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COULOMB EXCITATION OF RUTHENIUM ISOTOPES

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The $B(E2)$ values of the 89.4, 340.4, 575.5, 617.4 and 719.2 keV states of ^{99}Ru and 127.2, 306.8, 422.0 and 544.9 keV states of ^{101}Ru have been deduced by measuring the yields of gamma-rays following Coulomb excitation of a metallic ruthenium target with 3.0 MeV protons at Variable Energy Cyclotron, Chandigarh. The gamma-ray spectra were measured at 55° to the beam line using a 50 cm^3 Ge(Li) detector (resolution: 2.5 keV at 1332 keV). The present $B(E2)$ values for different states in ^{99}Ru and ^{101}Ru are compared with the values available in the literature.

1. Introduction

Several authors have tried to describe the low-lying states of Ru isotopes on the basis of the simple shell model [1], the core-excitation model [2] and the Nilson model [3]. The large quadrupole values and much enhanced E2 transition rates for some of the states in various Ru isotopes indicate their strong collective character, but because of considerable mixing of the single-particle states with the collective states, the theoretical predictions so far are inadequate to fully account for all the states.

In addition, experimental investigations involving radioactive studies have also been reported by Kistner et al. [2], Chlosi et al. [4] and Woods et al. [5] and are used to assign spins and parities to some of the levels in Ru isotopes. The Coulomb excitation work [6–11] has yielded the reduced E2 transition probabilities and mixing ratios. These experiments were performed using 4 cm^3 Ge(Li) and NaI(Tl) detectors. The present measurements were, therefore, carried out using a 50 cm^3 Ge(Li) detector having better resolution and employing protons as projectiles.

2. Experimental procedure

The natural thick metallic Ru isotope in a powder form was obtained from a proper chemical reduction of the compound $RuCl_3 x H_2O$. The powder was compressed hydraulically under 4000 lb/in^2. pressure into a pallet form 200 mg/cm^2 thick and 1 cm in diameter.

The 3.0 MeV proton beam was obtained from the Variable Energy Cyclotron, Chandigarh. The deexciting gamma-rays from Coulomb excitation of Ru-isotopes were detected by a 50 cm^3 Ge(Li) detector having an energy resolution of 2.5 keV at 1.332 MeV gamma-ray energy. Fig. 1 shows a typical gamma-ray spectrum obtained at 3.0 MeV proton energy. The detector was kept at an angle of 55° to the beam direction and at a distance of 15 cm from the target. Identification of the deexciting gamma-transitions was made on the basis of their well known energies from previous work [6–11]. Levels up to 719.2 keV in ^{99}Ru and upto 544.9 keV in ^{101}Ru (level schemes: figs. 2a and 2b) have been excited.

Reduced transition probability values $B(E2)$ were extracted from the thick target gamma-ray yields using the prescription of Alder et al. [12] and are compared with the values obtained by other workers in table 1. Contributions due to compound nucleus formation are considered negligible at the present energy of the experiment, i.e., $E_p = 3.0$ MeV and, therefore, were not taken into account [13]. The $B(E2)\downarrow$ values for the transitions to the ground states have also been determined from the calculated $B(E2)\uparrow$ values and are shown in table 2. Also shown in the last column in the table are the ratios of the $B(E2)\downarrow$ values compared to the single particle estimates $B(E2)_{s.p.}$ [12].

3. Results

3.1. Levels in ^{99}Ru

The $B(E2)\uparrow$ value obtained for the level at 89.4 keV in the present work is in good agreement with the value obtained by Kistner et al. [8] (table 1). The comparison of our $B(E2)\downarrow$ value with the single particle estimates (last column, table 2) shows the strong collective nature of this state.

There is a marked difference in the $B(E2)\uparrow$ value obtained for the transition to the state at 340.4 keV in our measurements compared to that obtained by Kistner et al. [8]. This could be attributed to the large uncer-

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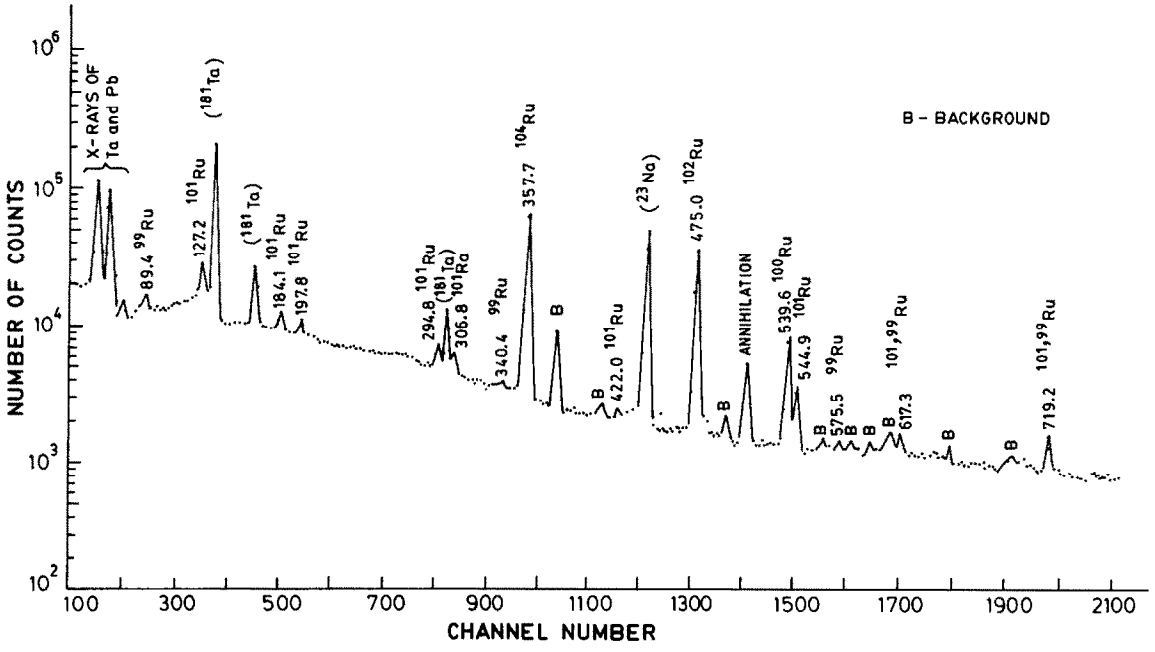

Fig. 1. A typical gamma-ray spectrum from Coulomb excitation of Ru isotopes at 3.0 MeV incident proton energy.

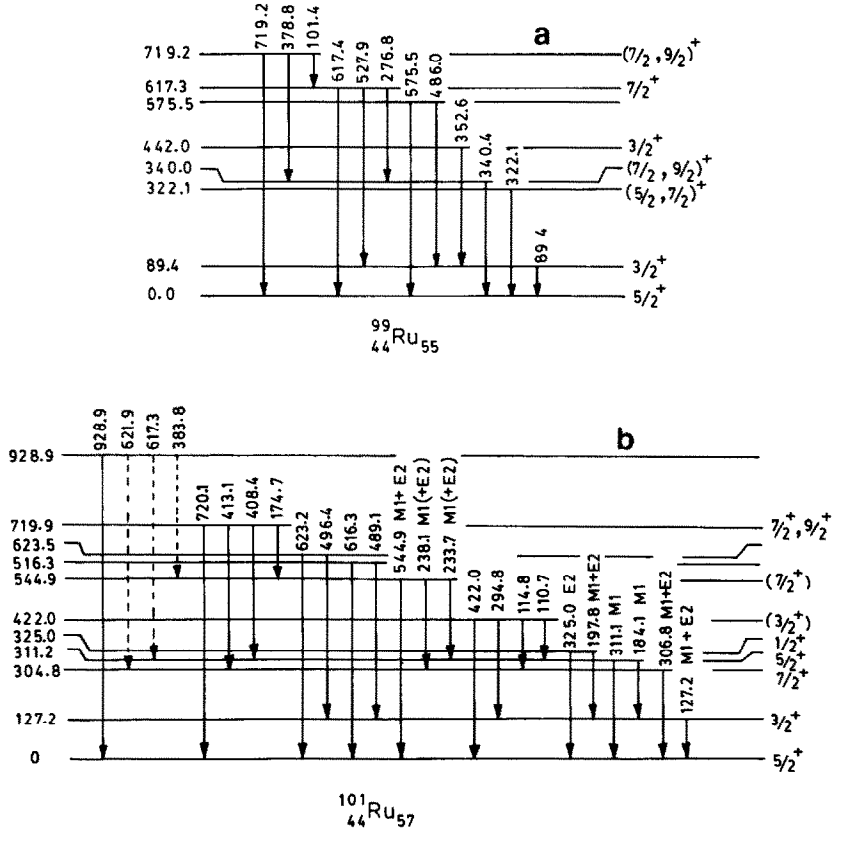

Fig. 2. Level schemes for (a) ^{99}Ru and (b) ^{101}Ru.

Table 1
Comparison of $B(E2)\uparrow$ ($e^2 \times 10^{-48}$ cm^4) values with earlier work [6–8]

Isotopes	Energy level (keV)	$B(E2)\uparrow$ ($e^2 \times 10^{-48}$ cm^4)			
		Present work	Temmer et al. [6]	Ritter et al. [7]	Kistner et al. [8]
^{99}Ru	89.4	0.030 ± 0.003	–	–	0.034 ± 0.004
	340.4	0.011 ± 0.002	–	–	< 0.001
	575.5	0.031 ± 0.003	–	–	0.024 ± 0.003
	617.4	0.082 ± 0.009	–	–	0.083 ± 0.008
	719.2	0.207 ± 0.021	–	–	0.128 ± 0.015
^{101}Ru	127.2	0.039 ± 0.004	0.061	0.0254	0.032 ± 0.003
	306.8	0.024 ± 0.003	–	–	0.007 ± 0.002
	422.0	0.023 ± 0.003	–	–	0.017 ± 0.002
	544.9	0.127 ± 0.012	–	–	0.140 ± 0.010

tainty quoted by Kistner et al. [8]. The enhancement factor for this state shows its single particle nature. The $B(E2)\uparrow$ value for the transition to the level at 575.5 keV is slightly higher than that obtained by Kistner et al. [8].

In the present work, the $B(E2)\uparrow$ value determined for the transition to the 617.4 keV level agrees very well with the value quoted by Kistner et al. [8]. The comparison of our $B(E2)\downarrow$ value with the single particle estimates give a large enhancement factor for this level. The contribution due to the 616.3 keV transition in ^{101}Ru was neglected as the intensity of the 616.3 keV transition in ^{101}Ru was very small compared to the 617.4 keV transition in ^{99}Ru.

The reduced transition probability value $B(E2)\uparrow$ for the transition to the level at 719.2 keV is significantly different from the value obtained by Kistner et al. [8]. Also the enhancement factor is very large.

3.2. Levels in ^{101}Ru

For the evaluation of the $B(E2)\uparrow$ value for the transition to the level at 127.2 keV, the effective thick-target yield is obtained by subtracting the contributions to the yield due to 184.1, 197 and 294.8 keV transitions which feed this level from the higher levels. Our $B(E2)\uparrow$ values so obtained agree well with the values determined by Kistner et al. [8] but differs from the value obtained by Temmer et al. [6] and Ritter et al. [7]. Similar to the first level in ^{99}Ru, this level also shows a large collective nature since the enhancement factor for it is quite large. The $B(E2)\uparrow$ values obtained for the transitions to the levels at 306.8 and 422.0 keV are quite different from the values quoted by Kistner et al. [8]. The enhancement for these levels indicate admixture of collective and single particle nature.

The observed $B(E2)\uparrow$ value for the transition to the 544.9 keV level agrees well with the value of Kistner et al. [8]. This level also shows a large enhancement ratio.

4. Discussion

For the first time 3.0 MeV protons have been used as as projectiles to Coulomb-excite the low lying states of odd Ru isotopes. The $B(E2)\uparrow$ values obtained in the present work agree fairly well with the values obtained by Kistner et al. [8] for most of the transition in ^{99,101}Ru. The disagreement in the $B(E2)\uparrow$ values as

Table 2
Present $B(E2)\downarrow$ ($e^2 \times 10^{-48}$ cm^4) and $B(E2)\downarrow / B(E2)_{s.p}$

Isotope	Energy level (keV)	Transition (keV)	Spin	$B(E2)\downarrow$ ($e^2 \times 10^{-48}$ cm^4)	$B(E2)\downarrow / B(E2)_{s.p.}$
^{99}Ru	89.4	$89.4 \rightarrow 0$	3/2	0.045	3.3 ± 0.3
	340.4	$340.4 \rightarrow 0$	(7/2, 9/2)	(0.008, 0.006)	$(0.58 \pm 0.06, 0.48 \pm 0.05)$
	575.5	$575.5 \rightarrow 0$	–	–	–
	617.4	$617.4 \rightarrow 0$	7/2	0.061	4.5 ± 0.4
	719.2	$719.2 \rightarrow 0$	(7/2, 9/2)	(0.155, 0.124)	$(11.3 \pm 1.1, 9.1 \pm 0.9)$
^{101}Ru	127.2	$127.2 \rightarrow 0$	3/2	0.059	4.2 ± 0.4
	306.8	$306.8 \rightarrow 0$	7/2	0.018	1.3 ± 0.13
	422.0	$422.0 \rightarrow 0$	3/2	0.035	2.5 ± 0.2
	544.9	$544.9 \rightarrow 0$	(7/2, 5/2)	(0.095, 0.127)	$(6.7 \pm 0.7, 8.9 \pm 0.9)$

observed in the present measurements and that reported by Kistner et al. [8] for the 340.4 keV and 719.2 keV transitions in ^{99}Ru and the 306.8 and 422 keV transitions in ^{101}Ru could be attributed to the large uncertainties quoted by Kistner et al. [8].

The enhancement factors, i.e. the ratio of experimental $B(E2)\downarrow$ and $B(E2)_{s.p.}$, is quite large for 89.4, 617.4 and 719.2 keV states in ^{99}Ru, and 127.2 and 544.9 keV states in ^{101}Ru. These levels in ^{99,101}Ru, according to the core excitation model, may possibly be the members of the multiplets in which the coupling of the single odd nucleon to the collective 2^+ excitation of the core are considered. The enhancement factors for the $2^+ \rightarrow 0^+$ transition in the neighbouring even–even nuclei lend support to such a possibility. Detailed calculations involving the configurational mixing of the single particle states and those due to core excitation could further help in understanding of the other states in ^{99,101}Ru.

References

[1] M.G. Meyer and J.H.D. Jansen, Nuclear Shell Structure (Wiley, New York, 1955).
[2] O.C. Kistner, Phys. Rev. 144 (1966) 1022.
[3] N.K. Aras, G.D. O'Kelley and G. Chilosi, Phys. Rev. 146 (1966) 869.
[4] G. Chilosi, E.K.G. Lobner, R. Moro, P.R. Speranza and G.B. Vergiani, Phys. Rev. 148 (1966) 1168.
[5] G.T. Wood and S. Koicki, Phys. Rev. 150 (1966) 956.
[6] G.M. Temmer and N.P. Heydenburg, Phys. Rev. 104 (1956) 967.
[7] R.C. Ritter, P.H. Stelson, F.K. McGowan and R.L. Robinson, Phys. Rev. 128 (1962) 1320.
[8] O.C. Kistner and A. Schwarzscheld, Phys. Rev. 154 (1967) 1182.
[9] P.H. Stelson and F.K. McGowan, Phys. Rev. 110 (1958) 489.
[10] D. Eccleshall, B.M. Hinds and M.J.L. Yates, Nucl. Phys. 32 (1962) 190.
[11] F.K. McGowan, R.L. Robinson, P.H. Stelson, W.J. Milner, Nucl. Phys. A113 (1968) 529.
[12] K. Alder, A. Bohr, T. Huus, B. Mottelson and A. Winther, Rev. Mod. Phys. 28 (1956) 432.
[13] K.P. Singh, D.C. Tayal, B.K. Arora, T.S. Cheema and H.S. Hans, Can. J. Phys. 63 (1985) 483.