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INTERNATIONAL NUCLEAR DATA COMMITTEE

Progress Report to the INDC
from the Republic of South Africa
1977

Compiled by D. Reitmann

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IAEA NUCLEAR DATA SECTION, KÄRNTNER RING 11, A-1010 VIENNA

REPUBLIC OF SOUTH AFRICA

PROGRESS REPORT TO THE INDC

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1. SOUTHERN UNIVERSITIES NUCLEAR INSTITUTE, FAURE, CAPE PROVINCE

The major research facility at SUNI is a 5,5 MV pulsed Van de Graaff accelerator which is also used by staff members and students from the universities of Cape Town and Stellenbosch. The research program covered a wide variety of topics, the most relevant of which are listed below:

1.1 Neutron reaction studies

1.1.1 The level structure of ^{115}In

- I.J. van Heerden, W.R. McMurray

Coulomb excitation, transfer reaction and decay studies[1] are the main sources of our knowledge of the levels of ^{115}In. Apart from those levels which have been interpreted in terms of coupling of the $1g_{9/2}$, $2p_{1/2}$ and $2p_{3/2}$ particle-hole states to vibrations of the ^{116}Sn core, the low spin positive states at 828,6 ($3/2^+$), 864,1 ($3/2^+$), 933,8 ($7/2^+$), 941,3 ($5/2^+$) and 1418,2 keV ($9/2^+$) have been ascribed to a $K = 1/2^+$ rotational band based on a deformed Nilsson $\{431\}$ state. In the present study de-excitation γ-rays from levels in ^{115}In were observed following inelastic neutron scattering at incident energies between 1,0 and 2,57 MeV. The γ-ray yields were corrected for incident neutron flux, γ-ray attenuation, detection efficiency and for the effect of the time-gate used for background suppression. The levels observed below 1.5 MeV, γ-ray energies, branching ratios and the deduced spin and parity values are given in table 1.

Three new levels are listed here, viz. 1041,5, 1347,5 and 1497,2 keV. The 1041,5 keV level could possibly be the $\ell = 3$ transition which has been observed in the $^{116}Sn(d,{}^{3}He)^{115}In$ reaction and which would correspond to the pick-up of a $f_{5/2}$ proton[2]. Eighteen other levels have also been observed at 1602,3, 1607,8*, 1736,0, 1872,4*, 1917,3*, 1971,4, 1978,3*, 1999,0*, 2057,3, 2071,0*, 2107,7*, 2113,7, 2170,7*, 2234,0, 2264,0, 2283,0, 2380,6 and 2442,2 keV. Levels marked by an asterisk could correspond to ones observed using the $^{115}In(d,d')$ reaction[3]. The present results (see fig. 1 and table 1) do confirm the spin assignments of the positive parity levels which, to first order, have been explained by particle-core coupling. The complexity of the observed level structure makes it difficult to compare the states above 1.5 MeV with those that have been predicted by theory.

1) W.K. Tuttle, et al.: Phys. Rev. C13 (1976) 1036 which also includes other relevant references.

2) W.H.A. Hesselink, et al.: Nucl. Phys. A226 (1974) 229

3) F.S. Dietrich, et al.: Nucl. Phys. A155 (1970) 209

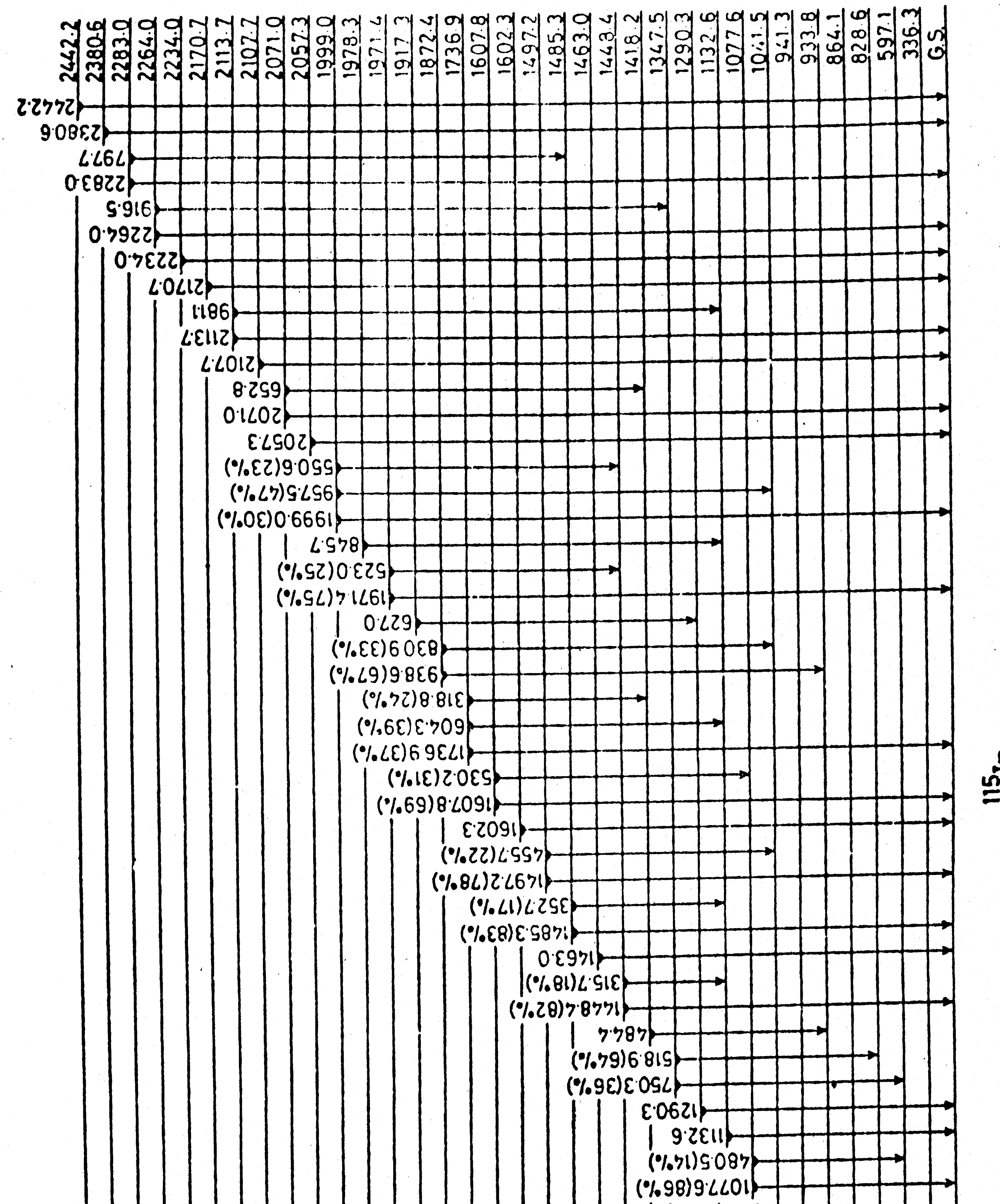

Fig. 1   Level scheme and decay properties of Indium-115.

TABLE 1. Level energies and gamma decays of In-115

Level Energy keV	J^{π}	E_{γ} Branching ratio in brackets	(keV)
0	$9/2^+$		
336,3 ± 0,2	$1/2^-$	336,3	
597,1 ± "	$3/2^-$	260,8	
828,6 ± "	$3/2^+$	492,3	
864,1 ± "	$3/2^+$	572,8	
933,8 ± "	$7/2^+$	933,8	
941,3 ± "	$5/2^+$	941,3 (85);	344,2 (15)
1041,5 ± "	(5/2)	705,3 (88);	444,3 (12)
1077,6 ± "	$5/2^+$	1077,6 (86);	480,5 (14)
1132,6 ± "	$11/2^+$	1132,6	
1290,3 ± "	$13/2^+$	1290,3	
1347,5 ± "	$(5/2^+, 7/2^+)$	518,9 (64);	750,3 (36)
1418,2 ± "	$9/2^+$	484,4	
1448,4 ± "	$9/2^+$	1448,4 (82);	315,7 (18)
1463,0 ± "	$7/2^+$	1463,0	
1485,3 ± "	$9/2^+$	1485,3 (83);	352,7 (17)
1497,2 ± "	$(5/2^+)$	1497,2 (78);	455,7 (22)

1.1.2 The level structure of ^{159}Tb from (n,n'γ) measurements

- I.J. van Heerden, W.R. McMurray

The main sources of knowledge of the level structure of ^{159}Tb and of its decay schemes have been radioactive decay[1] and Coulomb excitation[2] studies. Additional levels have also been observed in ^{158}Gd(^{3}He,d) and ^{158}Gd(α,t) reaction studies[3,4], but the spin assignments of these levels are very uncertain.

Work using the (n,n'γ) reaction and a time-of-flight gated Ge(Li) detector has recently been started to obtain a more precise level and decay structure for ^{159}Tb. In the preliminary studies γ-ray spectra were obtained for incident neutron energies between 700 and 1500 keV in energy steps of about 50 keV.

Threshold energies of the observed γ-rays were used in conjunction with the requirement that for associated branch decays, the energies must sum to within the experimental uncertainties, to construct the energy level scheme shown in fig. 2. The spin assignments are obtained from published data [5], and are consistent with the observed decay transitions. Additional work is being planned, not only to confirm this level scheme, but also to extend it to higher energies.

1) R.M. Diamond, B. Elbek, F.S. Stephens, Nucl. Phys. 43 (1963) 560.

3) G.G. Seaman, E.M. Bernstein, J.M. Palms, Phys. Rev. 161 (1967) 1223.

3) J.S. Boyno and J.R. Huizenga, Phys. Rev. C6 (1972) 1411.

4) J.C. Tippett, D.G. Burke, Can. J. Phys. 50 (1972) 3152.

5) Nuclear Data Sheets 9 (1973) 454.

1.1.3 Polarization in n-p and n-d scattering at $E_n < 23$ MeV

- B.R.S. Simpson, F.D. Brooks, C.M. Bartle, D.T.L. Jones*, I.J. van Heerden

Work is continuing on the polarization experiment and a comprehensive run has now been made using the modified equipment previously reported[1]. We have now reached the stage of analysing the n-p data which has proved more difficult than in some previous experiments. This is probably due to the un= usual pulse-height characteristics which have been exhibited by the anthracene crystal used. These characteristics are being investigated. Two computer programs have been developed for this purpose and progress has been made in extracting reliable polarization values.

1) Item 1.1.3, SUNI Annual Research Report (1976)

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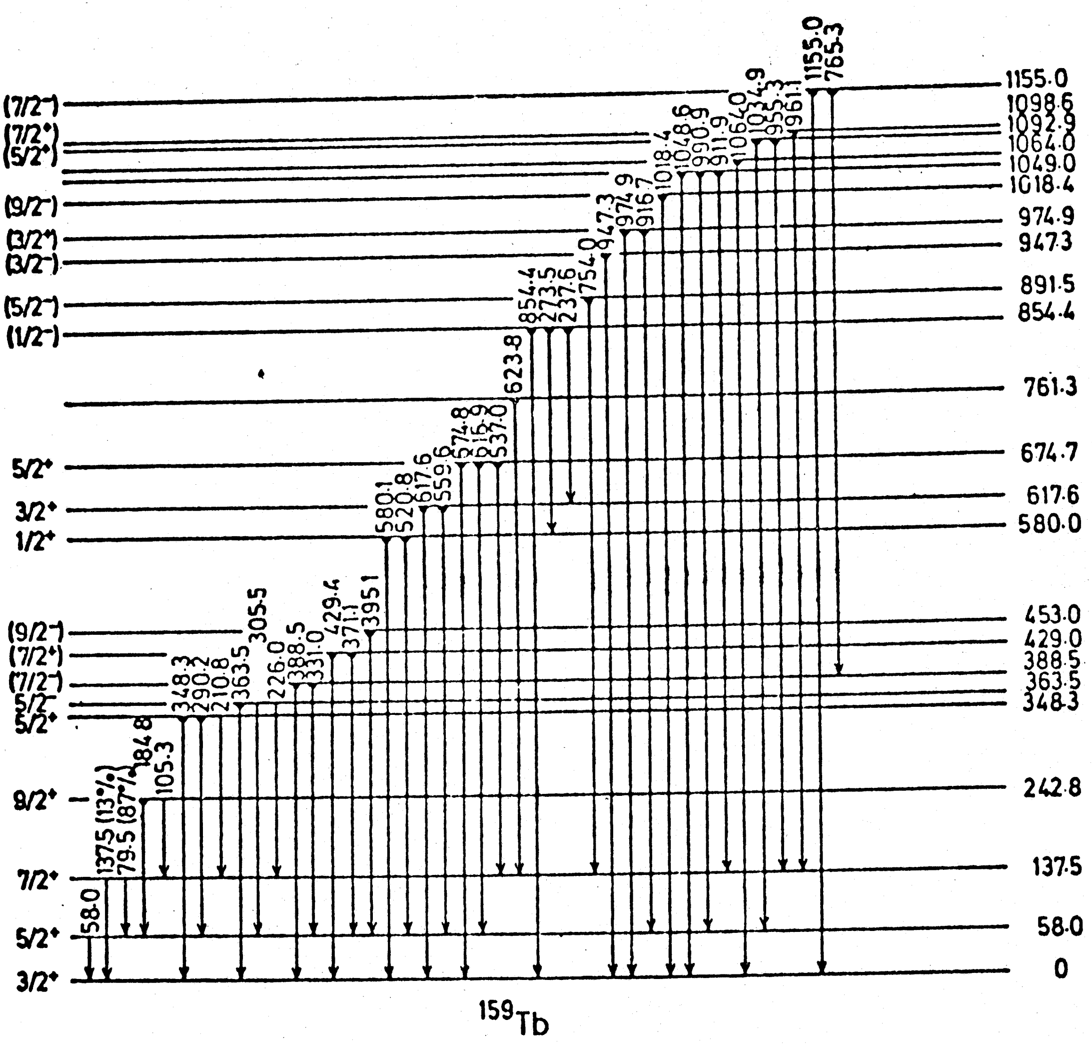

Fig. 2 Level scheme and decay properties of Tb-159

1.1.4 Cross section for neutron-proton bremsstrahlung

- J. Whittaker, F.D. Brooks, I.J. van Heerden

Since the previous report[1)] on this project, the experiment has been considerably refined with a view to maximising the numbers of bremsstrahlung events, with respect to the many possible varieties of background. The most intractable variety has been shown to be double scatters consisting of n-p and (n,n'γ) inelastic scatters from a number of nuclei present in the experiment. In order to prevent these processes, the following changes have been made to remove nuclei with excited states at less than 4 MeV:-

1. The NaI detector for the photon has been replaced by a stilbene crystal.
2. A scattering chamber has been constructed containing ^{4}He, thus excluding ^{14}N in air.
3. The incident energy has been reduced to 4.8 MeV so that the scattered neutron from $^{12}C(n,n'\gamma)$ is below detection threshold.

Analysis is proceeding on the results of a run completed in June 1977, and the results are being transformed so as to relate to the more usual "Harvard" geometry[2)], for which some theoretical predictions have been made. Work to date indicates an upper limit of 500 $\mu b/sr^2$ for the cross section $d^2\sigma/d\Omega_p d\Omega_n$ for bremsstrahlung production at 4.8 MeV in Harvard geometry, where the scattered proton and neutron have angles of 25° and 35° respectively. Further analysis is expected to reduce this limit.

1) Item 1.1.4, SUNI Annual Research Report (1976)
2) Item 2.1.4, SUNI Annual Research Report (1975)

2. NATIONAL ACCELERATOR CENTRE, COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH, PRETORIA

The classical solid-pole cyclotron of the C S I R has for many years been used for research with charged particles and the production of radio-isotopes. The proposed separated sector cyclotron with a maximum proton energy of 200 MeV, is now in its final design stage and is expected to be sited in the Western Cape Province.

2.1 Determination of excitation functions and thick-target yields of alpha- and proton-induced reactions in the energy range up to 100 MeV

- F.J. Haasbroek*, J. Steyn*, R.D. Neirinckx*, G.F. Burdzik*, M. Cogneau+ and P. Wanet+

These studies[1)] formed part of a programme to evaluate the potential of medium-energy alpha-particles and protons for the production of radio-isotopes.

The stacked-foil technique was used to determine excitation functions, from which thick-target yields as a function of energy were derived. Stacks were prepared by staggering in rotation thin discs of the natural target elements of interest (Ag and Zn for alpha-particle and Co, Ni, Mg and Ta for proton bombardment). Bombardments were performed in the Louvain-La-Neuve Cyclotron in Belgium. In a few cases thick-target yields were also determined directly by bombarding thick targets. The average beam current was ~1 μA and the integrated current ~2 μAhr. The residual activities in the bombarded discs were measured directly with calibrated Ge(Li) detectors. Only ^{55}Fe induced in the Co targets was separated chemically and measured by an absolute standardization method.

Alpha-particles of 100 MeV energy yielded production rates of 900 $\mu Ci \cdot \mu Ahr^{-1}$ for ^{67}Ga and 3.2 $\mu Ci \cdot \mu Ahr^{-1}$ for ^{68}Ge

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+ Laboratoire de Chimie Nucléaire, Université de Louvain, Louvain-La-Neuve, Belgium

Calculated and directly-measured thick-target yields in target elements bombarded with protons

Proton Energy (MeV)	Thick-target yields ($\mu Ci \cdot \mu Ahr^{-1}$)							
	Na-22 (from Mg)		Fe-55* (from Co)		Co-56 (from Ni)	Co-57 (from Ni)	Co-58 (from Ni)	Hf-175 (from Ta)
	Calculated	Directly measured	Calculated	Directly measured	Calculated	Calculated	Calculated	Calculated
25			0.5		Traces	24	Traces	
40	4.6		5.1		84	108	38	
55	19.0	18.8 ± 1.1	7.2		288	168	116	4
70	33.8	34.4 ± 2.1	17.0		444	236	186	101
85	49.0	46.7 ± 2.8	31.3	31.9 ± 1.6	598	298	248	416
100	64.6				750	356	310	638

*Results from 85 MeV protons only

in Zn and 8.3 μCi·μAhr^{-1} for ^{109}Cd in Ag. The production rate of ^{111}In in Ag by 42 MeV alpha-particles is 310 μCi·μAhr^{-1} and increases only very slowly with projectile energy above this energy. The results for the proton bombardments are summarized in the table below.

1) F.J. Haasbroek, J. Steyn, R.D. Neirinckx, G.F. Burdzik, M. Cogneau and P. Wanet: Int. J. Appl. Rad. Isotopes 28 (1977) 533

3. PHYSICS DIVISION, ATOMIC ENERGY BOARD, PELINDABA, TRANSVAAL

The major facilities used for neutron physics research are the 20 MW research reactor, Safari-1, and a 3.75 MV pulsed Van de Graaff accelerator with terminal bunching and an on-line computer system.

3.1 Prompt neutrons from thermal-neutron induced fission of ^{235}U

- F.D. Brooks[+], C.B. Franklyn, C. Hofmeyr, D.W. Mingay and J.S. Pringle[+]

A more extensive analysis of the n-n angular correlation measurements of prompt fission from $^{236}U^*$ has been undertaken. The results could be satisfactorily described by a Monte Carlo simulation, utilizing a simple evaporation model of fission assuming isotropic emission of neutrons from fully accelerated fission fragments, under the following conditions:

1) An isotropic scission neutron component of around 20 % had to be assumed.
2) The neutron multiplicities from the fission fragments were described by binomial distributions.

+ University of Cape Town

Apart from these assumptions the Monte Carlo incorporated only quantities and distributions defined by measurements (e.g. mass division, fragment and neutron kinetic energies, $\overline{\nu}(A)$, etc). The simulation in the above form, in addition satisfactorily described the angular correlation between the light fragment and neutrons (n-f), the total neutron multiplicity distribution and the laboratory frame neutron energy spectrum. No comparable fit to all the relevant measured parameters could be produced when Gaussian distri= butions of the fragment neutron multiplicities were assumed, the largest discrepancy in this case occuring in the n-n angular correlation data.

The same model with the relevant input parameters for ^{252}Cf (s.f.) failed to describe either the n-f or the n-n angular correlations as satisfactorily.

The experimental results for n-n correlation data as a function of fission neutron energy for $^{236}U^*$ are being enhanced by time-of-flight measurements. A more physical Monte Carlo simulation of the fission process is also being investigated.

3.2 Thermal-neutron capture

- C. Hofmeyr and C.B. Franklyn

A triple constant fraction timing technique was utilized with a large coaxial Ge(Li) detector to obtain delayed coincidence time spectra of low-energy transitions in lutetium populated by thermal-neutron capture. Primary gamma rays were detected in a plastic scintillator. Although the time spectra were appreciably improved regarding resolution and "tailing", there is a progressive loss of efficiency below about 400 keV, which constitutes the main region of interest for delayed coincidence time measurements in the nanosecond range for many nuclei.

A study of $^{85}Rb(n,\gamma)^{86}Rb$ in the excitation region below 2.6 MeV has been started.

3.3 Fast neutron scattering

3.3.1 ^{103}Rh

– E. Barnard and D. Reitmann

The detailed study of fast neutron scattering from ^{103}Rh has been completed. Cross sections for the excitation of a large number of nuclear energy levels, including the isomeric state at 40 keV, were obtained from time-of-flight- and (n,n'γ)-measurements and compared with Optical Model and Hauser-Feshbach calculations. A somewhat unusual choice of potential parameters was required to explain the excitation of levels with both parities simultaneously. A detailed level scheme, as shown in fig. 1, was derived from the (n,n'γ)-measurements. Asterisks indicate γ-transitions and energy levels which have not been reported before. A full account of all the results has been accepted for publi= cation in Nuclear Physics.

3.3.2 The (n,n'γ)-reaction in Ag

– E. Barnard, D.W. Mingay, D. Reitmann and J. White

Approximately 200 γ-rays from inelastic scattering of neutrons from natural silver have been observed. Cross sections and excitation functions for most of these have been measured up to 2 MeV. In order to assign transitions uniquely to either of the natural isotopes, a series of measurements was done with a highly enriched sample of ^{109}Ag. Analysis of the data is in progress.

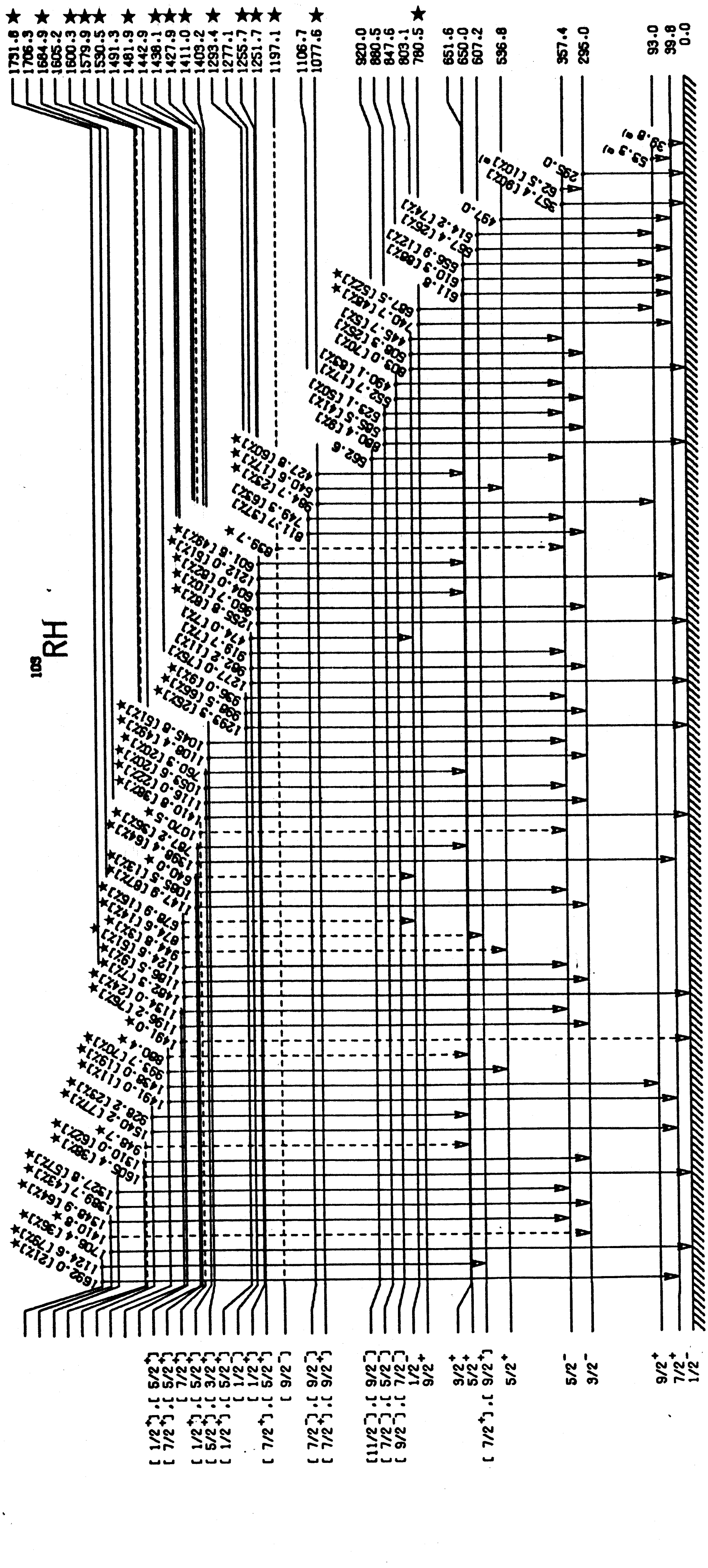

Fig. 1