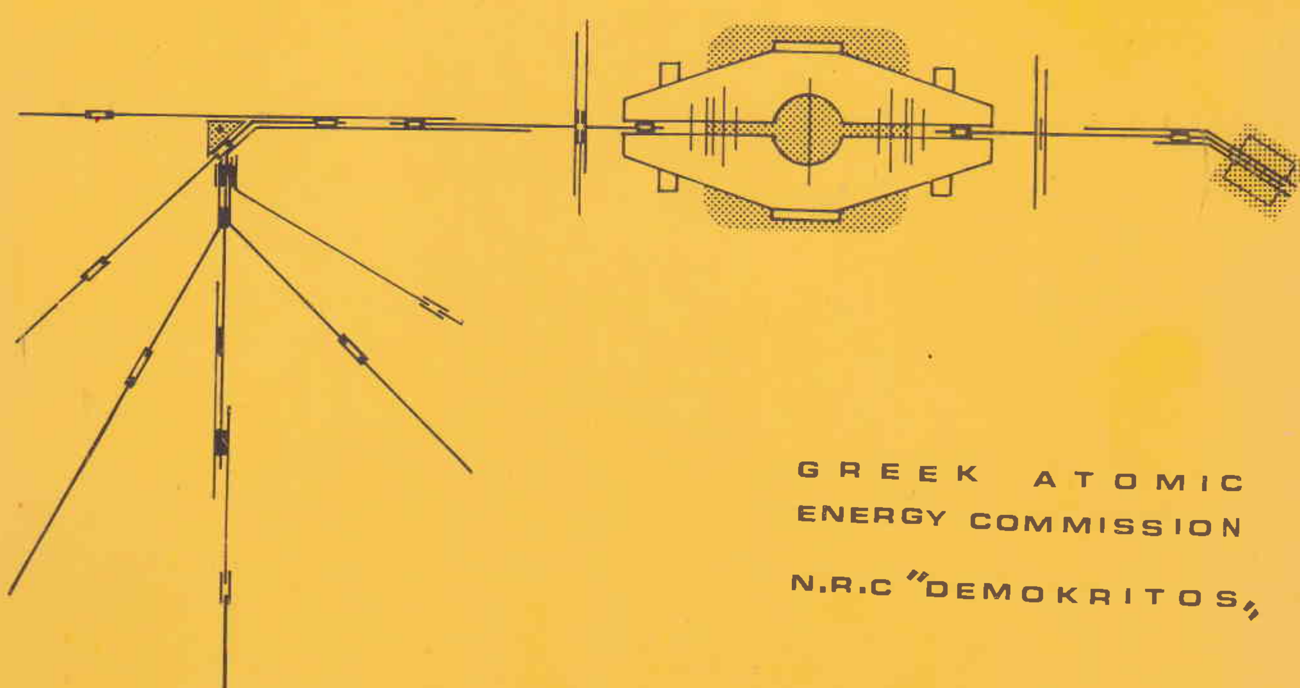
TANDEM ACCELERATOR LABORATORY

ANNUAL REPORT

1976



GREEK ATOMIC
ENERGY COMMISSION

N.R.C "DEMOKRITOS"

NUCLEAR RESEARCH CENTER DEMOKRITOS

TANDEM ACCELERATOR LABORATORY

ANNUAL REPORT 1976

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I N D E X

Introduction

The second year of operation of our laboratory showed an increase in research activity and a higher productivity rate than in the previous year. Work continued along the general guidelines established in the previous year, ie. heavy ion reactions, induced X-rays, γ-ray spectroscopy and theoretical nuclear physics.

In heavy ion reactions, the (^{16}O,2p) reaction proved to be an effective way for mass measurements. Work continues with the above reaction, coupled with measurements of the γ-rays resulting from the deexcitation . The (^{16}O,^{20}Ne) reaction at several energies has given information on the validity of the DWBA method for the analysis of α-transfer reactions. In beam gamma ray spectroscopy produced useful information on the structure of several nuclei and established the decay mode of various g 9/2 analogue states. In atomic physics the induced X-ray method either with charged particles or with fluorescence has been extensively used for trace element analysis in blood and tissue samples, air pollution, target thickness measurements and various other applications.

On the theoretical side, work continued on the extension of the VMI model to explain the backbending and "downbending" phenomena in high spin states. Application of the isomorphic model continued in heavier nuclei. Realistic shell model calculations have been performed to nuclei at the Zr region. The importance of effective 3 body forces in the same region was investigated and the construction of appropriate effective operators at the beginning of the s-d shell is under way.

We continued profiting from our collaboration with visitors from abroad and from the Greek Universities.

We wish to acknowledge the efforts of our technical personnel in maintaining and upgrading our laboratory facilities. Their unselfish efforts and cooperative spirit has contributed in the smooth operation of the laboratory.

G.Vourvopoulos

I HEAVY ION REACTIONS

1. *Mass Measurements of neutron-rich Light Nuclei*

P.Kakanis, E.N.Gazis , E.Kossionides, N.Xiromeritis and A.D.Panagiotou*.

A possible way to produce neutron-rich nuclei , such as ^{34}Si, is to use reactions in which both projectile and target are already neutron-rich, as for example the ^{18}O (^{18}O, 2p) ^{34}Si reaction. In order to detect the two protons and measure their energy, we have developed a very simple new method, in which we detect the 2p's in space- and time-coincidence in a single telescope, consisting of ΔE, E and A/C Si-detectors. Considering the simultaneous passage of two protons through this detector system and using Bethe's relation we arrive at a Particle Indentification function, (PI):

$$PI \propto mz^2 \frac{(E_1+E_2)^2}{E_1 \cdot E_2}$$

where E_1, E_2 are the lab energies of the two protons and m, z their mass and charge. This PI function assumes the continuous values between "4",(case $E_1 = E_2$) and "5.3",($E_1 = \frac{1}{3} E_2$), for all practical purposes. We expect then to see in the mass spectrum a broad distribution, corresponding to the " 2p-particle " group, just after the triton mass.

To develop the method we employed the ^{12}C (^{16}O, 2p) ^{26}Mg reaction at 33 and 35 MeV incident energy. Fig. 1 shows a typical mass spectrum, in which we clearly see the "2p" group, identified as "^{4}H".

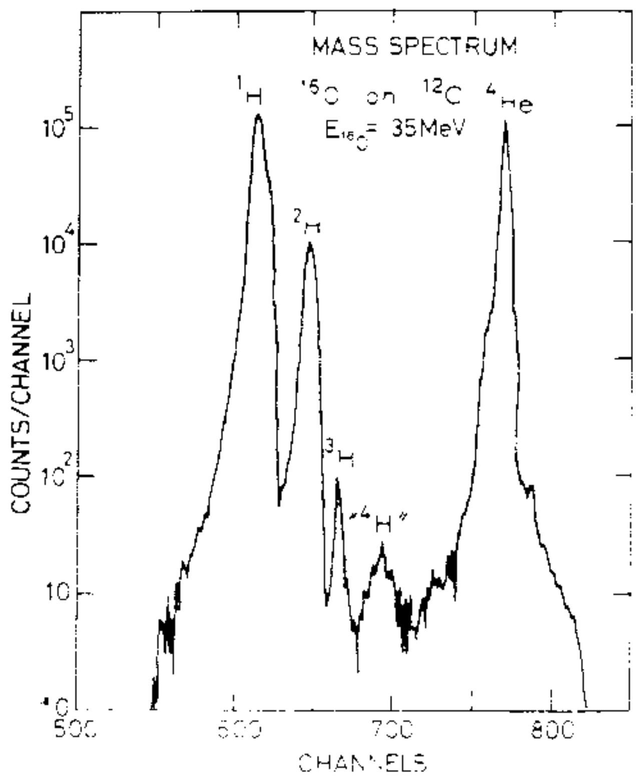

Fig.1. Typical mass spectrum. The peak marked "^{4} H" corresponds to the " 2p-particle".

From the width of the "^{4}H" distribution we calculate the two protons to have very similar energies: $E_1-E_2 \leq 5$MeV. This energy difference is consistent with the assumed average break-up energy of about 380 KeV for the unbound ^{2}He-system. A possible explanation for the ^{2}He emission by the compound nucleus may be given in terms of the penetration probability of the two protons through the combined Coulomb and centrifugal barrier, which is largest for $E_1^{cm} = E_2^{cm}$.

Fig. 2 shows the 2p-energy spectrum, in which the first

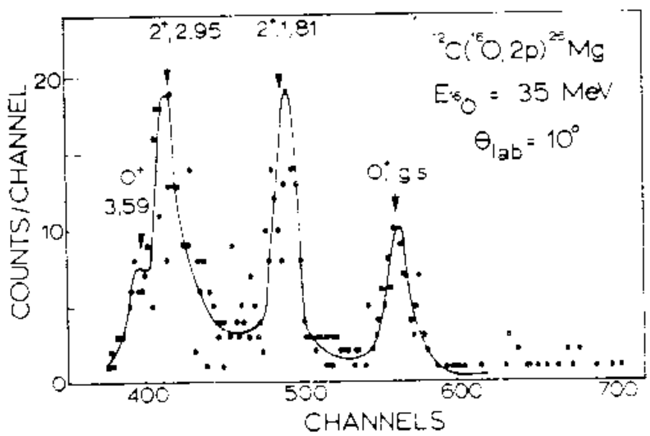

Fig. 2. Total "^4H" energy spectrum. States of ^{26}Mg are indicated in the figure

few levels of ^{26}Mg are clearly identified. Fig. 3. exhibits

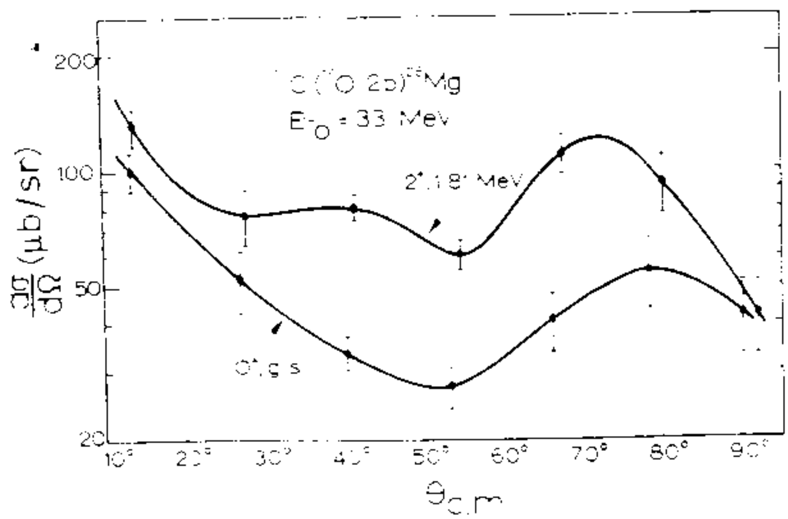

Fig. 3. Angular distributions for the "^4H" leaving ^{26}Mg in it's ground and first excited states. Smooth curves are drawn through the data points.

the angular distribution of the 2p's leading to the first two levels of ^{26}Mg. The absolute cross sections quoted are correct to about 40% . The overall shape of the distribution is reminiscent of compound system formation, in accord with fusion studies of the ^{12}C+^{16}O system at slightly lower energies.[1] From the ground state transition we have estimated the total error in the mass of ^{26}Mg to be about ± 120 KeV, which we believe we can reduce further.

Having developed this new method of 2p-detection we are currently undertaking measurements of light exotic nuclei.

★ University of Athens

(1). P.R. Christened et all, LAP-136 Report,
California Institute of Technology.

2. *Nuclear Structure Investigation of Exotic Nuclei*+

E.N.Gazis, P.Kakanis, A.Xenoulis, J.Kechayias* and A.D.Panagiotou.*

In order to study the properties of nuclei away from the valey of stability special experimental techniques have to be employed, such as mass-separator, helium-jet or in-beam heavy-ion reaction spectroscopy. If one wishes to study the excited states of an exotic nucleus which is completely unknown the experimental situation is much more demanding, since an identification of the radiations related to the unknown nucleus has to be first established.

We have initiated a project in order to investigate the nuclear structure of exotic nuclei in the (s-d) shell, for which very little experimental and theoretical information is available. In particular we shall study nuclei with $2 \leq T_Z \leq 3$, for which almost nothing is as yet known. We intend to obtain energy-level schemes spin and life-time values and measure the properties of electromagnetic transitions. This experimental information will be compared with new shell-model calculations.

The experimental technique employed is particle -gamma spectroscopy initiated by heavy ion reactions. The identification of the γ-rays emitted from an unknown nucleus can be achieved by detecting the emitted particles, leading to this nucleus, in coincidence with the deexciting γ-rays. For this purpose a scattering chamber has been constructed, which permits maximum counting efficiencey for both, particle ang γ, radiations and also permits wide range angular correlation measurements. For the identification of the emitted charged particles a ΔE-E-A/C counter-telescope has been used, employing the semi-empirical power law $(E+\Delta E)^{1.73} - E^{1.73}$. The electromagnetic radiation was measured with Ge (Li) detectors. In order to develop the technique, we investigated the reaction $^{12}C\ (^{16}O,x\gamma)\Psi$, where x can be be p, d, 2p and α, at 24 MeV incident energy. Fast timing and pile-up rejection has been employed.

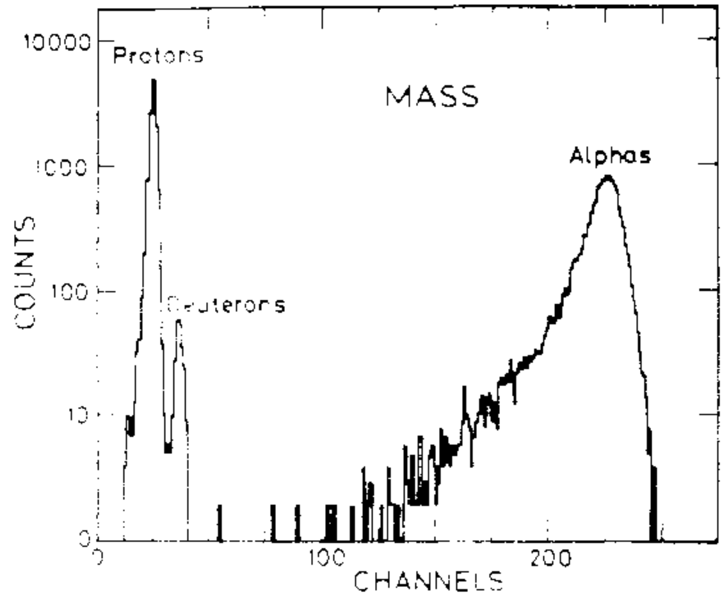

Fig.1.Mass-identified spectrum of the particles emmited in the bombardment of the ^{12}C with 24 MeV ^{16}O beam.

Coincident γ-ray spectra were obtained with each particle group appearing in the mass spectrum (fig. 1). The γ-ray spectra coincident with alphas and protons are shown in fig's. 2 and 3, respectively. In fig. 2 the dominant 1368 KeV ($2^+ \rightarrow 0^+$) ground state transition and the weaker $4^+ \rightarrow 2^+$ transition, related to the $^{12}C(^{16}O,\alpha)^{24}Mg$ reaction channel are seen.

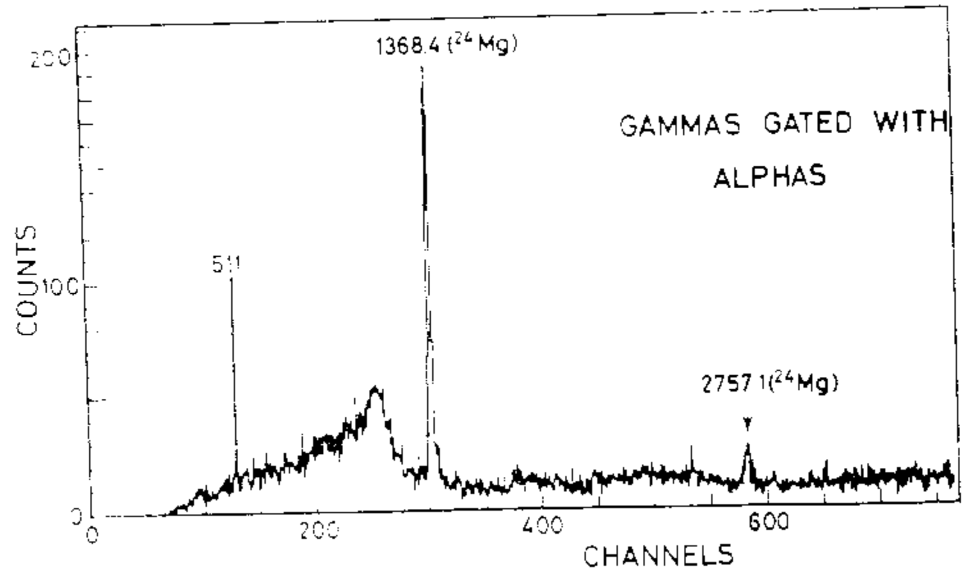

Fig.2. Spectrum of γ-rays emitted in the bombardment of ^{12}C with 24 MeV ^{16}O beam in coincidence with outgoing protons.

Fig. 3 exhibits γ-rays corresponding to the ^{27}Al and ^{26}Mg residual nuclei, produced by p and 2p emission respectively. In the case of ^{27}Al no strong transition is seen , due to the spread of the deexcitation cascade. In the case of ^{26}Mg the dominant $2^+ \rightarrow 0^+$ ground state transition is observed .

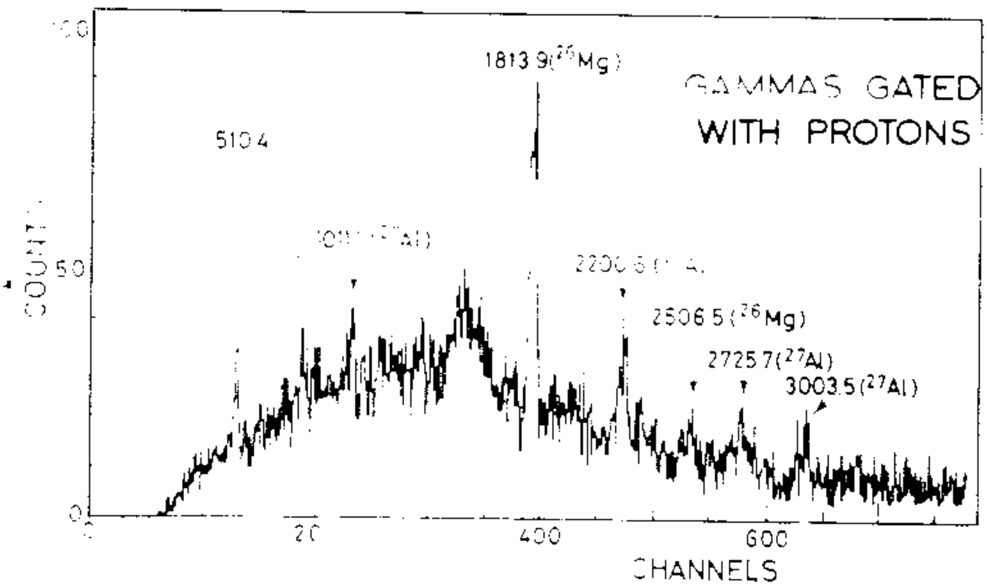

Fig. 3. Spectrum of γ-rays emitted in the bombardment of ^{12}C with 24 MeV ^{16}O beam in coincidence with outgoing alpha particles.

We are currently carrying our measurements for exotic nuclei in the mass region $28 \leq A \leq 36$.

+ Supported in part by the National Research Foundation, Athens, Greece

* University of Athens

3. *The ^{16}O (^{16}O, ^{20}Ne) ^{12}C Reaction*

N.Xiromeritis, G.Vourvopoulos, E.Kossionides,
P.Kakanis and E.Gazis.

The reaction ^{16}O (^{16}O,^{20}Ne) ^{12}C has been studied at 28.0 and 33.0 MeV incident energies. Evaporated self-supported S_iO_2 targets 118μg/cm^2 thick were used. A solid state detector telescope, consisting of a ΔE= 4μm and E= 300μm, was used to detect

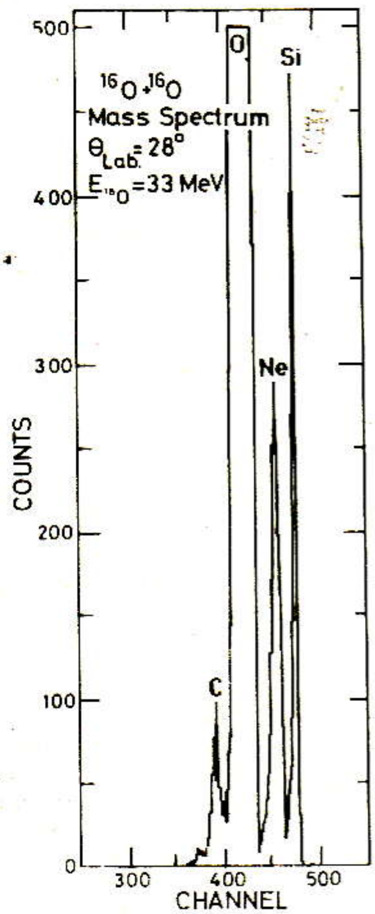

Fig. 1.Portion of the heavy ion mass spectrum from the reaction $^{16}O + ^{16}O$ at 33 MeV.

the reaction products. For the identification of the heavy particles, the formula

$$\Delta E(E' + E_0 + u\,\Delta E)^{\Theta} = KMZ^2$$

was employed, where ΔE is the energy deposited in the ΔE detector, E′ is the energy deposited in the E detector and E_0, u, E and Θ are four parameters. The above expression has been used in the computer code DETECT for the on-line data acquisition.

Fig. 1. shows portion of the mass spectrum obtained from the $^{16}O + ^{16}O$ reactions at 33.0 MeV. The clear identification of ^{12}C, ^{16}O, ^{20}Ne etc. is evident. Energy spectra for each outgoing particle were obtained by setting "windows" on each particle group in the mass spectrum.

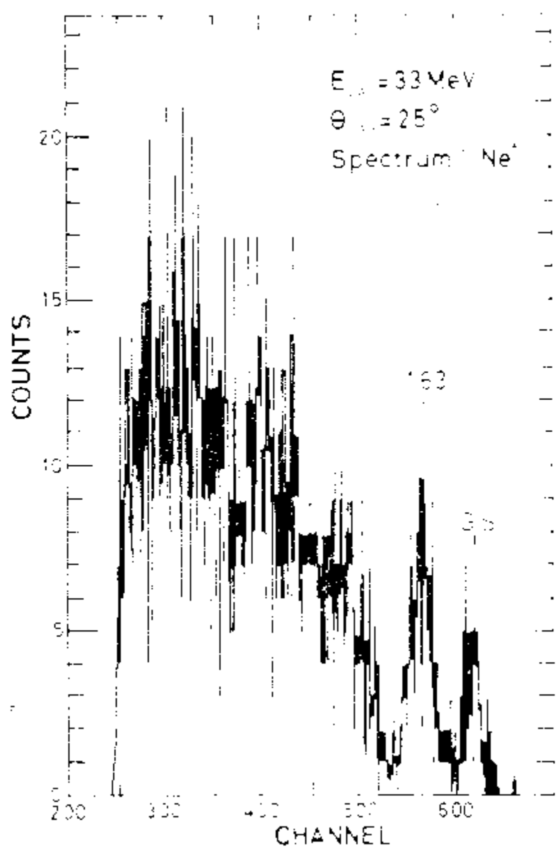

Fig. 2. Energy spectrum of ^{20}Ne from the reaction $^{16}O\,(^{16}O,\,^{20}Ne)\,^{12}C$

Fig. 2. shows a typical ^{20}Ne energy spectrum at 33.0 MeV. Angular distributions have been extracted for transitions to the ground state and first excited state at both energies studied. Figs 3 and 4 show the experimental angular distributions at 33. MeV.

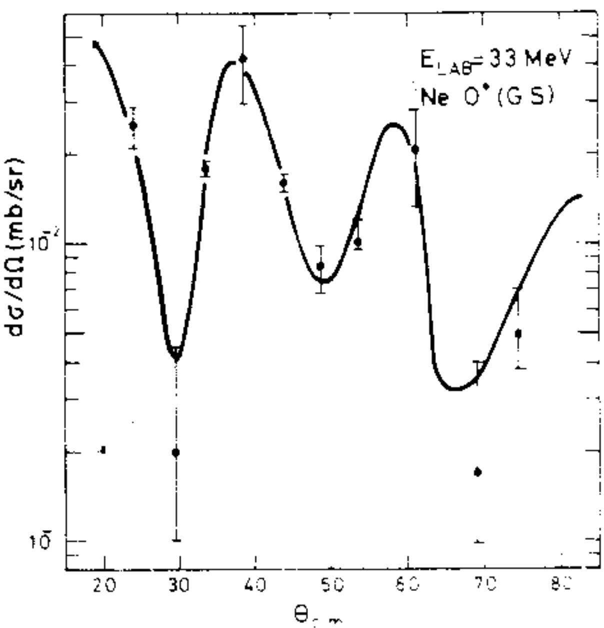

Fig.3 Angular distribution of the ground state of ^{20}Ne from the reaction ^{16}O(^{16}O, ^{20}Ne)^{12}C. Line through points is the DWBA prediction.

An analysis has been performed with the full finite range DWBA code BRUNHILD. Calculations are shown to be in quantitative agreement with the assumption that this reaction proceeds via the simple one-step transfer of an α-particle .

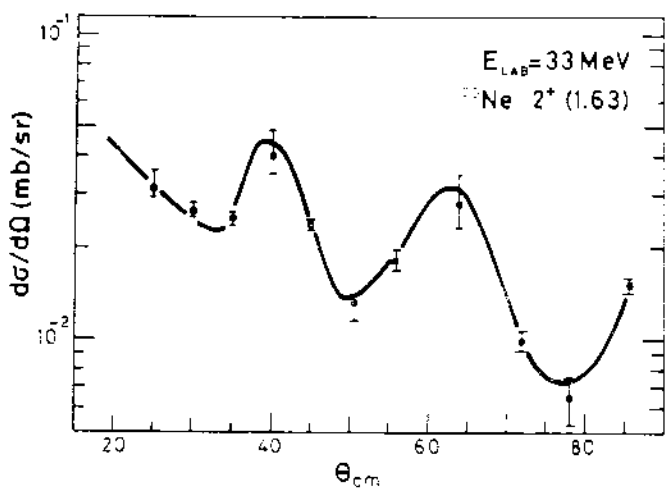

Fig 4. Angular distribution of the I^{st} excited state of ^{20}Ne from the reaction ^{16}O (^{16}O, ^{20}Ne) ^{12}C. Line through points is the DWBA prediction.

Spin and multipole mixing ratios assignments in heavy-ion reactions

E.Adamidis and A.Xenoulis

In order to test the reliability of spin and δ values extracted from angular distribution measurements of single γ-rays emitted in CN heavy-ion reactions we have analyzed a great number of data selected from bibliography. Specifically, A_2 and A_4 angular distribution coefficients were analyzed with a two-dimensional program in which the population of magnetic substates and the spin and δ values were treated as parameters. Within the restriction of alignment, several forms of substate distribution were tested. With a Gaussian distribution most of the spins and multipole mixing ratios obtained were in agreement with reliable results extracted from light ion CN reaction data. A systematic study is in progress in which we shall attempt to clarify the dependence of the substate population distribution on the kind of the projectile, the spin of the residual state, and the effect of deexcitation cascade from above.

5. *Study of High-Spin States in ^{42}Ca by means of Heavy-ion Reactions*

A.Xenoulis and E.Adamidis

The ^{42}Ca nucleus has been previously studied by means of ^{28}Si (^{16}O, 2p) and ^{27}Al (^{18}O, 2np) reactions [1,2]. It is, however, interesting to notice that the analysis of angular distribution measurements gives rather contradictory results.

Using an extended computer code in which we treat multipole mixing ratios and magnetic substates population distribution as continuous variables, we have reanalyzed the A_2 and A_4 angular distribution coefficients reported in Refs.[1,2] While we reproduce the spin sequences and δ values reported [1,2], we have obtained[3] unexpectedly narrow widths for the magnetic substates population distributions with the data reported for the (^{16}O, 2p) reaction[1].

Our results could be interpreted to mean that either there is a pronounced difference in the reaction mechanism between the (^{18}O, 2np) and (^{16}O,2p) reactions, or there is a large experimental uncertainty in the (^{16}O, 2p) measurements.

In order to clarify these points we have undertaken a careful study of the ^{28}Si (^{16}O,2p) reaction. For that purpose we have bombarded natural Si with 35 MeV ^{16}O ions. Single γ-rays have been measured at 90° and 55° with respect to the beam. Gamma-gamma coincidence spectra were measured with two Ge(Li) detectors, and analyzed with the gates placed at 611 KeV and 1524 KeV γ-rays in order to identify the electromagnetic transitions in ^{42}K and ^{42}Ca, respectively. Both these nuclei are produced in the bombardment of ^{28}Si. We plan to proceed with the angular distribution measurements.

1. R.L.Robinson, H.J.Kim, J.B.Mc Grory, G.J.Smith, W.T.Milner, R.O.Sayer, J.C.Wells and J.Lin, Phys. Rev. 13C (1976) 1922.
2. E.K.Warburton, J.J.Kolata and J.W.Olness, Phys. Rev. 11C (1975) 700
3. E.Adamidis and A.Xenoulis, unpublished results.

II GAMMA RAY SPECTROSCOPY

1. *Structure of ^{148}Sm Studied from the Decay of ^{148}Pm and ^{148m}Pm.*

C.A.Kalfas

Gamma-gamma directional correlation and coincidence techniques employing Ge(Li)-NaI (Tl) and Ge(Li)-Ge(Li) systems were used to investigate the de-excitation mechanism and character of several states in ^{148}Sm following the decay of ^{148}Pm and ^{148m}Pm. The radioactive source was produced by (p,n) reaction on mass separated ^{148}Nd. Considerable new information concerning the level structure and de-excitation mechanism of ^{148}Sm was obtained from the present data. Two new levels at 2057.9 and 2284.4 KeV are established, while spins and parities of all levels below 2.4 MeV are uniquely or nearly uniquely determined. The angular correlation results indicate the high spin positive parity states are not of collective character. A total of 22 γ-rays were observed following the decay of 5.4 d ^{148}Sm isomer while 21 γ-rays were observed following the 43 d isomeric decay.

2. *Structure of ^{97}Tc nucleus determined by the ^{97}Mo (p,n γ) reaction*

A.Xenoulis, M.Pantazi and C.Kalfas

There exists a continued experimental and theoretical interest in nuclei in the (0g 9/2) shell-model orbital, since the question about the theoretical interpretation of their properties has not be conclusively settled as yet.

We have undertaken an experimental study in order to determine the excited states and spins sequence in ^{97}Tc, and measure the electromagnetic properties of transitions in this nucleus. Extensive measurements of single γ-rays, excitation functions, γ-γ coincidence and angular distribution measurements have been performed in a bombarding energy range between 2 and 8 MeV. Thus, the level scheme, spins of excited states and multipole mixing ratios of electromagnetic transitions have been determined up to about 2 MeV excitation in the ^{97}Tc nucleus. The low lying states of ^{97}Tc determined in this work are shown in table 1. In this table the states in ^{95}Tc, as previously determined [1], are also shown for the shake of comparison. It is interesting to notice the similarity in the structure of these two nuclei. The compression of the excited states spectrum observed in ^{97}Tc compared to

^{95}Tc provides an outstanding case to test the theoretical assumptions about the residual interactions, since it can be assumed that the addition of two neutrons does not change the central potential considerably.

Level energy (KeV)		J^{π}
^{95}Tc	^{97}Tc	^{95}Tc or ^{97}Tc
0	0	$9/2^+$
39	97	$1/2^-$
336	216	$7/2^+$
627	324	$5/2^+$
646	580	$3/2^-$
667	657	$5/2^-$
882	772	$13/2^+$

1.D.G.Sarantites and A.C.Xenoulis, Phys. Rev. C10 (1974) 2348

3. *Excited states in ^{67}Ga observed in the ^{67}Zn (p,n γ) reaction*

T. Paradellis

Energy levels of ^{67}Ga populated by the ^{67}Zn(p,n) reaction at proton energies between 3.6 and 4.3 MeV and their gamma decay was studied. Spins were determined within the framework of the statistical theory, from angular distribution data and (p,n) cross-sections derived from gamma ray intensity data.

In Fig. 1. the decay scheme derived for ^{67}Ga is shown. The adopted spin and parity assignments and the branching ratios of the γ-rays are also shown in the same figure. Mixing ratios for many transitions have also been extracted. The lifetimes for 19 states in ^{67}Ga measured by DSA method are listed in table 1.

TABLE 1

Lifetimes for levels in ^{67}Ga, obtained by the Doppler shift attenuation method from centroid shift measurements in singles spectra.

Level (keV)	γ rays used	F(τ) at 3.65 MeV	F(τ) at 4.16 MeV	τ (fs) Present	τ (fs) Carlson et al[b]
828.09[a]	828.09	0.083 55	0.099 29	340^{+120}_{-90}	280^{+200}_{-100}
910.92[a]	910.92	0.042 42	0.074 15	360^{+135}_{-75}	370^{+500}_{-130}
1081.68[a]	1081.66, 914.66	≤ 0.100	0.075 40	505^{+600}_{-190}	
1202.25[a]	1202.25, 843.13	≤ 0.050	0.030 18	1080^{+840}_{-340}	≥ 600
1412.71[a]	1412.71, 1053.58	0.025 25	0.029 18	1360^{+3400}_{-560}	900^{+2500}_{-400}
1519.21	1160.04	0.026^{+46}_{-26}	0.029 21	1360^{+3400}_{-580}	750^{+1500}_{-400}
1554.60	1554.57, 1195.49 1387.58	0.123 21	0.157 24	253^{+69}_{-45}	190^{+60}_{-50}
1639.49	1472.48	0.216 51	0.225 43	144^{+50}_{-32}	150^{+50}_{-40}
1808.97	1808.98, 1449.88		0.287 48	105^{+36}_{-28}	
1977.91	1977.99, 1149.98 775.66, 1618.62		0.077 47	492^{+823}_{-217}	≥ 110
2040.88	2040.88		0.245 27	129^{+40}_{-30}	150^{+90}_{-60}
2073.72	871.49		0.045^{+83}_{-45}	≥ 300	
2124.46	1765.26, 1296.41		0.119 42	305^{+202}_{-103}	
2141.84	1974.82		≤ 0.09	≥ 360	
2172.11	2172.11, 1344.16		0.139 39	256^{+123}_{-77}	
2176.07	2176.05, 1816.92		0.324 32	59^{+24}_{-19}	80^{+40}_{-30}
2190.62	1279.68		0.058 58	≥ 300	
2263.75	1350.90, 1061.33		0.273 31	112^{+50}_{-40}	
2281.94	1922.77, 1371.03		0.329 61	86^{+36}_{-24}	

a) Mean lives for these levels are extracted after correction for observed feeding from higher lying states.

b) Aust. J. Phys. 27 (1974) 37

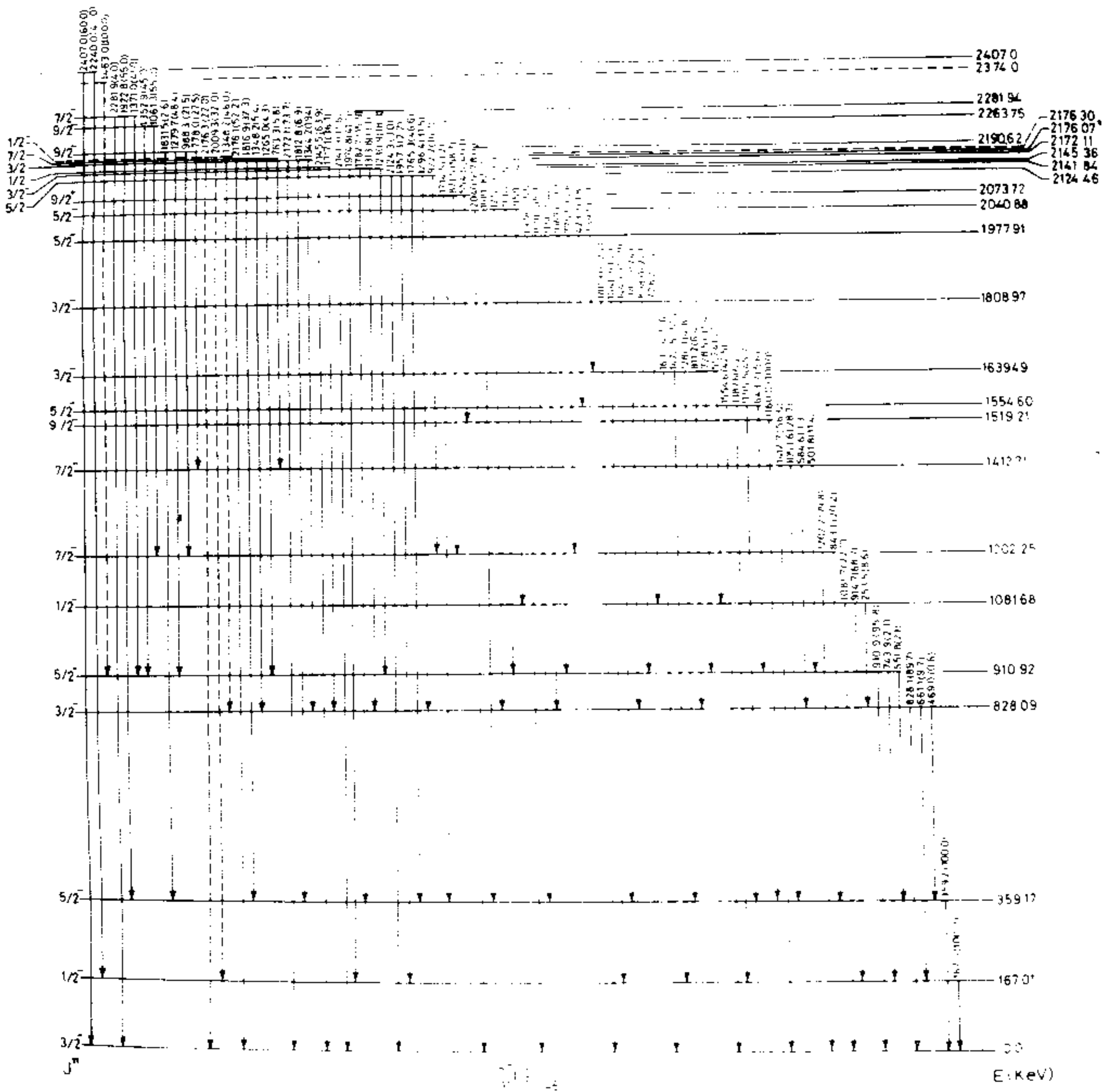

Fig. 1. The decay scheme of ^{67}Ga

4. States in ^{65}Cu from the ^{65}Cu (p,p'γ) Reaction

A.G.Hartas, G.T.Papadopoulos and P.A.Assimakopoulos

Levels in ^{65}Cu up to an excitation energy of 2.7 MeV were studied through the ^{65}Cu (p,p'γ)reaction at incident proton energies E_p=5.25 and 6.0 MeV. Singles γ-ray spectra were obtained with a high resolution Ge(Li) detector at $\vartheta_\gamma=0^\circ$, 20°, 40°, 55°, 70° and 90° and a second (monitor) Ge (Li) fixed at ϑ_γ(monitor)= 90°. Transition energies were measured and levels deduced from the $\vartheta_\gamma= 90^\circ$ spectra with an accuracy better than ± 0.5 keV. Branching ratios were extracted from the $\vartheta_\gamma=55^\circ$ spectra. The life-times of two levels were determined through the Doppler shift attenuation method by studying the energy shift of γ-ray peaks in the angular distribution data. The analysis of angular distributions yielded multipole mixing ratios and J^π values for several states. The experimental information obtained in this work, whenever complete, was employed to calculate reduced transition probabilities.

Fig. 1 shows the proposed decay scheme for ^{65}Cu.

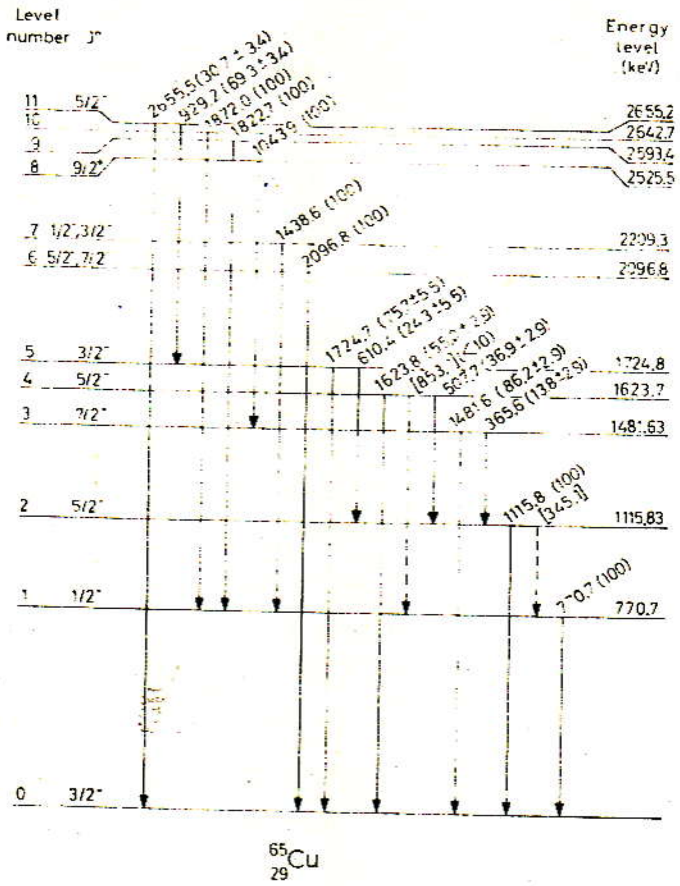

Fig. 1. Proposed decay scheme for ^{65}Cu.

5. *Electromagnetic properties of states in ^{63}Cu through the inelastic scattering of protons*

G.T.Papadopoulos, A.G.Hartas, P.A.Assimakopoulos, G. Andritsopoulos[+] and N.H.Gangas.[+]

Levels in ^{63}Cu up to an excitation energy of 2.8MeV were studied through the ^{63}Cu (p,p'γ) reaction at incident proton energy E_p= 5.0 MeV. Singles γ- spectra were obtained with a high resolution Ge (Li) detector at angles of observation Θ_γ = 0°, 30°, 55°, 70°, 90° and 125° and a second (monitor) Ge (Li) fixed at Θ_γ(monitor) = 90°. The lifetimes of 18 levels were determined through the Doppler shift attenuation method by studying the systematic energy shift of γ-ray peaks in the angular distribution data. The relevant data are shown in table 1. The analysis of angular distributions yielded multipole mixing ratios and J^π values for several states. The experimental information, whenever complete, was employed to calculate reduced transition probabilities. The results obtained are compared to theoretical predictions in the framework on the weak-coupling model.

TABLE 1

The experimental averaged attenuation factors and lifetimes deduced for states in ^{63}Cu

Level energy (keV)	Transition energy (keV)	$\tilde{F}(\tau)$	τ(fs)
1327.0	1327.0	0.053 ± 0.013	640^{+200}_{-140}
1412.0	449.9	0.023 ± 0.021	>740
	742.4	0.030 ± 0.030	
	1412.0	0.046 ± 0.017	
1547.0	[illegible]25.0	0.232 ± 0.033	140^{+22}_{-16}
	1547.0	0.193 ± 0.032	
1861.2	899.1	0.054 ± 0.016	760^{+190}_{-120}
	1861.2	0.047 ± 0.013	
2011.2	1049.2	0.523 ± 0.063	46^{+6}_{-3}
	1341.6	0.462 ± 0.063	
	2011.2	0.483 ± 0.057	
2062.2	1392.2	0.066 ± 0.025	440^{+140}_{-70}
	2062.2	[illegible] ± 0.022	
2081.5	754.4	0.170 ± 0.037	166^{+27}_{-18}
	2081.5	0.199 ± 0.065	
2092.7	765.6	0.042 ± 0.021	535^{+155}_{-85}
	1130.7	0.070 ± 0.020	
	2092.7	0.076 ± [illegible]	
2208.0	881.0	0.087 ± 0.025	445^{+140}_{-70}
	1245.9	0.076 ± 0.022	
2336.5	1374.4	0.065 ± 0.031	510^{+170}_{-35}
	2336.5	0.074 ± 0.019	

TABLE 1 (cont.)

Level energy (keV)	Transition energy (keV)	$\tilde{F}(\tau)$	T(fs)
2404.8	1077.8	0.137 ± 0.055	180^{+53}_{-30}
	1442.7	0.191 ± 0.041	
2497.1	1827.5	0.142 ± 0.066	145^{+32}_{-16}
	2497.1	0.223 ± 0.036	
2512.0	2512.0	0.152 ± 0.030	220^{+65}_{-42}
2535.8	2535.8	0.076 ± 0.025[a]	470^{+250}_{-110}
2696.5	2026.9	0.093 ± 0.052	265^{+136}_{-64}
	2696.5	0.137 ± 0.046	
2716.7	2716.7	0.062 ± 0.051	>310
2780.4	2780.4	0.377 ± 0.070	67^{+24}_{-16}
2806.3	2806.3	0.077 ± 0.050	>270

α Value corrected for feeding from above.

+ University of Ioannina, Greece

6. *Decay of the g 9/2 analogue in ^{63}Cu*

G.Vourvopoulos, Th.Paradellis , G.Costa+ and
G. Bergdoldt+.

Following the announcement of the establishment of the g 9/2 analogue in ^{63}Cu [1] we wished to examine the decay scheme of the analogue in detail. An excitation function was taken and the gamma ray yield as a function of incident proton energy is shown in Fig. 1.

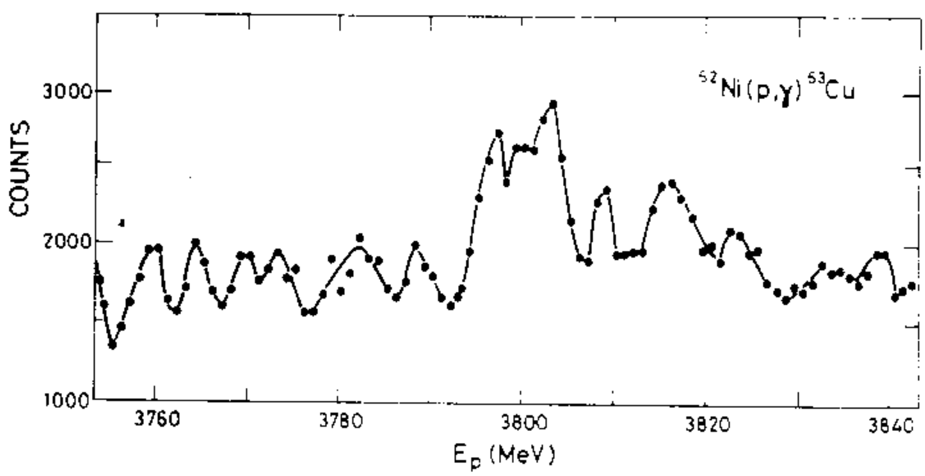

Fig. 1. Gamma ray yield as a function of incident proton energy. The energy gate is E_γ > 7MeV.

These data were taken at CNRS Strasbourg and were later repeated in Demokritos. Several long runs were taken with a 100 cc Ge (Li) detector to establish the decay scheme of these resonances. The resonances found were a few KeV apart from the ones mentioned in ref [1]. Angular distributions were taken for the ground state transition of some of the larger resonances (Fig.1) These distributions indicate that the resonances observed are not the analogue resonances since they do not have the expected pattern for an M1 transition. We cannot identify any of the resonances mentioned in ref.[1] as analogue states and it is possible that the g 9/2 analogue state in ^{63}Cu is largely fragmented among the neighboring $T_<$ states.

+ CNRS, Strasbourg

1). I.Szentpétery and J.Szücs, Phys.Rev.Lett.28 (1972)378

7. *Decay of the g 9/2 analogue in* ^{55}Co

G.Vourvopoulos, T.Paradellis

An excitation function (Fig. 1.) was taken to establish the excitation energy of the $9/2^+$ analogue state in ^{55}Co. This state is the analogue of the 3.80 MeV $9/2^+$ state in 55 Fe. The excitation function revealed not a single resonance but two adjacent ones.

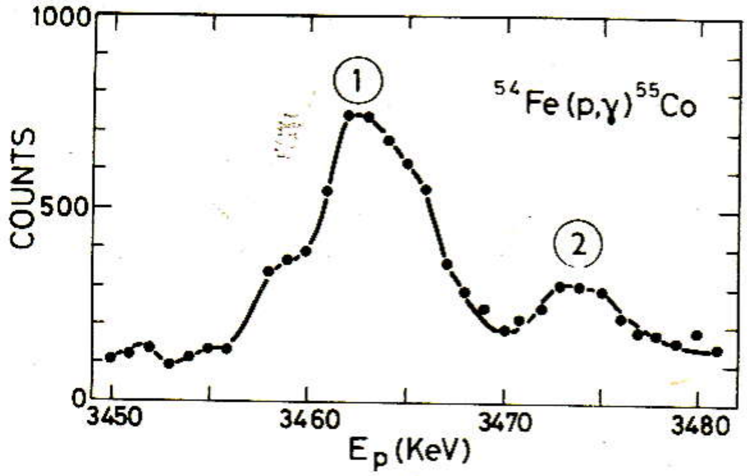

Fig. 1. Gamma ray yield as a function of incident proton energy. The energy gate in $E_\gamma > 2.7$ MeV.

Previous measurements [1)] indicated that only the large resonance at 3.462 MeV incident proton energy was the g 9/2 analogue. Gamma ray spectra taken in our laboratory at 3.462 , 3.470 and 3.474 MeV show that the resonances at 3.462 and 3.474 MeV (Fig. 2) have the same decay pattern, decaying

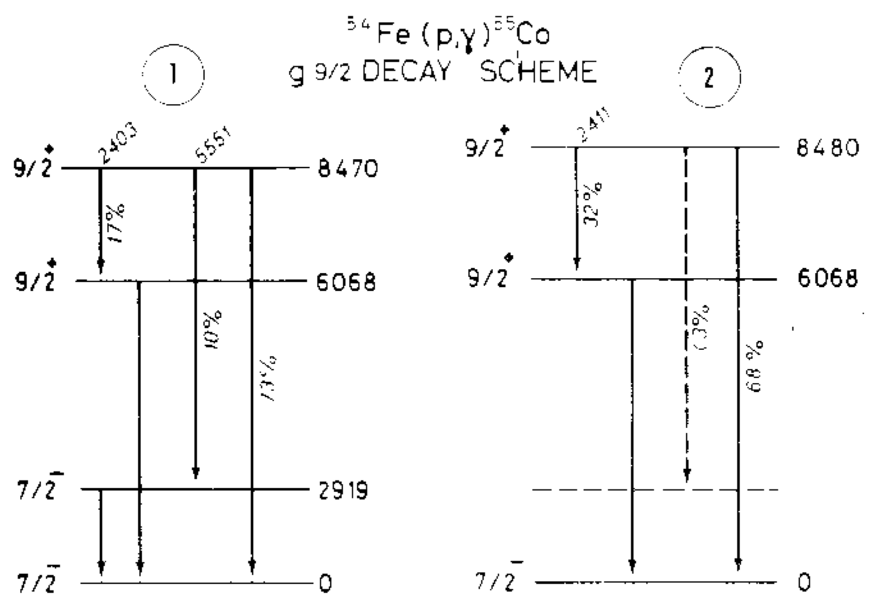

Fig.2. Decay scheme of the two fragments of the g 9/2 analogue in ^{55}Co.

mostly to the $7/2^-$ ground state. We observe therefore therefore a fragmentation of the analogue state in two parts. Calculations are in progress to examine the amount of retardation of the M1 analogue decay.

8. *The ^{16}C + ^{58}[illegible] reaction*

C.Costa[+], F.Gulbault[+], A.Ardouin[+], C.Lebrun[+], M.Vergnes[+] and T.Paradellis.

This reaction has been studied originally at 40 MeV in our lab (see Prog. Rep. 1975). The experiments have been continued in the MP Tandem in Strasbourg. On line gamma ray yields have been measured for $E_{^{16}O}$= 37-50MeV. After each bombardment, residual radioactivity has been measured in preselected time intervals. Gamma-gamma coincidences have been also measured at the 47.5 MeV bombarding energy. Reaction cross section for about ten exit channels are extracted as a function of energy and the level scheme for a number of nuclei is currently constructed.

+ [illegible]

9. *The ^{29}Si [illegible], α,γ) [illegible]*

E. Adamidis and A.Xenoulis

The γ-rays emitted in the deexcitation of states in residual nuclei produced in the bombardment of a 200 μg/cm^2 ^{29}Si target with ^{16}O beams were measured as a function of projectile energies. Single γ-rays were measured at 90° and at 55° for energy and intensity determination. The data at 55° are also used for the extraction of levels life times by fitting the distorted peak shape of the shifted γ- ray.

III X-RAYS

1. *Elemental X-ray microanalysis by charged-particle excitation with applications to local problems* *

A.Katsanos, A.Hadjiantoniou[†], A.Xenoulis and R.Fink[++]

The aim of the present work is the adaptation and development of nuclear techniques suitable for practical applications, as well as the utilisation of such techniques for investigating specific practical problems. On this line a new technique was developed for sample irradiation in free air. This technique besides being a more convenient and universal method for PIXE analysis for Z>19 than the in-vacuum method, it also proved to be superior from the point of sensitivity and peak to valey ratio in the X-ray spectra.[1)]

Thin metallic targets prepared by vacuum evaporation on mylar or carbon foils in our laboratory, and others purchased from MICROMATTER Co in Seattle, USA., were used for cross section measurements and calibration. In other cases mixtures of elements from solutions were either deposited on various backings or mixed and homogenized with various samples for the different applications.

On the other hand in order to demonstrate the capabilities of the method for investigating and solving local problems, biological, air and water polution, as well as various other samples were tested.

Various air pollution samples collected by us as well as others furnished by the pollution Control Agency in Athens were analysed, as a preliminary work. The X-ray spectrum of a characteristic sample is shown in Fig. 1.

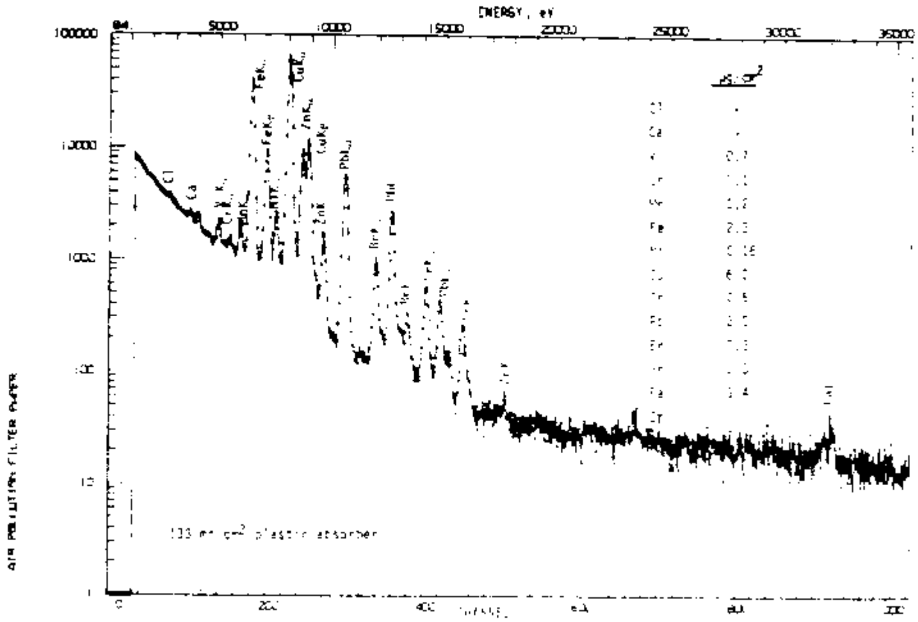

Fig. 1. The X-ray spectrum of an air pollution sample collected on filter paper, using Ge (in) detector and 133 mg/cm^2 plastic absorber. Proton energy 2.0 MeV.

In Fig. 2. the X-ray spectrum of a sediment sample from the Pollution Control Agency is also shown. Another point of interest was the determination of uranium in rock samples for the IAEA - DEMOKRITOS uranium search program. Our conclusion was that, depending on the presence of other elements, the sensitivity was usually less than 5-10 ppm for thick rock

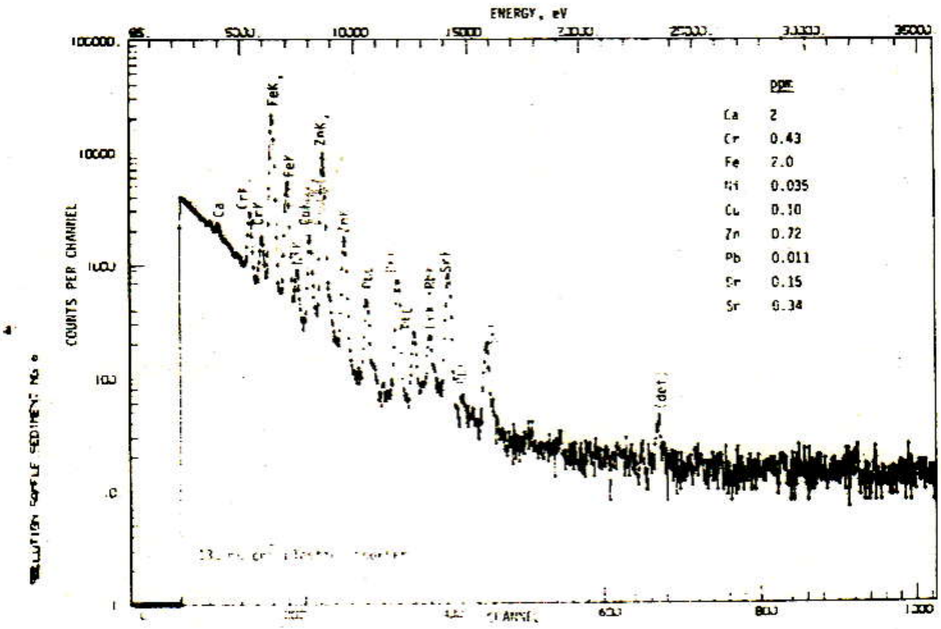

Fig.2. The X-ray spectrum of a sediment sample, with a Ge(in) detector and 133 mg/cm^2 plastic absorber . Proton Energy 2.0 MeV

samples , which was not sufficient for the requirements of the project.

Similarly, the purity of some magnesium samples , used for the preparation of Grignard reagents was also succesfuly tested by external PIXE analysis. Finally, extensive work has been started on biological samples.

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1) A.Katsanos, A.Xenoulis, A.Hadjiantoniou, and R.W.Fink
Nucl. Instr. and Meth. 137 (1976) 119-124

* Supported in part by the IAEA, Vienna

+ Health Physics Division N.R.C.DEMOKRITOS

++ Permanent address :Chemistry Department Georgia Institute of Technology

2. *Trace Multielement Analysis of Biological Samples by External Beam PIXE*★

A.Katsanos, A.Hadjiantoniou,+M.Salaha and A.Zannis.++

The public Electric Company in Greece, as well as various other institutions requested the analysis of Pb contamination in human blood. Samples were prepared by acid digestion and deposition on thin carbon foils, by drying, and by ashing whole blood. The first method was more time consuming without increasing the sensitivity relative to the drying method which was about 0.2 ppm with the intrinsic Ge detector and about 0.5 ppm with the Si (Li) one. By ashing the sample, however , sensitivity well below 0.1 ppm can be achieved , as shown in Fig 1. Care must be taken for standardization of the ashing conditions and calibration. The content of 0.2ppm of Pb is considered normal. It should be noted that the use of chromium critical X-ray absorbers for the iron peaks, did not increase the sensitivity for lead. After the preliminary tests, blood analysis of people working in lead contaminated environment, showed lead content between 0.1 - 0.6 ppm in whole blood, and up to 2ppm in urine samples.

Some samples of human femur heads were also analysed for trace elements. Specimens with visual indications of deterioration showed relatively high concentration of Cr, Mn, Cu and Ni.

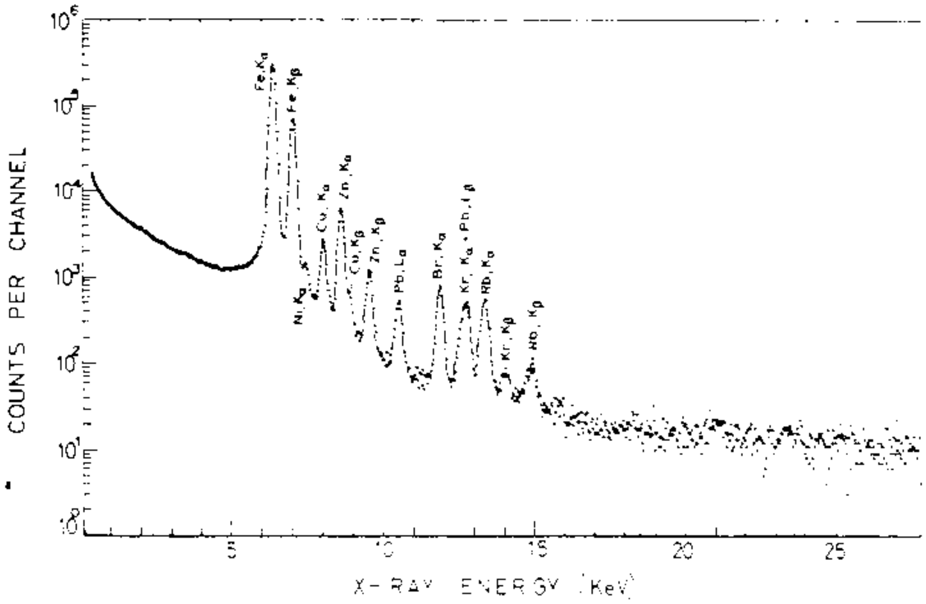

Fig.1. The X-ray spectrum of ashed human blood with 0.2 ppm Pb added, using an intrinsic Ge detector and 133 mg/cm^2 plastic absorber. Proton Energy 2.0 MeV

However, this project was not continued due to the fact that healthy specimens could not obviously be obtained and conclusive results would be difficult.

Other biological samples of interest analysed were human cancer tissues in comparison with healthy ones, furnished by Dr. R.Sarper through Prof. Fink of Georgia Institute of Technology. High concentration of Pb in some cases as well as other indications have not yet been fully evaluated.

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* Supported in part by IAEA, Vienna

+ Health Physics Division, NRC DEMOKRITOS

++ Health Center NRC DEMOKRITOS

3. *Proton Induced X-ray Emission Elemental Microanalysis in Stone Age Tools*

D.van Horn[+], M.Greefield[++], A.Hadjiantoniou[+++] and A. Katsanos.

Recent excavations at the site Frachthi in the Peloponnesus (Greece) uncovered remarkable findings of human habitation in the Old and New Stone Age.

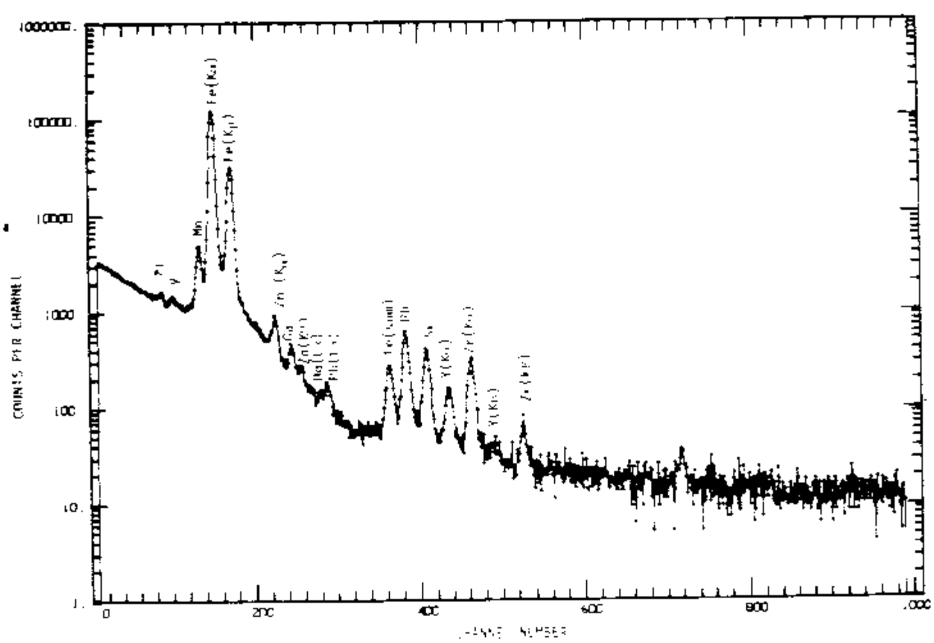

Fig. 1. The X-ray spectrum of a mesolithic flint tool with absorber for the low energy X-rays of light elements.

Work has been starte[illegible] this laboratory to identify the sources on the flint-stone used for the tools in various ages. For this purpose a non-destructive multielement trace analysis is performed by proton induced X-ray emission on the tools and stone samples from various sources.

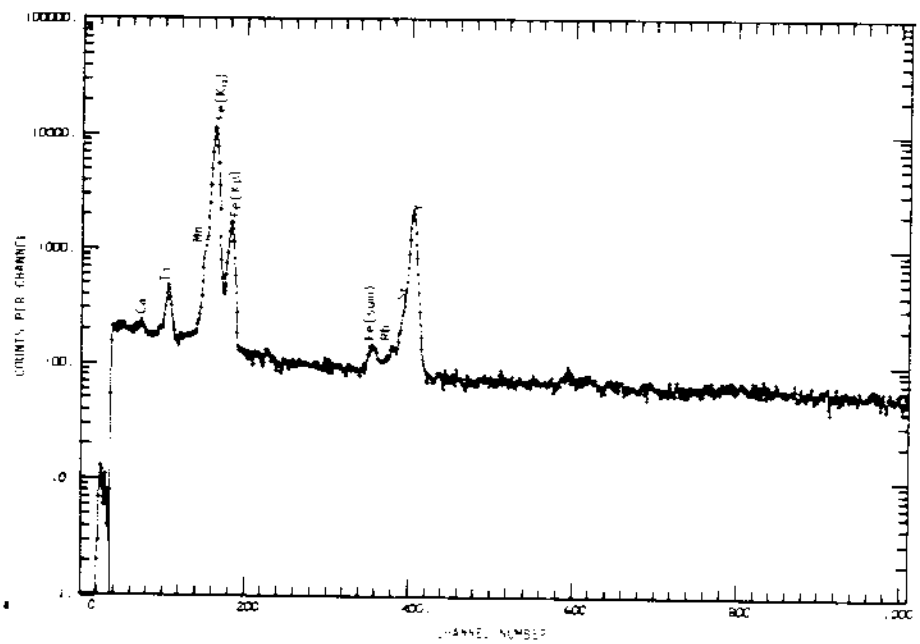

Fig.2. The X-ray spectrum of another mesolithic flint tool from a different source, again with absorber for the energy x-rays of light elements

Two spectra with different composition of trace element are shown in Figs. 1. and 2.

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++ Permanent Address:Physics Department, Florida A and M University
+++ Health Physics Division, NRC DEMOKRITOS

4. *Determination of trace elements in blood samples by photon induced X-ray fluorescence.*

T. Paradellis

Whole blood samples have been analyzed by photon induced X-ray fluorescence. The blood sample is dried by an ashing process. Fig. (1)

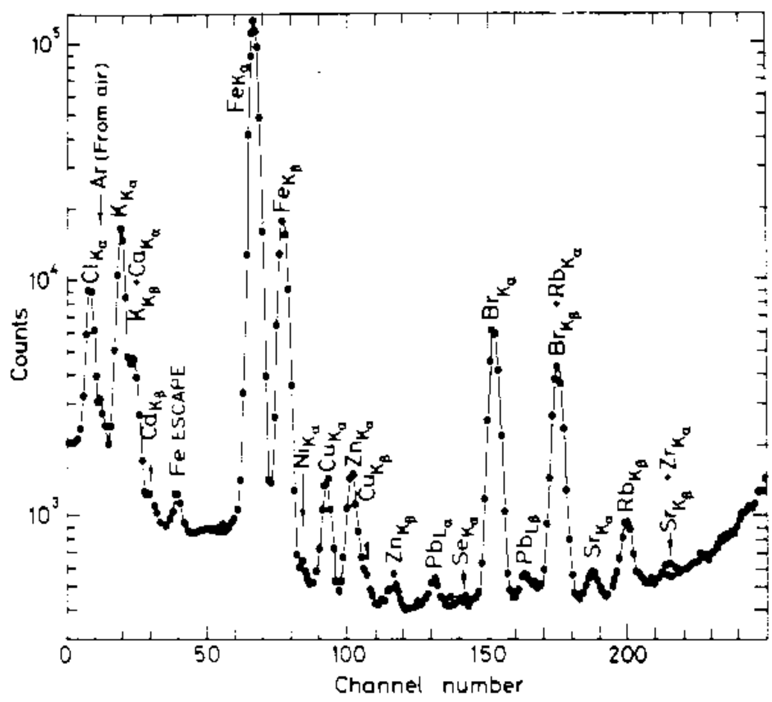


Fig . 1. Spectrum of an ashed blood sample , obtained with a 4mC Cd^{101} source in 100 min Concentrations of some elements are: Fe 46mg/ml Br= 522 µg/ml, Rb= 230µg/ml, Cu= 140µg/ml Zn=170µg/ml, Ni =11µg/ml, Se= 1.5 µg/ml , Pb= 25 µg/ml and Sr= 11 µg/ml.

shows an X-ray spectrum of an ashed sample obtained with a 4mC ^{109}Cd exciting source. The quantity of the elements involved has been measured using a) The relative intensity of each photopeak to the Iron peak, b) the known relative yields of the elements to the Iron obtained from thin films measurements (see Ann. Rep. 1975). c) the known amount of Iron in the sample which is determined directly from a thin blood sample obtained by depositing 0.5 ml of whole blood in a filter paper and d) a relative absorption curve obtained from the average composition of the samples. Quantitative results obtained have been checked for some elements by neutron activation and found in very good agreement with XRF data.
Under these conditions the detection limit for some important trace element (assuming a 20 mC source, 1 ml of blood and 20 min counting)is (in μg/100 ml)
$N_i \simeq 7$. $Se \simeq 0.8$, $Sr \simeq 1.0$ $Zr \leq 1$, $Hg \simeq 2$, $Pb \simeq 2$. $Mo \simeq 3$

5. *Pb, Sn, Sb air contamination in the Greek Gov. Printing office working spaces*

T.Paradellis and V.Katselis

A series of air pollution measurements has been conducted in some working areas inside the National Printing building. The most contaminated area was found to be the smelting room were the concentration of some toxic elements was Pb: 200-80 $\mu g/m^3$ Sn:51-27$\mu g/m^3$ Sb:34-14$\mu g/m^3$. Next in contamination was found to be the **Offset** room where Pb ranged from 27 to 7 $\mu g/m^3$ while Sn and Sb were less than 1 $\mu g/m^3$.

It was found that the size of the air particulates carrying Pb, Sn and Sb was large enough that a Whatman 41 paper filter would remove more than 98% of these elements from air passing through them.

IV THEORETICAL NUCLEAR PHYSICS

1. *The even parity states of ^{95}Tc.*

L.D.Skouras and C.Dedes[+]

An attempt is made to explain the observed even parity spectrum and transition rates of ^{95}Tc. The shell-model approach is followed and the three valence protons are restricted to the $0g_{9/2}$ orbital. On the other hand full configuration has been assumed for the two valence neutrons which are allowed to take all possible values in the $1d_{5/2}$, $2s_{1/2}$, $1d_{3/2}$ and $0g_{7/2}$ orbitals. Experimental single particle energies are used in the calculation while the two-body matrix elements are derived from the "Sussex" and "Yale" interactions by means of second order perturbation theory. Thus, using only one free parameter, namely the effective charge, we have reproduced to a good approximation, the excitation energies and transition rates of about thirty-five observed levels. In addition the calculation predicts a number of levels that, quite possibly, have not yet been experimentally observed.

+ University of Ioannina, Greece.

2. *The even parity states of ^{94}Mo*

C.Dedes+ and L.D.Skouras

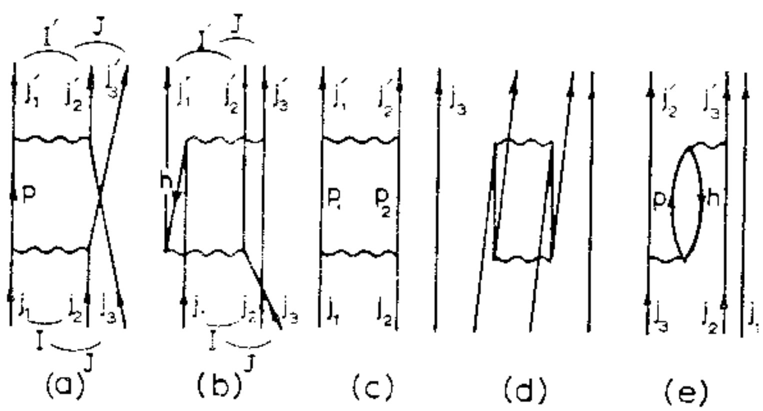
The even parity spectrum of ^{94}Mo is calculated in a basis constructed by coupling the $(0g\ 9/2)^2$ proton to the $(1d\ 5/2,\ 2s\ 1/2,\ 1d\ 3/2,\ 0g\ 7/2)^2$ neutron configurations. The effective interaction is calculated to second order and by allowing up to $2\hbar\omega$ excitations. The results of the calculations are in satisfactory agreement with experiment on both energy levels and transition rates.

+ University of Ioannina
Greece .

3. *Effective three-body interaction in ^{93}Tc, ^{93}Mo and ^{94}Ru*

H.A.Mavromatis+, L.D.Skouras and C.Dedes++

The influence of the effective three-body interaction on the spectra of ^{93}Tc, ^{93}Mo and ^{94}Ru is studied. The three-body interaction is represented by diagrams (1)(a) and (1)(b) of fig. 1 together with their eight exchange graphs which are not accounted for by the antisymmetrized two-body matrix elements.



In table 1 we make a comparison between the effective three-body and two-body (graphs 1 (c), 1 (d) and 1 (e)) contributions for the case of the J = 1/2 states of ^{93}Mo. These contributions have been calculated in the space of 2 $\hbar\omega$ excitations using the Sussex interaction .

TABLE 1

Three-body as compared to two-body contributions to the spectrum of ^{93}Mo in the case J= 1/2

Matrix Elements*	Two-Body	Three-Body
<1|1>	-3.135	.005
<1|2>	.563	-.005
<1|3>	- .658	-.003
<1|4>	.184	.008
<2|2>	-1.330	.007
<2|3>	.270	-.003
<2|4>	- .499	-.004
<3|3>	-1.217	-.006
<3|4>	.176	.001
<4|4>	-1.133	-.023

* $|1\rangle = |(0g_{9/2}p)^2\ 0,(2s_{1/2}n)\rangle$

$|2\rangle = |(0g_{9/2}p)^2\ 2,(1d_{3/2}n)\rangle$

$|3\rangle = |(0g_{9/2}p)^2\ 2,(1d_{5/2}n)\rangle$

$|4\rangle = |(0g_{9/2}p)^2\ 4,(0g_{7/2}n)\rangle$

It may be seen from table 1 that the contribution of the effective three-body is considerably smaller than that of the two-body diagrams. Similar results have been found for the other states of ^{93}Mo as well as for the states of ^{93}Tc and ^{94}Ru. On the other hand it is found that there is an exact cancellation between the Pauli violating terms of graphs 1 (a) and 1 (c) and the corresponding terms of 1 (b) and 1(e)

+ American University of Beirut, Lebanon

++ University of Ioannina , Greece

4. *Calculation of the single particle energies of ^{17}O*

H.A.Mavromatis[+] and L.D.Skouras

In order to obtain a more accurate estimation of the effective interaction for two particles outside the closed core, matrix diagonalization methods have been used. In particular this technique has been applied[1,2] for the space of 0 $\hbar\omega$ and 2 $\hbar\omega$ excitations for the case of closed core, closed core plus one and closed core plus two particle system. However due to the space truncation the method of matrix diagonalization has the disadvantage that it introduces unliked term contributions to the effective interaction[3]. In this work a technique has been developed which eliminates the unliked diagram contribution to the effective interaction. The method is currently applied to the case of ^{17}O.

+ Americal University of Beirut, Lebanon

1) N. Lo Judice, D.J.Rowe and S.S.M. Wong, Phys. Lett. 37B (1971) 44 and Nucl. Phys. A219 (1974) 171

2) A.Watt, B.C.Cole and R.R.Whitehead, Phys. Lett. 51B (1974) 435

3) H.A.Mavromatis, Nucl. Phys. A206 (1973) 477

5. *A calculation of the even parity states of ^{18}O*

H.A.Mavromatis[+] and L.D.Skouras

In this work a "realistic" shell-model calculation is attempted for the even parity states of ^{18}O. An inert ^{12}C core is assumed and full configuration mixing is allowed for the six valence particles in the Op 1/2, Od 3/2, 1s 1/2 and Od 3/2 orbitals. The two particle matrix elements are derived from the "Sussex" interaction in the space of 2 $\hbar\omega$ excitations by means of second order perturbation theory. Results obtained from the use of both experimental and calculated (see previous report) single-particle energies are to be compared.

+ American University of Beirut, Lebanon

6. *A unified Self-Consistent Description of Low and High Spin States in Ground-State Bands*

G.S.Anagnostatos

A unified description of low and high spin states in ground-state bands is presented, where the potential energy is a fourth degree polynomial in $(\mathcal{J}-\mathcal{J}_c)$ derived through a self-consistent approach and where the kinetic energy is a second degree polynomial in I (I+1). The model which is basically a variable moment of inertial model, is applicable to soft and well-deformed nuclei, and gives results which are in excellent agreement with experimental data.

7. *One Parameter Model for a Unified Description of Rotational Spectra*

G.S.Anagnostatos

As known, for the description of rotational spectra up to I ≅ 10 -12 in even-even nuclei two parameter models are used (e.g. the VMI model). For the description of higher spin levels even more parameters are employed. We have found that, if an appropriate determination of the potential and kinetic energy terms is made, one parameter is sufficient to describe both low and high spin levels of a whole group of rotational nuclei.

8. *Quadrupole Moments and RMS radii of Nuclei with* [illegible]

G.S. Anagnostatos, J.Yapitzakis[+], A.Kyritsis.[++]

In the present work the isoporphic model[1-3)] is applied [illegible] all nuclei with $8 \leq Z \leq 60$ and known experimental electric quadrupole moments. Nuclei with Z < 8 and Z>60 are not examined since the isomorphic model, in its present form, is not applicable to them. It is proved here that an exchange between a neutron and a proton reciprocal polyhedral shell is not permissible and that it is correct that some specific polyhedra are employed to represent proton average shell forms while some other specific polyhedra neutron average shell forms. Properties examined here are proton rms radii and electric quadrupole moments. All predictions of the model are in very good agreement with experimental data.

+ University of Athens

++ Technical University of Athens

1) G.S.Anagnostatos, Can. J.Phys. 51 (1973) 998

2) G.S.Anagnostatos, DEMO Report 74/6 (1974)

3) G.S Anagnostatos to be published in ATOMKERNENERGIE

9. *A Geometric High Symmetry Point Space with Quantum Mechanical Characteristics*

G.S.Anagnostatos, J.Yapitzakis[+], A.Kyritsis[++]

It has been found that the angles formed by the different orientations of the angular momentum and the quantization axis, i.e. the angles $\theta_{\ell}^{m} = \cos^{-1}\frac{m}{\sqrt{\ell(\ell+1)}}$, are <u>exactly</u> equal to the angles formed by axes of symmetry of a high symmetry point space (as specified in ref. 1) and by a specific fixed axis taken as the quantization axis. Thus, this work provides a geometrical interpretation of the angular momentum quantization. This result is of a significant importance for the isomorphic model regarding predictions of the spins and magnetic dipole moments.

1) G.S.Anagnostatos , Can. J.Phys. <u>51</u> (1973) 998

+ University of Athens

++ Technical University of Athens

V DATA COLLECTION AND PROCESSING

1. *Facilities Available*

During the report year the following were added to the facilites of the laboratory:

a. An Incremental Plotter and 8k of Memory to the PDP-15/76 (Total Memory 24 k)

b. An NS 1700 Multichannel Analyzer with 4k of data area, Industry Compatible Magnetic Tape, X-Y plotter and Interactive BASIC.

2. *Hardware Support*

V.Katselis, A.Sokos, A.Chionakis.

The main task of the group remains the maintenance of the data collection equipment including the computer. Minor constructions include:

a. Design of a+ 5VDC, 2A, 10^{-3} stability power supply which was produced in small quantity.

b. Design and construction of a power supply for 20-30 VDC, 2A, 10^{-3} stability.

c. A supply of 400 V, 2A for the new sputtering source and

d. Two low-vacuum detectors (Sparkplug) with 4KV, 1mA power units.

3. *Software Support*

S.Kossionides, K.Dimakou, X.Aslanoglou.

The main software effort concentrated on the creation of a new REAL TIME EXECUTIVE running under DOS V3B and the rewriting of the on-line software to exploit the new facilities. At the end of the report period the following modules were ready and tested but not yet released:

a) RTSYS The EXECUTIVE which contains a QUEIO facility, keyboard command processor and keyboard - user interface, PIP-like transfers between all standard peripherals and memory as well as run-time core allocation for data files.

b) VRA: A Handler for the VRI4 refresh display with Light Pen. The Handler is compatible with the XYA Plotter Handler and allows the implementation of a pre-plotting VIEW facility.

c) MTG: A Magnetic Tape Handler for fast recording and replaying of event by event data. This is a file oriented, DEC Tape and Cartridge Disk compatible, modification of DEC's MTF. Handler

d) ADC: A Handler for the ADC interface with special emphasis on fast double-buffering operation and the ability to group ADC'S into coincident groups as well as independent singles (e.g.MONITOR).

e) A number of User-Handler interface routines which allow use of the [illegible]lized Handler functions from MACRO or FORTRAN programs.

A secondary effort has also been undertaken to organize a library of commonly used FORTRAN programs running on our PDP-I5 or the CDC 3300 of the Computing Centre. The library contains currently the following (in parenthesis, the computer on which the program runs).

1.	DAMA	(3300) :	Multichannel Data Handling.
2.	ANNA	(15 &3300) :	Analysis of γ-ray Spectra.
3.	MANTYF	and	
4.	BARBYF	(3300) :	Hauser-Feshbach cross section calculations.
5.	DECAY 3	and	
6.	DECAY 4	(3300)	Combinatorial construction of level scheme from γ-ray decay energies.
7.	PAKINE 3	(3300):	Three body decay kinematics.
8.	PAKIPLOT	(3300)	Line Pointer Plot of PAKINE 3 results.
9.	BRUNHILD	(3300):	Heavy ion transfer reaction cross sections (DWBA).
10.	RELKIN	(15&3300):	Relativistic two body reaction kinematics.
11.	OPTIC II	(3300):	Accelerator Optics Calculations.
12.	MTREAD	(3300):	Subroutine to read NSI700 Magnetic Tapes in the CDC 3300.

4. *Mass Identifier*

V.Katselis, S.Kossionides.

The software simulator of the identifier has been extensively used during the report period and confirmed the initial confidence on the flexibility of the algorithm.

Mass spectra taken with the simulator are presented in the heavy ion section of tnis report in Papers 1 (Fig . 1) and 3 (Fig 1.)

VI ACCELERATOR OPERATION

1. Operation

N.Andreopoulos, A.Asthenopoulos, N.Divis, G.Prokos, E.Serveta.

During 1976 the Tandem was utilized for a total of 2440 hours. The machine time distribution is as follows.

Charged Particle Induced X-rays	171 hrs (7%)
Heavy Ion Reactions	976 hrs (40%)
Nuclear Structure Spectroscopy	659 hrs (27%)
Inelastic Scattering-	
- Gamma Ray Spectroscopy	390 hrs (16%)
Accelerator Support Group	244 hrs (10%)

Certain improvements were made concerning the transmission through the machine. At the higher terminal voltages the transmission was smaller than 50% placing strains on the tubes. Following computer runs performed at the University of Oxford, it was shown that moving the Einzel lens located in the drift tube between inflector magnet and tube entrance, close to the entrance of the tube, transmission should improve. We therefore moved the Einzel lens 90 cm from the tube entrance and have obtained transmission up to 80 % at the higher terminal potentials.

A set of limiting micrometer slits was placed after the inflector magnet for separation of different heavy ions and for limiting beam intensities. A fourth beam leg was installed to accomodate the new 30 inch scattering chamber. Most of the parts required were manufactured in our laboratory and the 30 inch scattering chamber is now operational.

2. *Instrumentation*

Inverted sputter Source

G.Vourvopoulos, O.Topikoglou, A.Asthenopoulos

Following the successful operation of the inverted sputter source at Florida State University, a decision was taken to install a similar one at the Demokritos Tandem. With the plans kindly supplied by Dr. Chapman of FSU, the source was manufactured in its whole in our laboratory. The manufacturing of the source required approximately 1000 manhours. The sputter source was installed in November 1976 with the guidance of Dr. Chapman and was successfully tested and placed in operation. We have optained 8μA of O^- and 7 μA of C^- at the low energy Faraday cup and we are currently developing other beams out of the source. The emmittance of the source is similar to that of the diode source, as indicated by the transmission through the accelerator.

We presently alternate between the diode and inverted sputter source, due to the requirement of large proton beams for an number of experiments. The switch over is performed during a scheduled maintenance period and does not require more than a few hours.

VII PERSONELL

Research Staff

Dr. G. Vourvopoulos , Director
Dr. G.Anagnostatos
Dr. P.Assimakopoulos
Dr. A.Hartas (Res.Assoc., till Sept.1976)
Dr. C.Kalfas
Dr. A.Katsanos
Dr. E.Kossionides
Dr. K.Papadopoulos (Res.Assoc., till Sept.1976)
Dr. Th.Paradellis
Dr. L. Skouras
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Graduate Students

E. Adamidis
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P.Kakanis
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B.Papaefthimiou
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N.Xiromeritis

Scientific Associates

Prof. G.Andritsopoulos (Univ. of Ioannina)
Prof. N.Gangas (University of Ioannina)
Prof. A.Panagiotou (University of Athens)
Dr. A.Hatjiantoniou (Demokritos)
Dr. C.Dedes (University of Ioannina)

Operational Staff

Accelerator Support Group

S. Valamontes (till April 1976)

N Andreopoulos

A. Asthenopoulos

N. Divis (from May 1976)

G. Prokos

H. Serveta

Electronic Group

V.Katselis, B.S,Mathematics-Electronics

A.Chionakis

A.Sokos

Computer Programmer

Mrs. K.Demakou , B.S.Mathematics

Machine Shop

O.Topikogou

Graphics

F.Trouposkiadis

Visiting Scientists

Prof. H. Mavromatis , American University of Beirut 15/10-15/12/76

Dr. G.Costa, Centre de Rescherches Nucleaires de Strasbourg 16/8 - 15/9/76

Dr.G.Doucas , University of Oxford 15/12-21/12/76

Prof.R.Fink, Georgia Institute of Technology 15/6- 15/7/76

Prof. M.Greenfield, Florida A + M University 25/6- 3/8/76

Prof. P.Hodgson, University of Oxford 5/9- 7/9/76

Prof. H. Wegner , Brookhaven National Laboratory 28/6 - 5/7/76

Prof. J.Vergados , University of Pennsylavania 1/9 - 31/12/76

VIII PUBLICATIONS

A) Papers published in 1976

1. P.A.Assimakopoulos,
Kinematics of three-body reactions.

Comp.Phys.Comm. 10 (1976) 385

2. P.A.Assimakopoulos and S.Kosionides
Anna: An interactive program for analysis of one-dimensional pulse-height spectra.

Comp. Phys. Comm. 11 (1976) 37

3. S.E.Filippakis , Y.Perdikatsis and T.Paradellis
An analysis of blue pigments from the Greek bronze age.

Stud.Conserv. 21 (1976) 143

4. L.D.Skouras
Even parity states of ^{36}S

Jour. Phys. G,2 (1976) 709

5. A.Katsanos, A.Xenoulis, A.Hadjiantoniou, and R.W.Fink
An external beam technique for proton-induced X-ray emission analysis.

Nucl. Inst. and Meth. 137 (1976) 119

6. A.C.Xenoulis , J.L.Wood, K.R.Baker, R.W. Fink, J.L.Weil, B.D.Kern K.J.Hofstetter, E.H.Spejewski, R.L.Mlekodaj, H.K. Carter, W.D.Schmidt-Ott, J.Lin, C.R.Bingham, L.L.Riedinger, E.F.Zganjar, K.S.E.Sastry, A.V.Ramayya , J.H.Hamilton and G.M.Growdy.
On Line mass separator investigation of the new isomer 2.9 sec ^{116}I

Phys. Rev. C13 (1976) 1601

7. J.H.Hamilton, R.R.Baker, C.R.Binham, E.L.Bosworth, H.K.Carter , J.D.Cole, R.W.Fink, G. Garcia Bermudez, G.W.Gowdy, K.J.Hofstetter, M.A.Igaz, A.C.Kahler, B.D.Kern, W.Laurens, B.Martin, R.L.Mlekodaj, A.V. Ramayya, L.L.Ridinzer, W.D.Schmidt-Ott, H.H.Spejewski, B.N.Sabba Rao, E.L.Robinson, K.S.Toth, F.Turner, J.L.Weil, J.L.Eood, A.Xenoulis and E.F.Zganjar.

New Isotope ^{183}Pb and the structure of ^{193}Tl; Shape coexistence in ^{188}Hg and in ^{189}Au.

Izvest Akad. Nauk.USSR,<u>40</u>(1976)1

B. *Papers accepted for publication to appear in 1977*

8. C.Dedes and L.D.Skouras

"The even parity states of ^{94}Mo"

Physics Lett. B.

9. L.D.Skouras and C.Dedes

"The Even parity states of ^{95}Tc"

Physical Rev. C

10. G.S.Anagnostatos

"Static Properties of Nuclei in the s-d shell"

Atomkernenergie

11. G.S.Anagnostatos
"Solar-System Abundances of Nuclides and Nuclear Structure".

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12. C.A.Kalfas
"Structure of ^{148}Sm studied from the decay of ^{148}Pm and ^{148m}Pm".

Jour. Phys. G.

13. A.G.Hartas, G.T.Papadopoulos, P.A.Assimakopoulos N.H.Gangas and G.Andritsopoulos
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14. G.T.Papadopoulos , A.G.Hartas, P.A.Assimakopoulos, G.Andritsopoulos and N.H.Gangas.
"Electromagnetic properties of states in ^{63}Cu through the inelastic scattering of protons."

Phys. Rev. C.

15. A.D.Panagiotou, P.Kakanis ,E.N.Gazis, E.Kossionides and N.Xeromerites
"The (^{16}O,2p) reaction on light nuclei "

Jour. Phys. G

16. T.Paradellis
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Nucl. Inst. Meth.

17. T. Paradellis

Excited states in ^{67}Ga observed in the $^{67}Zn(p,n\gamma)$ reaction

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18. A. D. Panagiotou

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Il Nuovo Cim.

IX ANNOUNCEMENTS

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   "Quadrupole moments of fpg shell nuclei"

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   1E , 29, 1976

2. S. Kossionides and V.Katselis

   "Peripheral Processors for the PDP-15/76"

   12th DECUS Europe Seminar, Munich, Germany,
   Sept. 76

3. P.Roussel, M.Bernas, B.Fabbro, F.Naulin, A.D. Panagiotou, E.Plagnol, F.Rougheon, G.Rotbard

   " Strong Orientation of the Residual Nucleus in the Reaction $^{16}O\ (^{16}O,\ ^{12}C)\ ^{20}Ne^{*}$ at 68 MeV"

   Proceedings "European Conference on Nuclear Physics with Heavy Ions" Caen, France September 1976, Pg. 38.

4. G.S.Anagnostatos, J. Yapitzakis and A.Kyritsis

   " A Geometrical High Symmetry Point Space with Quantum Mechanical Characteristics".

   Bull. Am. Phys. Soc. 21, 1313, 1976

5. A.Katsanos

   " Elemental Microanalysis by charged particle Induced x-ray emission Techniques and Applications."

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