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PROGRESS REPORT FOR HUNGARY

Institute of Nuclear Research, Debrecen

Institute of Experimental Physics
Kossuth University, Debrecen

and

Institute of Isotopes
Hungarian Academy of Sciences, Budapest

June 1989

IAEA NUCLEAR DATA SECTION, WAGRAMERSTRASSE 5, A-1400 VIENNA

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INSTITUTE OF NUCLEAR RESEARCH

DEBRECEN

APPLICATIONS OF FAST NEUTRON SOURCES BASED ON THE MGC-20 CYCLOTRON

A. Fenyvesi, T. Molnár[+], I. Mahunka

One of the projects at the MGC-20 cyclotron is the development and application of intense fast neutron sources for interdisciplinary and practical purposes. Based upon our p(18 MeV)+Be and d(10 MeV)+Be intense fast neutron sources , the following programs have been in progress in our laboratory:

a) production of carrier-free ^{24}Na isotope by the $^{27}Al(n,\alpha)^{24}Na$ reaction for investigation of water-transport in healthy and diseased oak (quercus peraea) trees for ecological and, in the case of tomato plants, for agricultural purposes

b) irradiations of grains of onions and capsicums for stimulation and mutation breeding purposes

c) irradiations of cultures of mammalian cells and tissues for basic radiobiological studies and to establish the techniques of biological dosimetry of mixed n-γ fields at our cyclotron neutron sources

d) elaboration and adaptation of methods capable of determination of fast neutron spectra and dose-rates at the irradiation positions and in the samples.
The necessary information on spectral distributions of fast neutrons above E_n=1 MeV was gained by multifoil activation and a spectrum unfolding technique.

The separate neutron and gamma dose-rates and their spatial distributions were measured mainly by the usual twin ionization chamber method. A TE-TE (tissue equivalent chamber flowed by tissue equivalent gas) and a Mg-Ar chamber were used in the biomedical investigations. A pair of CH-equivalent CH-C_2H_2 and Mg-Ar chambers recommended by the IAEA was used for agrobiological irradiations. Profiles and depth dose distributions of collimated beams were measured in water phantom also by solid state nuclear track detectors (SSNTD-s).

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EXCITATION FUNCTIONS FOR PROTON AND DEUTERON INDUCED NUCLEAR REACTIONS ON $^{66,67,68}Zn$

F. Szelecsényi, F. Tárkányi, Z. Kovács, L. Andó, S. Sudár[+]

For investigation of the production possibilities of medically important ^{67}Ga radioisotope with the Debrecen MGC compact cyclotron, (p,xn) and (d,xn) reaction cross sections were studied on enriched $^{66,67,68}Zn$.

Excitations functions have been measured with stacked-foil technique for $^{66}Zn(p,n)^{66}Ga$, $^{67}Zn(p,n)^{67}Ga$, $^{67}Zn(p,2n)^{66}Ga$, $^{68}Zn(p,n)^{68}Ga$ and $^{68}Zn(p,2n)^{67}Ga$ reactions up to 18 MeV protons and for $^{66}Zn(d,n)^{67}Ga$, $^{67}Zn(d,n)^{68}Ga$ $^{67}Zn(d,2n)^{67}Ga$ and $^{68}Zn(d,2n)^{68}Ga$ reactions up to 10 MeV deuterons.

The obtained results have been compared with previous measurements and with the predictions of the statistical/precompound reaction models. Our data in general are in good agreement with the existing previous results. In several cases, however the position of maximum of excitation function lies lower than it was reported. The calculated absolute cross sections are also in good agreement with our measured data.

It was found that in our available low energy range the $^{67}Zn(p,n)^{67}Ga$ and the $^{68}Zn(p,2n)^{67}Ga$ reactions are the major process of interest. The results for the $^{67}Zn(p,n)^{67}Ga$, and the $^{68}Zn(p,2n)^{67}Ga$ reactions are given in Fig. 1 and 2 in comparison with earlier reported experimental data (1).

Reference

(1) F.E. Little, M.C. Lagunas-Solar, Int. J. Appl. Radiat. Isot. 34 (1983) 34.

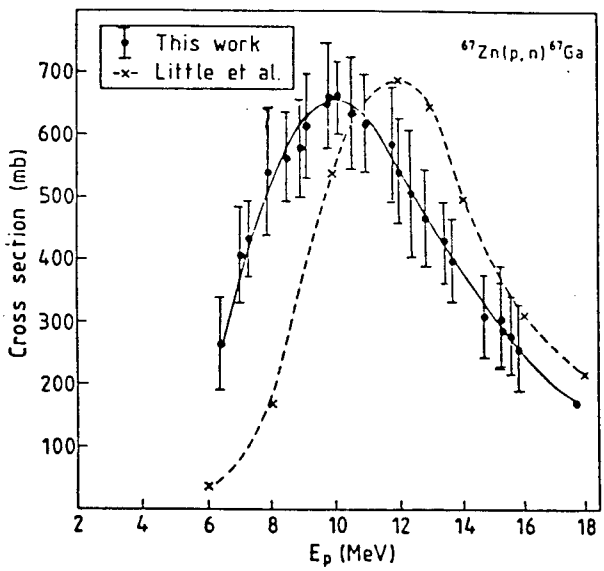

Fig. 1. Excitation functions of $^{67}Zn(p,n)^{67}Ga$ reaction

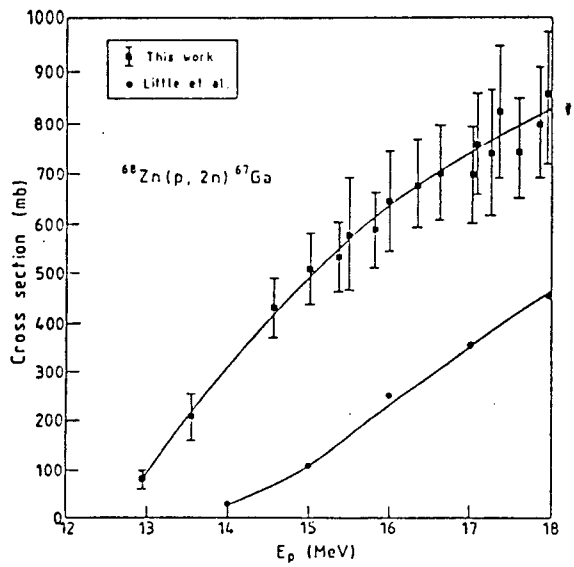

Fig. 2. Excitation functions of $^{68}Zn(p,2n)^{67}Ga$ reaction

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RADIOISOTOPE PRODUCTION AT THE MGC CYCLOTRON

I. Mahunka, F. Szelecsényi, L. Andó

One of the main tasks of the Debrecen cyclotron is the production of radioisotopes for medical application. The MGC-20 machine is capable for producing the most important radioisotopes used in nuclear medicine [1].

During the last year we started the routine production of ^{67}Ga, ^{111}In and ^{123}I non-positron emitter isotopes. The irradiatons took place at the vertical beam-line of the cyclotron [2] [3]. The irradiated targets were elaborated in our radiochemical laboratory to get intermediers and the labelling procedures were carried out in the Isotope Institute, Budapest[4]. The radiopharmaceuticals were distributed for medical use in Hungary.

Table 1 summarises some production parameters of radioactive isotopes for off-site use in 1988. The greatest demand was for ^{67}Ga which was made nightly and which is used in the detection of inflammatory diseases and in the practice of Oncology for detecting the presence of malignancy [5] [6].

Table 1. Production of radioisotopes for off-site use in 1988

Isotope	Target material	Reaction	Bombarding energy (MeV)	Target thickness (g/cm^2)	Yield ($mCi/\mu Ah$)
^{67}Ga	$^{67}Zn(91\%)$	$^{67}Zn(p,n)^{67}Ga$	14	0,25	1,3
^{111}In	$^{111}Cd(95\%)$	$^{111}Cd(p,n)^{111}In$	15	0,35	1,5
^{123}I	$^{123}Te(71\%)$	$^{123}Te(p,n)^{123}I$	15	0,25	2,0

To meet the future demand of our medical partners, several new radioisotop production method were (and are) elaborated in the cyclotron laboratory during this period.

We started the preliminary experiments to get ^{201}Tl using mercury gas target and two short-lived positron emitter radioisotopes (^{11}C, ^{18}F). The experiments for producing the PET isotopes are carried out in collaboration with the Biomedical Cyclotron Lab., Med.Univ.School of Debrecen and the Central Institute of Nucl.Res.Rossendorf, GDR.

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EXCITATION FUNCTIONS FOR PROTON AND DEUTERON INDUCED NUCLEAR REACTIONS ON $^{66,67,68}Zn$

F. Szelecsényi, F. Tárkányi, Z. Kovács, L. Andó, S. Sudár[+]

For investigation of the production possibilities of medically important ^{67}Ga radioisotope with the Debrecen MGC compact cyclotron, (p,xn) and (d,xn) reaction cross sections were studied on enriched $^{66,67,68}Zn$ [1], [2].

Excitation functions have been measured with stacked-foil technique for $^{66}Zn(p,n)^{66}Ga$, $^{67}Zn(p,n)^{67}Ga$, $^{67}Zn(p,2n)^{66}Ga$, $^{68}Zn(p,n)^{68}Ga$ and $^{68}Zn(p,2n)^{67}Ga$ reactions up to 18 MeV protons and for $^{66}Zn(d,n)^{67}Ga$, $^{67}Zn(d,n)^{68}Ga$ $^{67}Zn(d,2n)^{67}Ga$ and $^{68}Zn(d,2n)^{68}Ga$ reactions up to 10 MeV deuterons.

The obtained results have been compared with previous measurements and with the predictions of the statistical/precompound reaction models. Our data in general are in good agreement with the existing previous results. In several cases, however, the position of maximum of excitation function lies lower than it was reported. The calculated absolute cross sections are also in good agreement with our measured data.

It was found that in our available low energy range the $^{67}Zn(p,n)^{67}Ga$ and the $^{68}Zn(p,2n)^{67}Ga$ reactions are the major process of interest. The results for the $^{67}Zn(p,n)^{67}Ga$, $^{67}Zn(p,2n)^{66}Ga$ and the $^{68}Zn(p,2n)^{67}Ga$ reactions are given in Fig. 1 and 2 in comparison with earlier reported experimental data [3].

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IN-BEAM SPECTROSCOPY OF ^{106}In

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J. Kumpulainen** and R. Julin**

Gamma-ray and internal conversion electron singles spectra of the ^{106}Cd(p,nγ)^{106}In reaction were measured with Ge(HP), Ge(Li), LEPS and combined intermediate-image magnetic plus Si(Li), as well as superconducting magnetic lens plus Si(Li)spectrometers at various bombarding proton energies between 8.0 and 9.0 MeV. Gamma-gamma coincidence and angular distribution of gamma rays were also measured. More than 120 (among them 95 new) gamma transitions have been assigned to ^{106}In. From the conversion electron measurements internal conversion coefficients of 18 gamma-transitions have been determined for the first time.

A more complete level scheme of ^{106}In has been constructed, which contains about 40 levels below 1600 keV excitation energy. On the basis of the internal conversion coefficients of transitions, Hauser-Feshbach analysis of (p,n) reaction cross sections, gamma-ray angular distributions and other arguments spin and parity assignments to several levels have been made. Gamma branching ratios have also been deduced. Energies of sereval ^{106}In proton-neutron multiplets were calculated on the basis of the parabolic rule derived from the cluster-vibration model. Interacting boson-fermion-fermion / odd-odd truncated quadrupole phonon model calculations are in progress.

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NUCLEAR STRUCTURE OF ^{108}In

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The structure of ^{108}In has been studied with in-beam γ- and e^--spectroscopic methods [1]. A more complete level scheme of ^{108}In has been deduced which contains 54 levels below 1630 keV excitation energy (including 42 new ones). On the basis of the internal conversion coefficients of transitions, Hauser--Feshbach analysis of (p,n) reaction cross sections, γ-ray angular distributions and other arguments spin and parity assignments were made to 24 excited ^{108}In levels. Lifetime measurements were performed by delayed coincidence method. The energies of several ^{108}In proton-neutron multiplets were calculated on the basis of the parabolic rule derived from the quasi-cluster-vibration model (QCVM). In order to facilitate the configuration assignments the electromagnetic decay properties of the nuclear levels were also analysed. Members of different proton-neutron multiplets have been identified.

An interesting result is that the energy splitting of the $\pi\tilde{g}_{9/2}\nu\tilde{g}_{7/2}$ multiplet is much larger than expected, and the "parabola" is far not perfect. In order to get a better description for the nuclear structure interacting boson-fermion-fermion/ odd-odd truncated quadrupole phonon model calculations were also performed. The particle - vibration exchange interaction was included also in the calculations, and a reasonable description of the level energy spectrum and electromagnetic properties of ^{108}In was obtained. The inclusion of the particle-vibration exchange interaction resulted in a W tipe energy splitting of the $\pi\tilde{g}_{9/2}\nu\tilde{g}_{7/2}$ multiplet as a function of J(J+1), where J is the spin of the nuclear state.

This work was supported partly by the National Scienctific Research Foundation /OTKA/.

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[+]University of Jyväskylä, Department of Physics, Finland

NUCLEAR STRUCTURE OF ^{110}In

A. Krasznahorkay, Zs. Dombrádi, J. Tímár, Z. Gácsi, T. Kibédi
A. Passoja*, R. Julin*, J. Kumpulainen*, S. Brant** and V. Paar**

In our earlier work on ^{108}In [1] we observed some indications on deviation of the pattern of the $\pi(g_{9/2}^{-1})\nu(\tilde{g}_{7/2})$ multiplet from the one predicted by the parabolic rule. To obtain more information on this interesting multiplet splitting and to test the validity of predictions for the ^{110}In nucleus, where a similar deviation is expected, the nucleus ^{110}In has been studied via the reactions ^{107}Ag(α,nγ)^{110}In and ^{110}Cd(p,nγ)^{110}In.

γ-ray and $\gamma\gamma$-coincidence measurements have been performed. Energies and relative intensities of 137 transitions in ^{110}In have been determined. A more complete level scheme, containing 53 levels, has been deduced. The energy separation of the $J^{\pi}=7_1^+$ ($T_{1/2}$=4.9 h) ground state and the $J^{\pi}=2_1^+$ ($T_{1/2}$=69.1 min) isomer has been deduced, $E(2_1^+)$=62.08±0.04 keV. The electron spectrum of the reaction was measured with a superconducting magnetic spectrometer. Internal conversion coefficients of 30 transitions have been determined. Spins and parities have been deduced on the basis of the multipolarity of γ-transitions, and other arguments. Lifetime measurements were performed by delayed coincidence and DSA methods.

The energies and electromagnetic properties of the ^{110}In states were calculated using the interacting boson-fermion-fermion/odd-odd truncated quadrupole phonon model. Several approximate proton-neutron multiplet states were identified, the W-like energy splitting of the $\pi(g_{9/2}^{-1})\nu(\tilde{g}_{7/2})$ multiplet was reproduced, and the importance of the exchange interaction in spherical odd-odd nuclei was pointed out.

Reference: [1] A. Kasznahorkay et al., Nucl. Phis. **A**, in press

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BRANCHING RATIOS AND MONOPOLE STRENGTHS IN ^{116}Sn

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This contribution eliminates a discrepancy of a factor of three apparent in the data[1] on the branching ratios of the first 5^- level at 2366 keV excitation energy in ^{116}Sn (see Fig.1) and points out strong mixing between its low lying 0^+ states of different radii.

Gamma-ray and internal conversion electron spectra were recorded with Ge(Li) and superconducting magnetic lens plus Si(Li) spectrometers in (^{113}In + 14.5 MeV alpha) and (^{116}Sn + 7.2 MeV proton) reactions.

The branching ratio of gamma-rays from the 5^- level:

$$R_\gamma = I_\gamma(100keV)/I_\gamma(1072keV) = 100(4)/96(6)$$

and, combined with total internal conversion coefficients[1], the transition branching ratio:

$$R_{tr} = I_{tr}(100keV)/I_{tr}(1072keV) = 100(4)/37(3)$$

are obtained in good agreement with previous results. The discrepancy mentioned above is simply due to an inadvertent adoption of transition intensities as gamma intensities in the compilation[1], and is eliminated by a clear distinction between them.

Internal conversion electron branching ratios:

$$I_e(0_2^+ \to 0_1^+)/I_e(0_2^+ \to 2_1^+) = 0.33(5),$$

$$I_e(0_3^+ \to 0_2^+)/I_e(0_3^+ \to 2_1^+) > 4.9$$

have been determined. Using the absolute B(E2) values of *Ref.*2, electric monopole strength values of

$$\rho^2(0_2^+ \to 0_1^+) = 3.8(6) \times 10^{-3} \ (cf.,\ 4.3(13) \times 10^{-3},\ Ref.2)$$

$$\rho^2(0_3^+ \to 0_2^+) > 28.3 \times 10^{-3} \ (cf.,\ 103(21) \times 10^{-3},\ Ref.2)$$

are deduced. Such a large value of $\rho^2(0_3^+ \to 0_2^+)$ indicates[3] strong mixing of the two 0^+ states of different radii and possibly also a mixture between states of different shapes. The 0_2^+ level at 1757 keV excitation energy corresponds to the intruder deformed state and the 0_3^+ level at 2027 keV corresponds to the spherical one, as the unperturbed configurations.

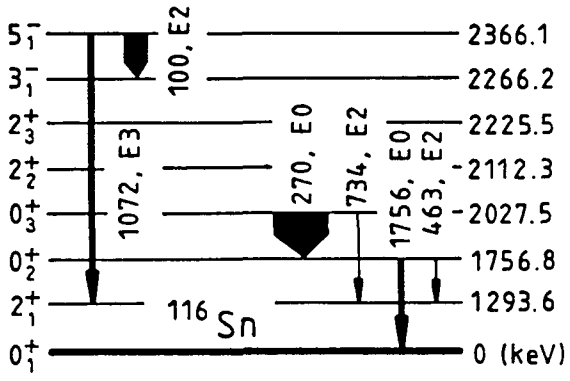

Fig.1. Low-lying levels of ^{116}Sn. The line-thickness represents relative transition intensity at the 5^- level and relative values of the monopole strengths for the E0 transitions.

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PROTON ELASTIC SCATTERING ON ^{114,122,124}Sn ISOTOPES NEAR THE COULOMB BARRIER

M. Józsa, Z. Máté, Z. Veress*, T. Vertse and L. Zolnai

In a previous paper [1] it was shown that the energy dependence of the real part of the volume integral of the proton optical potential has anomalous behaviour near the Coulomb barrier for the p+^{116}Sn and p+^{120}Sn systems. Similar result for the p+^{124}Sn system has been published in ref. [2].

The aim of the recent measurements for p+^{114}Sn, p+^{122}Sn and p+^{124}Sn systems was to extend the investigation along the Z=50 isotopes. The measurements were done using the proton beam of the MGC cyclotron of the Atomki at energies different from those of the isobar analogue resonances. The measured angular distributions are being analysed in the frame of the optical model. An example is shown in fig. 1.

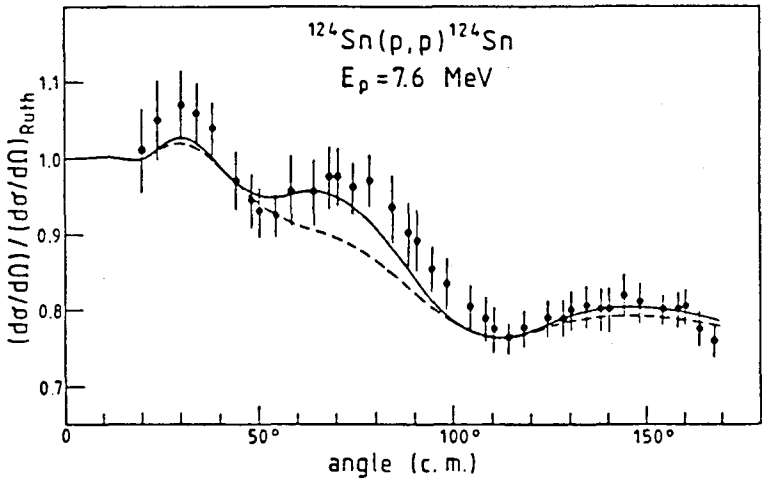

Fig. 1. Angular distribution of elastically scattered protons measured at the MGC cyclotron of Atomki. The full and broken lines are the optical model fits with Perey and Becchetti-Greenlees geometry, respectively.

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"MICROP" - A CODE TO CALCULATE MACROSCOPIC JLM POTENTIALS

L. Zolnai

In ref. [1] Jeukenne, Lejeune and Mahaux presented a parametric expression for a theoretical microscopic optical potential (OMP) derived from nuclear matter calculations. The basic assumptions of the calculations were (1) the Reid's hard core interaction, (2) the Brueckner-Hartree-Fock approximation and (3) the improved local density approximation. However, this potential was limited to proton or neutron energies from 10 to 160 MeV. In ref. [2] Lejeune extended this potential below 10 MeV. Such energies are involved in (1) the study of nuclear processes in astrophysics and (2) in practical reactor calculations.

For practical cases the potentials above have to be folded with the mass density distribution of the target nuclei. For this purpose a code (MICROP) has been developed in the institute in FORTRAN-IV which makes it possible to calculate the different characteristics of the macroscopic potentials (rms radii, real and imaginary potential depths as well as the volume integrals). An illustrative example is shown in fig. 1.

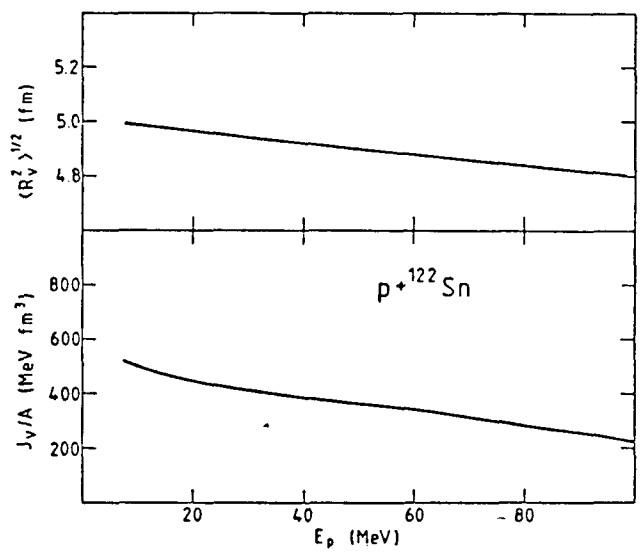

Fig.1. The full curves on the upper and lower parts represent the calculated values for the rms radius and the volume integral per nucleon of the real part of the proton OMP of ^{122}Sn.

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IDENTIFICATION OF COLLECTIVE STRUCTURES IN ^{127}Ce

B.M. Nyakó°, J. Gizon*, D. Barneoud*, A. Gizon*, W. Klamra+
F.A. Beck∇ and J.C. Merdinger∇

The neutron-defficient cerium isotopes have been the subject of studies concerning the γ-softness of nuclei near A≈130 [1,2]. Recently more attention has been paid to A≈125 ceriums [3] but no data was available for the high spin states of ^{127}Ce.

Excited states in this nucleus were populated via the ^{93}Nb(^{37}Cl,3n) nuclear reaction. Experimental details are given in our Report for ^{126}La in this booklet. Two rotational structures have been identified in ^{127}Ce as shown in fig.1. Their assignment to this nucleus is based on a recoil-γ coincidence experiment [4] and on γ-(Ce X-ray) coincidences. The tentative spin and parity of the states were derived from level energy systematics of neighbouring odd-neutron Ce isotopes: The negative parity band shows a signature splitting comparable to those of the $h_{11/2}$ neutron hole band in ^{125,129}Ce [1-3], the positive parity band shows no splitting, similarly to the $g_{7/2}$ neutron hole band in these nuclei. A backbending starts to develop in both the positive and negative parity bands as seen from additional transitions on top of those indicated in fig.1. The ordering of these transitions was difficult due to lack of statistics, but it seems obvious that these backbendings are caused by the alignment of $h_{11/2}$ protons. The aim of further works in progress is to extend the observed bands to higher spin.

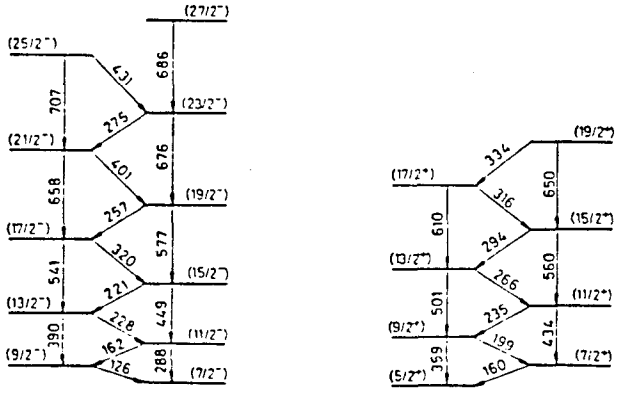

Figure 1. Proposed decay scheme of ^{127}Ce.

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SEARCH FOR SUPERDEFORMATION IN ^{129}La

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The first observation of superdeformed (SD) nuclear shape with a major-to-minor axis ratio of 2:1 at high spins [1] was followed by the identification of several A≈130 SD nuclei [2] with an axis ratio of 3:2. Calculations made by Chasman [3] using the Strutinsky method show that the observation of 2:1 SD bands in A≈150 nuclei can be well accounted for by the appearance of a deep "valley" in the well-depth of the SD minima calculated as a function of Z and N for spin I=50. The observed cases for 3:2 superdeformation, however, do not correspond to the region predicted by a shallower valley along Z≈57 where nuclei are difficult or impossible to produce in heavy ion induced reactions. The nucleus ^{129}La is near the end of this second valley, therefore it seemed to be a good candidate to search for superdeformation in it.

High spin states of ^{129}La were excited via the reaction ^{100}Mo+^{34}S at 165MeV bombarding energy. Coincidence γ-γ events were taken with the "Chateau de Cristal" multidetector system at CRN, Strasbourg. Data were analysed using the γ-energy correlation method. Perpendicular cuts to the equal energy diagonal in the E_γ-E_γ matrix show the probable exsistence of a rotational structure for which the dynamic moment of inertia decreases from $\mathcal{J}^{(2)}\approx$ 50 $\hbar^2$/MeV to $\mathcal{J}^{(2)}\approx$ 35 $\hbar^2$/MeV in the E_γ=1100-1600 keV interval with increasing energy. This could correspond to a highly deformed structure, but no discrete band has been identified yet. During the course of this work Nolan et al [4] discovered a superdeformed band in ^{130}La. This band, however, was not seen in our data. It should also be noted, that the effect of other open reaction channels has to be checked as some of those could lead to SD ^{131,132}Ce [4], and this is the subject of further data analysis.

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Microelemental Investigation of Different Types of Glasses by Using Cyclotron Beams

*F. Ditrói, S. Takács, I. Mahunka, Z. Gémesi**

A great problem of the glass production is the large variety of types of structural disorders. These disorders can cause the unexpected break of the glass product, and some types of them are visible and are not aesthetic. The aim of this work was to determine the elemental constitution of different types of structural disorders in different sorts of glasses, and the normal (good) quality part of the glass samples. From the comparison of the elemental constitution a conclusion could be made for the possible cause of disorder. More than 10 samples from different Hungarian glass factories were investigated with different nuclear analytical methods (CPAA, NAA) and the causes of the different types of disorders were concluded [1]. As an example the table shows the disorder/normal concentration ratio in two samples from the same glass-factory, which contain stone-like closure. The large amount of Zr in the vicinity of the disorder comes from the furnace wall.

elements	sample No. 2 disorder/normal	sample No. 7 disorder/normal
Na	1.12	0.78
Al	1.31	0.73
Ca	1.02	0.69
Fe	1.13	0.59
Zr	112.80	77.40

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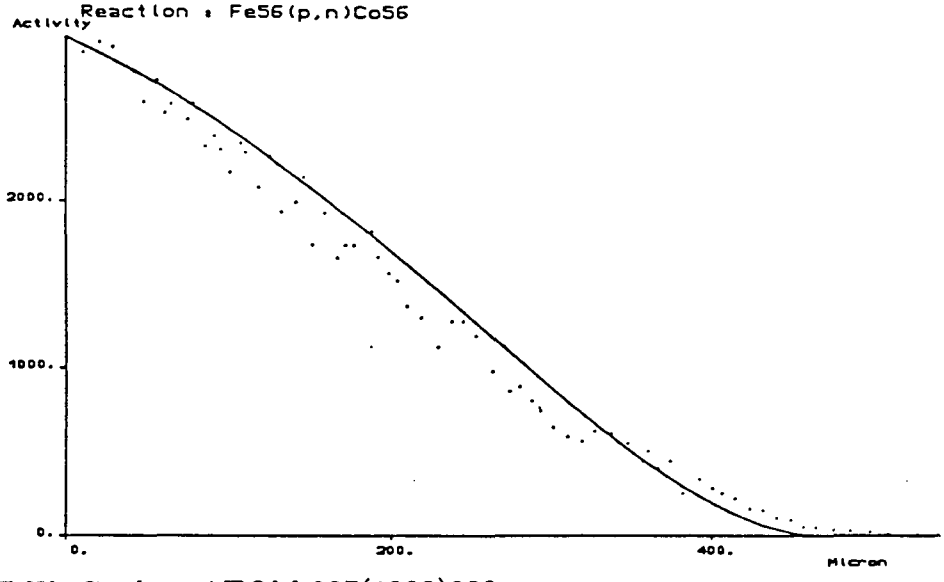
Determination of Wear by Thin Layer Activation in Iron

S. Takács, F. Ditrói, I. Mahunka

Thin Layer Activation (TLA) method is one of the most powerful possibilities to trace the wear, corrosion or erosion of materials. A common feature of these measurements is the doping of thin surface layers with trace quantities of radioactive species. From the change of the activity of the sample the material loss of the surface can be determined. The TLA has a great importance in areas such as steel-industry, railways, car, oil and electricity generating [1]. Using TLA method for wear, corrosion and erosion study one has to know the produced activity distribution under the surface. To study this phenomenon we made a set of experiments on steel material. The samples were irradiated with different particles accelerated by our MGC-20 cyclotron at different energies. Then the activated surface of the sample was polished away step-by-step, while the thickness of the remained layers and the change of the activity were measured in order to determine the activity-depth relation. The Figure shows the result coming from Ep=15.7 MeV proton irradiation (dots) the solid curve shows the result of the theoretical calculation.

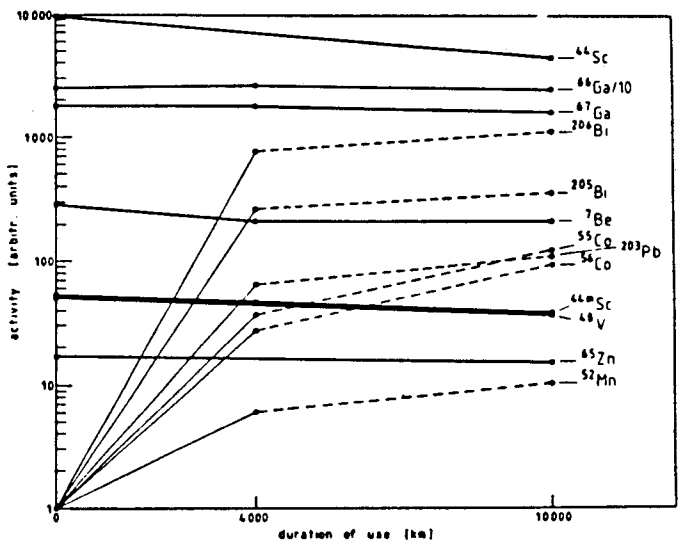


[1.] T.W. Conlon, ATOM 287(1980)233

Investigation of the micro-elemental composition of motor-oil after different duration of use

*I. Mahunka, F. Ditrói, S. Takács, S. Seif El-Nasr**

Normal motor-oil was investigated by CPAA method on external proton beam. The bombarding energy was 18 MeV. The oil samples were taken from the oil carter of a car after different duration of use [1]. One of the samples was unused oil. The beam was extracted to the air through a 11 μm thick Duratherm-type foil. The oil samples were filled into an aluminium cup and were covered by 13 μm thick aluminium foil to avoid evaporation. The change of the relative concentration of the trace elements is shown in the Figure.



To avoid contaminations from the container, the irradiations were repeated using plastic test tubes. The elements found in the samples were sorted according to their possible origins (engine-wall, piston-ring, factory-added, air pollution). This method is capable for testing the wear of engine parts and for comparing the different types of lubricants also.

[1.] F. Ditrói, I. Mahunka, S. Takács, S. Seif El-Nasr
to be published in J. Radioanal. Nucl. Chem.

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Determination of Bulk Oxygen Concentration in Aluminium Made by Powder Metallurgy

S. Takács, F. Ditrói

The recent developments in powder metallurgy require the quality control of its products. Samples from aluminium industry were measured by CPAA method. The aim of the investigation was to determine the thickness of the surface oxide-layer of internal aluminium granules. These granules were supposed to be spheres with an average diameter of 50 μm. The samples were irradiated by $^3He^{++}$ beams at 13 MeV particle energy, and the $^{16}O(^3He,p)^{18}F$ and $^{16}O(^3He,n)^{18}Ne \longrightarrow {}^{18}F$ reactions were used for oxygen determination [1]. The 511 keV annihilation radiation of the ^{18}F isotope was measured by Ge(Li) detector. The oxide-layer thickness on the surface of internal granules was determined by model calculation [2]. The calculated average oxide-layer thickness on the surface of internal granules was 8.5 ± 3nm. By using this method the quality of the products of powder metallurgy can be improved. It is also possible to use this method in the case of other metals [3] and developing ceramics [4].

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Laboratory for Materials Science and Application

I. Mahunka, I. Dombi, S. Takács, F. Ditrói

The demands of high technology makes it necessary to use nuclear methods in different fields of materials science. Taking into consideration the requirements for the application of nuclear analytical methods and thin layer activation technic a small laboratory has been established, connected to the cyclotron laboratory. The new laboratory consists of two parts.

a., sample preparation and handling room. Equipments (chemical box, laminary box, lead shielded manipulation table,...) and instruments (vacuum evaporator, metal microscope, thickness and hardness measuring instrument, ultrasonic cleaner, polishing machine,...) placed here could be used for the chemical and mechanical treatment of samples before and after the irradiation at the cyclotron beams.

b., low background measuring room. Semiconductor (HpGe, Ge(Li)) and scintillation detectors have been placed here for single gamma and gamma-gamma coincidence spectra measurements. To decrease the background a lead-cadmium-copper shielding could be used at the detectors. The electronic modules of the detector systems are connected to a Canberra S35-Plus portable multichannel analyzer which has connection to a minicomputer [1]. For off-site measurement we have a portable and computer controlled gamma-spectrometer too.

The arrangement and instrumentation of the laboratory give good possibilities to continue our investigations in the field of trace element analysis of high purity materials [2,3] and to use the thin layer activation technic in the areas of wear, corrosion and erosion [4]. The establishment of this laboratory was partially supported by the National Technical Development Committee (OMFB).

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[3.] F. Ditrói, I. Mahunka, S. Takács, S. Seif El-Nasr to be published in J. Radioanal. Nucl. Chem.

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DEVELOPMENT OF A PERSONNEL NEUTRON DOSIMETER

L. Medveczky

The neutron sensitivity of a dosimeter consisting of fission foils as radiator-converters and solid state nuclear track detector was studied [1]. The radiator-converters used in pairs were the following alloys: a.) Th-232 (99.5%)+ U-nat (0.5%) made by ÚJP (Zbraslav, ČSSR) and b.) Al+U made by Nukem GmbH (Hanau, FRG). This type of dosimeter was irradiated in free air with Am-Be and Pu-Be neutron sources and also with 14 MeV energy neutrons. The dosimeter was exposed also to moderated fission spectrum on the surface of a phantom. The sensitivity data of this dosimeter are given in Table I.

Table I.

Neutron source	Sensitivity of dosimeter μSv track/cm^2	
	0.5 eV - 10 MeV energy range of neutrons	1.4 - 10 MeV
reactor	832$\pm$ 95	218$\pm$ 25
Am-Be	55.2$\pm$5	14.4$\pm$1.2
Pu-Be	37.5$\pm$4	9.9$\pm$1
14 MeV	72 $\pm$16	23.8$\pm$3

The dosimeter is used as an emergency dosimeter as well as an area dosimeter [2].

For the purpose of obtaining information about the registering- limit of this dosimeter, of thermoluminescence dosimeters and also a dosimeter consisting of allyl diglycolcarbonate (Cr-39) track detector with a polyethylene radiator, a comparison was began exposing simultaneously [3] these dosimeters to mixed neutron-gamma field at the MGC type cyclotron in the ATOMKI.

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RADIOCHEMICAL SEPARATION OF CYCLOTRON ISOTOPES FOR INTERMEDIER PRODUCTION

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A 20 MeV MGC-type cyclotron was put into operation 3 years ago in Debrecen. A series of experiments have been carried out for introduction of home-produced radiopharmaceuticals into the Hungarian medical practice.

Production of $^{67}GaCl_3$ from ^{67}Zn

All the irradiations were carried out on the vertical beam-line. 300 mg/cm^2 thick enriched ^{67}Zn target was prepared by electrodeposition on a Ni plated Cu backing and compressed with 750 MPa to resist high current (up to 50 μA) irradiaton.

The $^{67}GaCl_3$ was separated from ^{67}Zn by using cation exchange. The ^{67}Zn was dissolved in cc. HCl and flown through a DOWEX 50 WX 2 resin. The adsorbed radiogallium was eluated with 4M HCl. 90% of radiogallium was collected in the eluate. This solution was analysed for traces of Fe, Zn, Cu, Ni and found to be pure for labelling for human and biological application. The ^{67}Ga-citrate radiopharmacon has been produced and used in patients routinely for several months.

Production of Na ^{123}I from $^{123}TeO_2$

400 mg/cm^2 thick target was prepared by melting $^{123}TeO_2$ onto a platinum plate. The separation of radioiodine was carried out by dry distillation in a directly heated quartz oven. The target was gradually heated up to 850 °C to melt the $^{123}TeO_2$ and after 30 seconds was allowed to cool down. The evaporated radioiodine was carried by air stream into a trap containing 0,002M NaOH solution. The separation yield was over 85% and the loss of enriched target material was less than 3 mg/run.

The chemical form of radioiodine was 95% I which is suitable for radiopharmaceutical requirements. The product is used with the Iodobell kits as o-Iodo-Hippuric Acid for kidney imaging and ^{123}I Heptadecanoic Acid for myocardial imaging.

Production of $^{111}InCl_3$ from ^{111}Cd

350 mg/cm^2 thick target was prepared by electrodeposition on a Ni plated Cu backing and compressed with 50 MPa to get better thermal conductivity. After irradiation the ^{111}Cd was dissolved from the backing in 6M HBr. From this solution the In isotopes were extracted by isopropyl-ether. The organic phase was washed three times by 6M HBr saturated with isopropyl-ether for removing the traces of ^{111}Cd and interfering radioisotopes.

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ANALYSIS OF /n,t/ EXCITATION FUNCTIONS

In a joint programme of Obninsk, Dubna /USSR/ and Debrecen, the $^{27}Al/n,t/^{25}Mg$ excitation function has been analysed [1] on the basis of compiled experimental data [2] and a new measurement [3]. The roles of the concurrent reaction channels are discussed. It is concluded that/in the emission of clusters/ the statistical mechanism determines chiefly the $^{27}Al/n,t/^{25}Mg$ and $^{27}Al/n,\alpha/^{24}Na$ cross-sections up to about 18 MeV. For a quantitatively correct description of the observed cross-sections, those level densities are essentially needed which are consistent with the width fluctuation analysis for the decays of highly excited nuclei together with spectroscopical data for the low-laying levels. Such level densities are provided, e.g., by the superfluid model of heated nuclei due to Grudzevich, Ignatyuk and Plyaskin.

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ACTIVATION CROSS-SECTIONS OF HIGH T_c SUPERCONDUCTING ELEMENTS

The measurement of some reaction cross-sections related to the nuclear heating of high T_c superconductors are in progress[1] in a joint programme of Debrecen and Geesthacht. Superconducting $Y_1Ba_2Cu_3O_{7\pm d}$ and $Tl_2Ca_1Ba_2O_8$ ceramics were irradiated with 14.8 MeV neutrons at the KORONA generator of GKSS Forschungszentrum Geesthacht[2]. The total neutron fluence determined by the $^{93}Nb(n,2n)^{92m}Nb$ reaction was in the order of $10^{14}n/cm^2$. The neutron energy has been determined by the $^{89}Zr/^{92m}Nb$ activity--ratio method. Determination of activation cross-sections are in progress for the following reactions:

$^{63}Cu(n,\alpha)^{60}Co$, $^{107}Ag(n,2n)^{106m}Ag$, $^{203}Tl(n,2n)^{202}Tl$, $^{89}Y(n,2n)^{88}Y$, $^{136}Ba(n,p)^{136}Cs$, $^{137}Ba(n,p)^{137}Cs$.

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MEASUREMENT OF ^{115}In+n REACTION CROSS SECTIONS AT ARROUND 14 MeV

A systematic investigation was carried out on ^{115}In isotope to determine the contribution of different reactions to the total non-elastic cross section in the 13.4 and 14.8 MeV range[1]. It was found that the experimental data available for σ_{NE} at 14 MeV as a function of mass number can be well approximated by the following expression $\lg\sigma_{NE}(b) = -0.68283 + 0.47011 \lg A$, from which we have a value of σ_{NE}=1930 mb for ^{115}In. All the component cross sections of σ_{NE} were measured with exception of the $\sigma(n,n')^g$. In the knowledge of σ_{NE} the energy dependence of $\sigma(n,n')^g$ cound be deduced,

i.e. $\sigma_{NE} - [\sigma(n,2n)^{g+m} + \sigma(n,n')^m + \sigma(n,ch) + \sigma(n,\gamma)] = \sigma(n,n')^g$. The isomeric cross section ratios both for (n,2n) and (n,n') processes were also determined in the given energy range. The present experiment proves the dependence of $\sigma^m/(\sigma^g+\sigma^m)$ ratio on the spin value (I_m) of the isomeric state in (n,2n) reaction[2]. Excitation functions of (n,2n) and (n,n') reactions were also calculated by using a modified STAPRE code.

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AN IMPROVED VARIANT OF THE JUMPING SPARK COUNTER

A Jumping Spark Counter /JSC/ applicable for the evaluation of angular distributions has been developed. It is combined with a personal computer to switch the voltage between electrodes automatically. It makes possible to count tracks at ten angles without changing the aluminized and the etched foils. The average number of tracks was calculated at each angles and a curve was fitted to the measured points [1]. Fission fragment angular distributions for fast neutrons from ^{235}U, ^{238}U and ^{237}Np were determined by the use of the JSC [2] as well as it was applied also in studying photofission of ^{232}Th, ^{234}U, ^{236}U and ^{238}U [3]. Further developments for the JSC are in progress.

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INSTITUTE OF ISOTOPES

HUNGARIAN ACADEMY OF SCIENCES

BUDAPEST

Nuclear Structure Studies I.

Institute of Isotopes

In the cooperation between the Institute of Isotopes of the Hungarian Academy of Sciences and the University of Kentucky (supported by NSF), the nuclear structure of various kinds of stable nuclei are studied by the (n,n'gamma) reaction. The target is usually 0.1 mol of enriched material, and the neutron beam is generated by the Van de Graaff accelerator of the Univ. of Kentucky. The measured values are gamma-ray angular distributions, excitation functions, and Doppler-shifts. The deduced values are gamma-ray and nuclear level energies, gamma-ray intensities, nuclear level spins and cross sections, branching ratios, multipole mixing ratios, and nuclear level lifetimes.

The following nuclei are under research or under publication:

Zr-96, Ba-134, Ba-135, Zr-90, Sm-144, Nd-142.

The Zr-96 is almost fully published, except for the entire set of inelastic neutron scattering cross section which is going to be published in a few months. The other nuclei are only partly published and still under active research.

Nuclear Structure Studies II.

Institute of Isotopes

Within the framework of a collaboration between the Institute of Isotopes of the Hungarian Academy of Sciences, Budapest, and Zentralinstitut für Kernforschung Rossendorf/Dresden (GDR) we investigate the structure of the semi-magic nuclei with neutron number N=82. As a part of this program presently we study the structure of the ^{139}La nucleus by means of (n,n'γ) reaction in Budapest and ^{136}Xe(^{7}Li,4n)^{139}La reaction in Rossendorf. We measure singles γ-spectra, γ-γ coincidences,γ-ray angular distributions, lifetimes, e.t.c. From the γ-spectroscopical data a detailed level scheme is obtained. The experimental data are compared with the results of the shell model calculations.

The structure of the N=80 two neutron hole nuclei have been studied in the collaboration of Institute of Isotopes and Institut für Kernphysik, Universität zu Köln. The ^{136}Ba nucleus have been studied in Budapest by means of (n,n'γ) reaction, and the ^{138}Ce nucleus have been investigated in Köln. In order to understand the structure of these nuclei theoretical calculations using the so called ALAGA model have been performed.