ${}^{18}O$ was studied. An excitation function in the energy range between 8 and 20 MeV was taken and the alpha groups leaving the residual nucleus in the ground state and the first excited state were observed at four angles $(15^{\circ}, 35^{\circ}, 45^{\circ} \text{ and } 65^{\circ})$. The target was a self-supported ${}^{13}C$ target 100 µg/cm² thick and the energy step was 250 keV.

Although the excitation function of individual states showed fluctuations in the measured yield, no clear correlation of these anomalies was observed among different angles and different particle groups. Our preliminary analysis therefore indicates that the ${}^{9}\text{Be+}{}^{13}\text{C}$ system does not exhibit resonances of magnitude such that can be easily detected.

+ University of Ioannina, Ioannina, Greece ++ R.Boskovic Institute, Zagreb, Yugoslavia 4) <u>Resonant Behaviour of the ¹⁸0+¹²C System</u>

X. Aslanoglou, G. Vourvopoulos, G. Andritsopoulos⁺ and P. Bakoyeorgos.

Among the conditions considered as necessary by a number of researchers for the existence of resonances in a particular system have been a) low level density in the excitation energies corresponding to a few MeV above the Coulomb barrier and b) an alpha particle-like structure of the two nuclei involved in the formation of the composite system.

To test the second criterion the $18_{0+}12_{C}$ system was studied. The extra two neutrons of ¹⁸O are the cause of a small α -spectroscopic factor for ¹⁸0. Excitation function of the γ decay of the first excited state of 29 Si, 29 Al, 26 Mg and 25 Mg seen through the 12 C(18 O,n) 29 Si, 12 C(18 O,p) 29 Al, $18_{C(18_{0,\alpha})}$ $^{26}_{Mg}$ and $12_{C(18_{0,\alpha})}$ $^{23}_{Mg}$ reactions was taken in the incident energy region between 18 and 30 MeV. Due to the beta decay of a number of unstable residual nuclei, there was considerable side-feeding so not all channels could be differentiated from each other. For the ${}^{12}C({}^{18}O,\alpha)$ ${}^{26}Mg$ reaction the excitation function of the 1.81 MeV γ ray deexciting the first excited state was measured. A pronounced anomaly was observed at 28.7 MeV incident energy and subsequent to the gamma ray data, an excitation function for the ${}^{12}C({}^{18}O, \alpha)$ ${}^{26}Mg$ reaction was taken in the energy region 14-30 MeV detecting the alpha particles at $\Theta_{\text{Lab}} = 8^{\circ}$. The results are shown in Fig. 1. For the 23.7MeV anomaly, an angular distribution was taken and the results for the alpha particles leaving ²⁶Mg to the ground state are shown in Fig. 2.

The fit through the data points in via a $P_{10}^2(\cos \vartheta)$ function indicating a resonance with $J^{\pi}=10^+$. Further investigation is under way to establish whether this is a resonance in the compound system or a shape resonance, since there seems to be a lack of other resonances in the excitation energies presently studied.

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5) ⁷Li Induced Reactions

S. Kossionides, N. Tsoupas, G. Vourvopoulos

A systematic study of ${}^{7}\text{Li-induced reactions}$ has started with the study of the system ${}^{7}\text{Li+}{}^{12}\text{C}$. This was deemed necessary since ${}^{12}\text{C}$ is the most common contaminant in targets. It will also be used as a reference.

Work so far was mainly concerned with the establishment of the measuring techniques and of the reaction channels which will receive attention. The preliminary results confirm the usual assumption that α and t emmission stems mainly from direct reaction mechanisms , while p,d,pn,pp evaporate from the compound nucleus.

6) <u>Study of the Reaction Mechanism in ¹²C(¹⁶0,2p)²⁶Mg</u> reaction

P.K. Kakanis, E.N. Gazis, A. Xenoulis and A.D. Panagiotou⁺

The mechanism of the ${}^{12}C$ (${}^{16}O, 2p$) ${}^{26}Mg$ reaction was studied by detecting the 2p's using two telescopes in coincidence.

The two telescopes were placed on opposite sides with respect to the beam and at angles: $\vartheta_1 = 10^{\circ}, 20^{\circ},$ $\vartheta_2 = 10^{\circ}, 15^{\circ}, 20^{\circ}, 25^{\circ}, 30^{\circ}, 35^{\circ}$ and 40° lab. The beam energy was 30 MeV. The possible ways for decay of the Compound Nucleus are:

- a. Direct three-body break-up
- β. Simultaneous 2p emission (2p-F.S.I.)
- Y, Sequential 2p decay

In case (a) we must have an isotropic energy distribution between two protons , because of the absence of any final state interaction between the two protons.

+ University of Athens

In case (β) we expect a maximum at one-half the total energy for the two protons, since the two protons with almost equal energies have larger emission probability and detection efficiency.

In process (γ) the spectrum should be quite different. The energy spectra obtained showed that process (γ) is predominant in the reaction ^{12}C ($^{16}O, 2p$) ^{26}Mg

7) <u>Mass Measurement</u> of ²⁹Mg

P.K.Kakanis, E.N. Gazis, A.D. Panagiotou⁺, P. Roussel, C. Détraz, M. Langevin, M. Bernas, D. Guillemaud⁺⁺

We obtained the mass excess for ^{29}Mg by measuring in one telescope the total energy of the two protons (2p) in the reaction ^{13}C ($^{18}O, 2p$) ^{29}Mg .

For the experiment we used ¹³C target 99.5% isotopically pure and ¹⁸O beam with energy of 32 MeV, provided by the MP-Tandem accelerator of the Institute de Physique Nucleaire Orsay (France).

From the preliminary analysis we have estimated the mass-excess of 29 Mg (g.s) and the energy of two excited states (fig. 1).

Mass excess of 29 Mg: -10.90±1,50 (MeV), and 1st excited state: 0.605 ±.150 (MeV) 2nd excited state: 1.53 ±.150 (MeV)

The two excited states identified here are in good agreement with results obtained by γ -ray measurements following the β^- decay of $^{29}Na^{(1)}$.

+ Nuclear Physics Lab., University of Athens, Greece ++ I.P.N.- Orsay (France) (1)Détraz et al private communication 8) Study of the "Isoproduct" channels by the (H.I., pn/d), (H.I., p2n /dn/t) Reactions

E.N. Gazis, A.C. Xenoulis, P. Kakanis, A.D. Panagiotou⁺, D. Bucurescu⁺⁺ and X. Aslanoglou.

The same residual nucleus may be formed by the emission of different particles from the compound system, leaving the same mass A and atomic number Z.

 $A+B \rightarrow (CN) \frac{*}{1} \qquad pn+R_1$ and $d +R_1$ $C+D \rightarrow (CN) \frac{*}{2} \qquad p2n+R_2$ $dn +R_2$ $t +R_2$

We see that the R nucleus can be formed either by \underline{pn} or \underline{d} emission and the R₂ by $\underline{p2n}$ or \underline{dn} or \underline{t} emission In such cases it is clear that although the entrance channel is the same, the exit channels should be considered as different reaction modes, which may be called ISOPRODUCT channels, competing for the production of the same residual nucleus.

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In order to investigate the importance of isoproduct competition we have initiated a systematic study of several heavy ion reactions. The double competition by <u>pn</u> and <u>d</u> emission as well as the triple competition by <u>p2n</u>, <u>dn</u> and <u>t</u> emission has been measured in the reactions $16,18_{0} + \frac{12,13_{0}}{16,18_{0}} + \frac{16,18_{0}}{16,18_{0}} + \frac{18_{0}}{18_{0}} + \frac{19_{F}}{19}$.

We utilized the intensities of characteristic γ rays in the residual nuclei which were measured in coincidence with proton, deuteron and triton particle groups of the mass spectrum, in order to measure the (pn:d) and (p2n:dn:t) isoproduct channels.

The ratios of the differential cross sections $d\sigma_{pn}/d\sigma_{d}$ and $d\sigma_{p2n}/d\sigma_{dn}/d\sigma_{t}$ were obtained for several bombarding energies from 24.5 MeV to 37.5 MeV with a E-AE Si detectors particle telescope at $\Theta_{lab} = 15^{\circ}$. It was found that significant competition occurs in all reactions. For example:

 ${}^{16}_{0} + {}^{12}_{C} := \frac{d\sigma_{pn}}{d\sigma_{d}} = 4.0 \pm 0.5 \text{ at } E_{lab} = 30 \text{ MeV}$ ${}^{18}_{0} + {}^{18}_{0} := \frac{d\sigma_{pn}}{d\sigma_{d}} = 35 \pm 10 \text{ at } E_{lab} = 34 \text{ MeV}$

Furthermore, angular correlation measurements of the cross section ratio have been obtained in the reactions ${}^{16}\text{O} + {}^{12}\text{C}$ at the incident energy 28 MeV, varying the angle of the Δ E-E telescope between 10° to 50° lab.

Qualitative agreement of statistical model calculations with experimental data was observed, even though the calculation referred to the total cross section ratios. Finally, p-n angular correlation measurements investigating <u>pn</u> emission, which could be either by pn consecutive emission or by unbound d^{*} break-up, have shown that, mainly, sequential pn emission occurs.

II. GAMMA RAY SPECTROSCOPY

1) High Spin States in ⁶⁹Ge from the ⁵⁵Mn (¹⁶0, pn) Reaction

T. Paradellis,⁺ C.J. Costa⁺⁺, R. Seltz⁺, C. Lebrun⁺⁺⁺, D. Ardouin⁺⁺⁺ F. Guibault⁺⁺⁺, M. Vergnes⁺⁺⁺⁺ and G. Berrier⁺⁺⁺⁺

Targets of 1mg/cm^2 ⁵⁵Mn evaporated on thick Au foils were bombarded with ¹⁶O beams from E=37.5 to E= 50 MeV. Gamma-gamma coincidence data of high statistical quality were obtained at 47.5 MeV bombarding energy. Angular distribution data obtained at 42.5 and 47.5 MeV and excitation functions were used to assign spin to levels of ⁶⁹Ge which are populated by the pn exit channel.

The main details of the decay scheme of 69 Ge are given in fig. 1. The observed structure of the nucleus is very well discribed by the coupling of a $g_{9/2}$ neutron to the 68 Ge excited states.

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Study of 64_{Zn} and 66_{Zn} through the (p,p'Y) Reaction

J. Galanakis and T. Paradellis

During the last months of 1977 we had started studying the ${}^{64}{}_{Zn}$ isotope and a decay scheme had been constructed through the single γ -ray spectra at Ep=5.5, 6.5, 7.5 MeV. Continuing the study of ${}^{64}{}_{Zn}$ we took a coincidence spectrum at Ep=7.5 MeV in order to verify and to complete the decay scheme. Angular distribution data have been collected at Ep=5.5, 6.5 and 7.5 MeV. The results of these measurements are almost ready. On the other hand a ${}^{66}{}_{Zn}$ target 4mgr/cm² thick has been bombarded with protons at Ep=5.5 MeV. Single γ - ray and coincidence spectra were obtained. Through the collected data a decay scheme has been constructed, (which is not still complete), with the following levels (in keV).

1039	1873	2375	2450	2765
2780	2828	2941	3077	3107
3214	3229	3332	3381	3433
3503	3533	3575	5726	3739
3746	3929	4087		

Life time measurements in 64 Zn and 66 Zn are in progress as well as angular distribution measurements in 66 Zn.

3) <u>Alignment of Nuclear States in (p, y) Reactions on</u> <u>Semithick Targets</u>

T. Paradellis, G. Costa⁺, G. Vourvopoulos

The previously reported $^{(1)}$ alignment of nuclear states after (p,γ) reaction on 3-5 mg/cm² even Zn isotopes has been observed in a number of other nuclei.

Targets of a few mg/cm² of ⁵⁶Fe, ⁶²Ni, ^{66,68}Zn has been bombarded by 2-4 MeV protons. The anglular distribution of the γ -rays from the low lying states of the residual nuclei, have been measured. From the AD and the known electromagnetic properties of these states (J_i, J_f, δ) the alignment of these states has been deduced.

The results indicate that within experimental error the alignment coefficients of the different states depend only on the spin of the state and remain constant in the region of the nuclei studied. The average deduced alignments for the states observed in 57 Co, 63 Cu, 69 Ga are:

J $B_2(J)$ $B_4(J)$ 3/2 -0.22 (4) 5/2 -0.45 (3) 0.06 (8) 7/2 -0.63 (4) 0.16 (3) 9/2 -0.66 (7) 0.33 (19)

The observed alignment is interpreted as a result

of the significant feeding of these states by direct or two step γ -cascades originating from a great number of states excited in the continuum

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(1) Paradellis T, Vourvopoulos G. (1978) Fizika <u>10</u> Suppl. p.29-30 4) Study of the Even Nickel and Odd Copper Isotopes

P. Bacoyeorgos⁺, P. Assimakopoulos,⁺⁺ G. Vourvopoulos⁺, X. Aslanoglou^{+,++}

The purpose of this work is to study the low lying states in ^{58,60,62,64}Ni and ^{59,61,63,65}Cu, their electromagnetic properties and lifetimes.

This study will further investigate the relation between the E1 transitions from the first 3^{-} to the first 2^{+} state in the Nickel isotopes and the first $9/2^{+}$ to the first $7/2^{-}$ in Copper isotopes in the framework of the weak coupling model.

To this purpose the Ni(p,p^{γ}) and Cu(p,p^{γ}) reactions were used at Ep=4 MeV, 6 MeV but no useful results were obtained due to the presence of a very strong (p,n) channel.

Thus this investigation will be continued through $(d,p \gamma)$, (d,d^{γ}) and $(d,n \gamma)$ reactions on Nickel isotopes by observing the γ -rays in coincidence with the outgoing protons and deuterons.

Some difficulties associated with counting rate and background are being presently investigated.

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5) Measurements of Multipole Mixing Ratios of Some

Transitional Even-Even Nuclei

S. Papaioannou⁺and C. A. Kalfas

The systematic study of the $2\frac{1}{2} \rightarrow 2\frac{1}{1}$ transition of the transitional even-even nuclei in the A-150 region shows a consistent sign of the E2/M1 mixing ratio δ over a wide range of nuclei. A sudden change of this sign occurs when going from N=88 to N=90. An attempt is made in this work to correlate the behaviour of the N=72, 74 nuclei with the one of the N=88, 90 nuclei.

Using the reaction $126_{Te}(p,n)$ 126_{I} the mixing ratios of the 753.2 keV and 490.8 keV $2_2^+ + 2_1^+$ transitions in ¹²⁶Te and ¹²⁶Xe have been studied.

In the angular correlation experiments a Ge(Li) detector and a Na (I) crystal were used and the data were stored in a TN-1700 M.C.A. based on a NOVA computer. The deduced A22 and A44 coefficients were respectively

> 753.2 keV A22 = 0.055 ± 0.006

> $A_{44} = 0.320 \pm 0.009$

 $A_{22} = -0.151 \pm 0.004$ $A_{44} = 0.329 \pm 0.007$

490.8 keV

and the E2/M1 mixing ratios:

 δ (753.2) = -5.8 ± 0.2 δ (490.8) = 9.2 ± 0.5

which indicate a similar trend.

Further work is in progress in the 128 Xe, 130 Xe, and 124 Te nuclei.

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) The Nuclear Structure of ⁹⁶Ru

E. Adamides and A.C. Xenoulis

The level and decay scheme of 96 Ru was constructed via γ -ray spectroscopy following the 9,5-min and 1,5-min decay of ground and metastable states in 96 Ru which was produced via the 96 Ru(p,n) 96 Rh reaction.

Time-sequential spectra of γ -rays were accumulated in repeated cycles. The constructed decay curves of about 100 γ rays permitted the assignment of these γ rays to the decay of the ground or the metastable state. From these measurements and energy intensity and $\gamma\gamma$ - coincidence data a decay scheme of ⁹⁶Ru was constructed which incorporates 30 new states with spin values in the range between 1 and 8.

 J^{π} assignments to the identified states are in progress via the interpretation of extracted logft values.

7) <u>Nuclear Structure Study of ⁹⁴Tc</u>

E. Adamides and A.C. Xenoulis

The structure of an odd-odd nucleus, usually characterized by a complicated spectrum of excited states, constitutes a severe test for the applicability of a theoretical model in a certain mass region. The study of the structure of 94 Tc has been undertaken in order to provide the necessary experimental information for testing shellmodel predictions in the A=90-100 mass region.

The level and decay scheme of 94 Tc were constructed by means of singles γ , $\gamma\gamma$ -and $n\gamma$ - coincidence measurements following the 94 Mo (p,n γ) reaction. Twenty levels were identified up to 2 MeV of excitation.

For J^{π} assignments excitation functions of single γ rays were measured at 12 energies between 5,4 and 7,2 MeV. Furthermore angular distribution measurements were carried out at 6.0, 6.4 and 6.9 MeV. For life-time determination DSA measurements were carried at 7.2 MeV. Analysis of these measurements is in progress.

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8) <u>Study of ⁹⁴Mo Mucleus</u>

E. Adamides and A.C. Xenoulis

The nucleus 94 Mo is being studied by means of the reaction 94 Mo(p,p'y) 94 Mo.

A $\gamma\gamma$ - coincidence experiment was done at Ep=7.8 MeV in order to complete the existent decay scheme,

 γ - ray angular distributions were taken at Ep=5 MeV because at higher energies ⁹⁴Mo nucleus is also populated by the decay of ⁹⁴Tc^m, radioactive nucleus produced in the (p,n γ) channel and this contribution would not permit the results to be analysed using the statistical model.

A life time experiment at 5 MeV is in progress for the purpose of calculating the life-times of the populated states.

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III. APPLIED ATOMIC AND NUCLEAR PHYSICS

1) Correlation Study of Trace Elements in Skin Cancer

by External Proton Beam PIXE

A. Hadjiantoniou⁺, A. Katsanos⁺, V. Papasotiriou⁺⁺, D. Tsampaos⁺⁺ J.Stratigos⁺⁺ and J.Capetanakis⁺⁺.

The external proton beam¹ has been proved to be a very valuable technique for elemental microanalysis by the Proton Induced X-ray Emission (PIXE) method. The irradiation of targets in air is more advantageous especially for the case of non-conductive and heat sensitive samples. For this reason the external beam method is ideal for the analysis of thin and thick biolocial samples. Skin cancerous and precancerous tissues were analyzed and compared with healthy ones in order to establish variaton in the concentration of various trace elements. The elemental analysis was performed by PIXE at the Tandem Accelerator Laboratory of the Democritos N.R.C. utilizing the external proton beam facility established in this laboratory. Skin tissues samples were collected at the "A" Sygrou Hospital Dept. University of Athens. Targets were prepared in 3 different ways be acid digestion and deposition on thin carbon foils, by simple drying or by complete ashing of the sample. The detection sensitivity² varied between 0.1-10 ppm, depending on the element and the interferences from neighboring peaks and the method of sample preparation. The results obtained so far indicate correlation between malignancy of the skin tissue and an increased concentration of certain metalic elements .

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Nickel and lead were the most frequent detected elements in the malignant tissue samples. Whenever lead was detected increase lead concentration was also observed for most of the cases in the healthy samples from the same person, but with less concentration than in the cancerous tissues.

A. Katsanos, A. Xenoulis, A. Hadjiantoniou and R.W. Fink, Nucl. Instr. and Meth. 137 (1976) 119.

A. Katsanos and A. Hadjiantoniou , Nucl . Instr. and Meth . 149 (1978) 469

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2) Elemental Analysis of Liquids by External Beam Pixe

down to PPB Level

A.H. Khan⁺, M.Khaliquzzaman⁺, M. Husain⁺, and M. Abdullah⁺ and A.A. Katsanos ⁺⁺

A method was developed for the direct elemental analysis of solutions and liquids by PIXE, utilizing the external proton beam facility at the van de Graaff accelerator of the Atomic Energy Center Dacca. The samples were irradiated in liquid form through a thin mylar window holding the liquid in a small polyethylene cup. The proton beam was allowed to pass from the vacuum into the air through a 7 μ m Be window, then through an air-path of 23 mm and the mylar window of the sample cup, into the solution. Mylar windows of thickness up to 1 mg/cm² were used. The X-rays were detected at 90^o relative to the beam with a Si(Li) detector. Minimum detection limits and efficiency curves were determined as well as the behavior of some ions during irradiation.

It is shown that under favorable conditions the sensitivity of the method can reach the PPB level

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Study of Possible Changes in Trace Element Concentrations of guinea Pig's Skin after Administering Retinoid Ro-9359

A. Katsanos, A. Hadjiantoniou⁺, D.Tsampaos, B.Papasoteriou⁺⁺

The Retinoid R_0 -9359 or ALL-TRANS-9-(4-METHOXY-2,3,6, TRIMETHYLPHENYL) 3,7 -DIMETHYL-2,4,6,8,-NONATETRAENOATE, is a derivative of vitamin A. Recent studies, of the past six months, proved that the systematic administration of Retinoid for the treatment of incurable up to date skin deseases (e.g. psoriasis, ichthyasis) which are characterized by high mitotic activity of skin cells, has given excellent results.

Using the external beam PIXE method for the elemental microanalysis of biological samples, the possible change in concentration of trace elements in the skin of guinea pigs is studied before and after administering Retinoid R_0 -9359

The results do not indicate so far any significant change in the concentrations of K, Ca, Fe, Cu, Zn, Br and Rb.

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 Study of Conformational Changes in Bovine Serum Albumin by Perturbed Angular Correlations of Y Rays

P.W. Martin⁺, C.A. Kalfas and K. Skov⁺⁺⁺

The properties ofbovine serum albumin (BSA) have been studied extensively by a variety of techniques, the results of which have been summarized in the review articles of Peters {1} and of Steinhardt and Beychok {2}. In particular, the region around pH=4 has received a great deal of attention owing to the onset of conformational changes which occur in the molecule. The existence of this N-F transition region, marking the transition from a normal (N) form to a faster migrating (F) form was first proposed by Foster {3}.

To our knowledge, the only reported study of BSA using perturbed angular correlations (PAC) of γ -rays is that of Leipert and Baldeschwieler {4}, in which measurements were made at pH 2.8 and pH 5.7. Although no quantitative analysis of the data was attempted, the authors concluded that at the higher pH a definite increase was manifested in the molecular rotational correlation time, τ_c . Such a finding is contrary to a process in which a transition is envisaged from a globular form at higher pH to that of an idealized ellipsoid at lower pH with axial ratio of the order of 10/1.

In view of the contradictory evidence resulting from different techniques, we have performed PAC measurements as a function of pH in the region of interest.

In terms of general features, the data exhibit progressively more structure as the pH is increased from 3.5 to 6.2. This agrees with the qualitative features of the data of Leipert and Baldeschwieler {4} and is consistent with an increase in the rotational correlation time. The fits to the data show in fact that τ_c increases from 125 ns at pH 3.5 to 312 ns at pH 6.2. These values are in the region estimated by Shirley {5}. Reasonable fits to the data could only be achieved with the inclusion of the exp (- λ t) term, which represented a short time constant component, as shown in the following Table.

рН	f _o	f1	1/λ (ns)	τ _c (ns) (ω _o MH _z)
3.5	0.51±.04	0.29±0.02	46 ⁺⁴ -2	125 ⁺²⁰ -15	16 <u>+</u> 1
4.0	0.25±0.02	0.29 <u>+</u> 0.02	17 <u>+</u> 2	141± ⁵² 30	25 <u>+</u> 2
6.0	0	0.45 <u>+</u> 0.04	4 <u>+</u> 1	312± ⁵⁵ 40	21 <u>+</u> 2
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Another general feature of the data is the increasing fraction of unbound¹¹¹ In as the pH is lowered (f_0 =unbound fraction, f_1 and $\{1-f_1-f_0\}$ bound fractions with time constants τ_c and $1/\lambda$ respectively.)

It was also found that samples which were cycled through a range of pH demonstrated the reversibility of the conformational changes, but with some degree of hysteresis. Further work on this aspect is in progress.

The PAC results are in contradiction with the data obtained from hydrodynamic techniques and electron microscopy, indicating a significant increase in the rotational correlation time at higher pH. A detailed knowledge of the binding of ¹¹¹In to BSA may be necessary in order to explain these discrepancies.

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IV. THEORETICAL NUCLEAR PHYSICS

1) The Isomorphic Model as: Applied to Lighter Nuclei

G.S. Anagnostatos

The isomorphic model , supporting that the nucleon most probable positions form a high spatial symmetry point space, is here presented on more fundamental grounds, and is successfully applied to almost all ground-state properties of nuclei between 0 and Ni.

The isomorphic model¹⁻³ is in essence a shell model, although it has been developed independently of the established shell model.

The main assumption of the simple shell model, i.e. that each nucleon in a nucleus moves (in an average potential due to the other nucleons) independently of the motions of the other nucleons is here understood in terms of a dynamic equilibrium in the following sense. Each nucleon in a nucleus at the ground state is in a dynamic equilibrium with the other nucleons and, as a consequence, its motion may be described independently of the motions of the other nucleons. In particular, here, we consider a specific equilibrium of nucleons, which is valid whatever the law of nuclear force may be. This leads directly to Leech⁴ polyhedra which are employed to represent dynamic average forms of the nuclear shells, separately for neutrons and protons. A basic $property^5$ of these polyhedra is that the angles ${\mathfrak{A}}_{\ell}^{m} = \cos^{-1}(m/\sqrt{\ell(\ell+1)})$ formed by the possible directions of the orbital angular momentum vector with respect to the quantization axis are identical to the angles formed by

certain symmetry polyhedral axes with respect to an axis common for all polyhedra and taken as the quantization axis. This property permits the assignment of the quantum numbers & and m to the polyhedral vertices. In order to differentiate among vertices which correspond to successive appearances of the same & value, the principal quantum number n is employed and in order to differentiate vertices of neutron polyhedra from those of proton polyhedra the isospin quantum number τ is employed. Finally, we draw a distinction between two neighboring vertices of the same polyhedron (same τ) which both have the same set of the three quantum numbers n, l and m, by using the spin quantum number s. Thus the model permits, in a physical sense , a one-to-one correspondence (isomorphism) between the sets of five quantum numbers $(n, l, m, s and \tau)$ and the Leech polyhedral vertices. This means that a nucleus with known quantum numbers of its nucleons has a unique representation in the isomorphic point space. The properties of this nucleus result directly as properties of this isomorphic structure.

Properties of nuclei between O and Ni examined in a consistent manner using no adjustable parameters are magic numbers, average nuclear density, overall neutron-proton ratio, rms neutron, proton, and mass radii, quadrupole moments, isospin symmetry, spin, parity, magnetic moments and Coulomb energies. The predictions in almost all cases are within the experimental error.

In general, it seems that the isomorphic model contributes significantly to a better understanding of the independent particle model.

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2) A Further Extension of the VMI Model

G.S. Anagnostatos

All extensions of the VMI model to fit high spin states introduce higher order terms of $(J-J_0)$ in the phenomenological potential used^{1,2,3)}. The exclusion of lower order terms, however, has never been justified. In the present work no restrictions to lower on higher order terms are considered. We rother start with a complete polynomial of a certain degree for the potential energy and which of its terms are significant or not for a particular nucleus comes out by the procedure followed. For the Vast majority of known⁴⁾ rotational spectra, a fourth order degree polynomial is sufficient.

. In order to facilitate the comparison, for the demonstration of the present model we choose the same nuclei used in ref. 2 for the demonstration of the VMI234 model, which is closer to our model than any other extension of the VMI model. As seen from Fig. 1 the results of our model are very good and better than those of the VMI234 model. This is particularly apparent in the cases of $^{164}{\rm Er}$, $^{172}{\rm Hf}$, $^{174}{\rm Hf}$, and $^{176}{\rm Hf}$ (where the VMI234 model gives no realistic predictions, since leads to complex energies after a certain value of I) and in the cases of $^{160}{\rm Dy}$ (where the VMI234 model predicts backbendings which are not justified by the experimental data.)



Fig. 1: 2J vs ω² plots. Solid lines represent the results of this work, while brocken lines those of the VMI 234 model, and □ the experimental points.

In general we may say that the fit of the energies alone (like in the VMI234 model) is not a sufficient criterion to judge a model and rather, in addition, the moments of inertia or the fit to the diagram $2j-\omega^2$ should be considered, particularly if we want to have a rather reliable extrapolation of data.

 Y.P. Varshni and S. Bose, Phys. Rev. <u>C6</u>,1770, 1972
 T.K. Das and B. Banerjee, Phys. Rev. <u>C7</u>, 2590, 1973
 A.N. Mantri, Phys. Rev. <u>C12</u>, 1687, 1975.
 R.O. Sayer, J.S. Smith III, and W.T. Milner, Atomic Data and Nuclear Data Tables <u>15</u>, 85, 1975.

3) The Down-Bending Effect

G.S. Anagnostatos

As known, the term back-bending phenomenon stands for the decrease of the square of angular speed (ω^2) , while the moment of inertia (J) increases for some interval of ω^2 values. In a similar manner we define a new phenomenon called down-bending, where the moment of inertia (J)decreases, while the square of the angular speed (ω^2) increases for some interval of ω^2 values. Such bands appear in the cases of ${}^{96}{}_{MO}$, ${}^{104}{}_{Pd}$, ${}^{124}{}_{Te}$, ${}^{126}{}_{Te}$, ${}^{126}{}_{Ba}$, ${}^{130}{}_{Ce}$, ${}^{132}{}_{Ge}$, ${}^{134}{}_{Ce}$, ${}^{146}{}_{Sm}$, ${}^{154B}{}_{Gd}$, ${}^{156B}{}_{Dy}$, ${}^{158}{}_{Er}$, ${}^{166}{}_{Yb}$, ${}^{170}{}_{W}$, and ${}^{182}{}_{OS}$ (see ref.1).

We have probed that there is no way to reproduce such $2J-\omega^2$ plots with any addition of terms in the potential energy, as happens in the case of back-bending. It comes out that what we need to modify is the kinetic energy. An additional term, i.e_x{I(I+1)}²/J² is needed. Such a term describes the contribution of vibrations to the kinetic energy. Such results are expectable for nuclei in the transitional region.

 R.O. Sayer, J.S. Smith III, and W.T. Milner, Atomic Data and Nuclear Data Tables <u>15</u>, 85, 1975.

4) <u>Additional Members of Rototional Spectra in Transitional</u> Nuclei

G. S. Anagnostatos and N. Saloustros +

We found that for some transitional nuclei (e.g. Hg isotopes), if a restoring potential is determined using the "Yrast-States", this potential in the frame work of the VMI model, leads to additional levels for some values of the angular momentum , which are justified by the experimental data.

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V. DATA COLLECTION AND PROCESSING

1. Hardware Development and Maintenance

1.1. General

V. Katselis , A. Sokos, A. Chionakis , S. Kossionides

The data collection system suffered from a major disk break-down. Due to the lack of a "fast-response" channel with DEC the disk units remained out of action for about three months. However, the data collection software was adapted to the DEC-Tape resident ADSS-Monitor and data collection proceeded until one of the disk units was repaired. Minor repairs and adjustments were performed on

- The power supplies of the PDP-15 and the PDP-11 computers.
 - The DEC-Tape transport, TV.56
 - The Teletype, KSR35
- The Display Controller, VR14
 - Several analog and digital NIM modules

The Mass Calculator¹⁾ was wired and tested. Some changes were found necessary and the device is again ready for tests. The ADC Controller²⁾ is back on the draughting board to accommodate a generalized handling of coincident conditions.

- S. Kossionides and V. Katselis, Proceeding of the DECUS, Munich, 1976
- S. Kossionides and V. Katselis, Proceedings of the DECUS, Strassbourg, 1972.

1.2 Dead Time Counter

The accurate measurement of dead time losses is essential for the determination of the yield of a radiation source. The dead-time meters provided on most ADC'S are useful as indicators but may lead to serious errors especially with a time-varying source as the beam of a Tandem Accelerator.

For the accurate measurement of the total dead time influencing a measurement, a device was designed and given for construction to the Electronics Dept. The device receives the BUSY signal from the ADC and gates with it a 1MH_Z crystal oscillator to a six-decade counter. The overflow of this counter is available as standard NIM signal and indicates that one dead-time second has elapsed (Fig.1). Four such counters have been implemented within a double-width NIM module.

Tests with the device have shown that the total losses from a spectrum are accurately accounted for by the dead time. However, losses from the net peak area, due to pile-up cannot : be accounted for by the dead time. Tests are under way to establish an accurate method for the measurement of losses from the net peak area.



2. Software Development

S. Kossionides , K. Dimakou

Event-by event recording and play-back of multiparameter data were released to the users. The Eventby-Event Processor Module is activated from any of the User Programs which acquires multiparameter data. When activated, the Processor runs at higher priority than the user program ensuring that all data acquired by the ADC's are written onto tape. If the rate is very high (>1500 events /sec) events may be lost but are accounted for. Also the user program will obtain very few events for processing. As the rate decreases the proportion of events processed on-line increases to 100% at ~750 events/sec.

Frequent disk failures resulting in a total shut -down of the disks for the last quarter have halted the revision, and final release, of the Real Time System. They have, however, prompted the adaptation of RTS to the DEC-Tape resident ADSS monitor. Thus the availability of the system is ensured in case that either the Disk or the DECtape fails.

The Real Time System has now reached a relatively stable state. Thus writing of the User and System manuals could start. Most system modules are now documented at the level of the User manual while the System manual is in preparation.

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At the end of the report year the following programs were available to the users:

Program Name		Déscription	DOS	ADSS
POLA	and more r	General Multichannel 4 ADC'S, all periphera	v als	-
GAMBLE		Sorting of events 4 ADC'S, no plotter	ν	ν.
MTGAMBLE		Sorting of events from tape , no plotter	n v	ν
CREAM		Mass calculation and sorting , 4 ADC'S, no plotter	ν	ν
MTCREAM		Mass calculation and sorting of events from tape, no plotter	v	
MARGY	· 19	Limited version of POLA with little usage	v	-

An effort is being undertaken to install in the CDC 3300 of "DEMOKRITOS" a suite of programs for sorting event by event data. The subroutines for reading the tapes are under test.

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VI. ACCELERATOR OPERATION

A. Asthenopoulos, N. Andreopoulos, N. Divis , G. Prokos and E. Serveta-Moschoti

During 1978 the Tandem was utilized for a total of 3710 hours . This corresponds to a 76% increase over 1977. A minimum of maintenance was necessary and no major breakdowns occured in the equipment associated with the accelerator. The low energy tube which previously has given us many problems has already been used for 4900 hours and shows no visible signs of damage. We can routinely operate the accelerator up to 5 MV without any tube or tank sparking.

A new ion source (an off-axis duoplasmatron) was ordered to replace the diode source for the production of large proton currents. The inverted sputter source has continued performing very well with up to a month of continued performing very well with up to a month of continued operation without servicing.

A laser which was purchased for alignment purposes can now be routinely used in conjuction with a photo-cell for alignment of parts on the accelerator and the drift tubes. The laser base is thus constructed that it can alternately be used with a theodolite. Desalination equipment were purchased for the cooling water of the vacuum pumps and the magnets. The plant will become operational in 1979.

VII PERSONEL

Research Staff

- Dr. G. Vourvopoulos, Director
- Dr. G. Anagnostatos
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VIII. PUBLICATIONS

A. Papers published in 1978

1. G. S. Anagnostatos

"Maximum Abundant Isotopes Correlation"

Astroph.and Space Sc.53 (1978) 227

2. G. S. Anagnostatos

"Angular Structure of Unique Spherical Shells"

Lett. Nuovo Cimento 22 (1978) 507

3. G. S. Anagnostatos

"The Isomorphic Model as applied to Lighter Nuclei"

Fisika 10 (1978) 59

4. G. Vourvopoulos and T. Paradellis

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J. Phys. G. Nucl. Phys.5 (1979) 309

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Phys. Rev. C.

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Z. Phys.

16. E. Mavrommatis

" Evaluation of some integrals encountered calculations in many-fermion systems".

J. Inst. Math. Applic.

IX. CONFERENCE CONTRIBUTIONS

- 1. A. Katsanos
 - " Analysis of trace elements in biological materials by X-ray methods".

Invited lecture Intern.Symp. on Nuclear Activation Techniques in Life Sciences, Vienna, 1978

2. A. C. Xenoulis and A. Katsanos

" Elemental analysis of light elements by proton elastic scattering".

> 5th Symp. on Recent Developments in Activation Analysis, Oxford, 1978

 A. Hadjiantoniou, A. Katsanos, J. Stratigos and J. Kapetanakis

"Correlation study of trace elements in skin cancer tissues by external proton beam PIXE".

5th Symp. on Recent Developments in Activation Analysis, Oxford, 1978

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