ISOMERIC PROPERTIES OF EVEN-EVEN NUCLEI ^{76}Ni TO ^{94}Pd FOR N= 48 NEUTRONS

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ABSTRACT

The isomeric properties of even-even nuclei from ^{76}Ni to ^{94}Pd for N= 48 neutrons are studied in this paper. We have calculated binding energies, half-life, reduced transition probabilities in ^{76}Ni, ^{78}Zn, ^{80}Ge, ^{82}Se, ^{84}Kr, ^{86}Sr, ^{88}Zr,^{90}M$_o$,^{92}Ru and ^{94}Pd nuclei. The energies of projectile-like fragments, coulomb barrier and Q-value in ^{76}Ge (635 MeV) + ^{198}Pt reactions are calculated. The theoretical calculations of projectile-like fragments (PLFs) energies are compared with experimental values. The systematic 8^+ isomeric levels, half-lives, energy level of 8^+, 6^+, 4^+, 2^+ and 0^+ state of even-even nuclei from atomic number Z= 28-44 for neutrons N=48 are investigated

ABSTRAK

Ciri-ciri isomer teras yang walaupun genap dari ^{76}Ni ke ^{94}Pd kerana N= 48 neutron dikaji dalam kertas ini. Kami telah mengira tenaga-tenaga yang mengikat, separuh hayat, mengurangkankebarangkalian peralihan dalam ^{76}Ni, ^{78}Zn, ^{80}Ge, ^{82}Se, ^{84}Kr, ^{86}Sr,teras ^{88}Zr ,^{90}Mo ,^{92}Ru and 94Pd. Kuasa-kuasa serpihan-serpihan seperti serpihan bentuk projektil, sawar coulomb dan Nilai-Q dalam ^{76}Ge (635 MeV) + tindakbalas ^{198}Pt adalah dikira. Pengiraan teoretikal serpihan-serpihanseperti peluncur (PLFs) kuasa-kuasa dibandingkan dengan nilai-nilaiujian. 8+ sistematik tahap-tahap isomer, separuh hayat, tahap tenaga8+, 6+, 4+, keadaan 2+ and 0+ teras yang walaupun genap dari nombor atom Z= 28-44 kerana neutron N=48 adalah dikaji.

Keywords- Binding energy, projectile-like fragments, Half-life; Q-value

INTRODUCTION

The region of even-even nuclei with N = 48 and Z = 28-46 has recently got interest in the studies of nuclear structure. Because N = 50 is a magic number which shows strong shell closure and is accessible to experimental investigations. The nucleons *with* N = 48 and existed less two neutron from N = 50 magic numbercan form two hole $g_{(9/2)}^{-2}$ configuration of a nuclear structure. However, the lifetime of ground state of unstable nuclei is short and this makes the laboratory study extremely difficult [1].

Isomeric spectroscopy was performed to search for an $I^{\pi} = 8^+$ isomer in $g_{(9/2)}^{-2}$ configuration. Electric quadrupole (E2) transition in even-even nuclei for N=48 have recently been of much interest both theoretically and experimentally. It is known that 8^+ to 6^+ states are firmed E2 transition and show isomeric properties from even-even nuclei ^{76}Ni to ^{94}Pd [2, 3, 4, 5, 6, 7]. The details calculation of projectile-like fragments (PLFs), Q-value, binding energy, $g_{(9/2)}^{-2}$ configuration of *8^+* state of even-even nuclei for N=48 are not been calculated yet. At present, we have (it should be are) presented PLFs value, Q-value, binding energy, E2 transitions energy from

$8^+ \rightarrow 6^+$, reduced transition probabilities, precise calculation of half-lives and other nuclear spectroscopic properties of even-even nuclei with N = 48 and Z = 28-46 nuclei, by theoretical investigations.

FORMULA FOR THEORETICAL CALCULATIONS

Binding Energy (B.E)

The binding energy can be calculated using:

$$B.E = \Delta m.\, c^2 \qquad (1)$$

where: Δm (mass defect) = $[Z\,(m_p+m_e) + (A-Z)m_n] - m_{atom}$

Neutron excess parameter (η)

The neutron excess parameter can be calculated using:

$$\eta = (N - Z) / A \qquad (2)$$

N is neutron number, Z is atomic number and A is mass number.

Coulomb Barrier

The following formula is used to calculate the Coulomb barrier:

$$E_c = \frac{Z_1 Z_2}{A_1^{\frac{1}{3}} + A_2^{\frac{1}{3}}} MeV \qquad (3)$$

where

Z_1= Proton number of projectile nucleus

Z_2= Proton number of target nucleus

A_1= Atomic number of projectile nucleus

A_2= Atomic number of target nucleus

Q-value

The Q-value of the reaction ^{76}Ge (635 MeV) + ^{198}Pt is calculated by equation (4):

$$Q = m\,(a) + m\,(b) - [m\,(A) + m\,(B)]\, c^2 \qquad (4)$$

where, m(a) = mass of PLF , m(b) = mass of TLF

m(A) = mass of projectile, m(B) = mass of target, c = velocity of light

Projectile-like fragments (PLFs) energies

The PLFs are calculated by equation (5),

$$\frac{E_1}{E_2} = \frac{m_1^2}{(m_1+m_2)^2}[cos\psi + \{(\frac{m_2}{m_1})^2 - sin^2\psi\}^{\frac{1}{2}}]^2 \qquad (5)$$

where, E_1: PLFs energies, E_2: projectile energy

m_1: mass of projectile nucleus, m_2: mass of target nucleus

Ψ: scattering angle

Half life

The γ-ray half life $T^{\gamma}_{1/2}$ is calculated [13] using equation

$$T^{\gamma}_{1/2} = T_{1/2}\,(exp)\,(1 + \alpha_{tot}) \tag{6}$$

B(E2) in units of e^2b^2

$$T^{\gamma}_{1/2}(second) = \frac{56.57}{B(E2)\downarrow E^5_{\gamma}(keV)} \tag{7}$$

The upward transition probability $B(E2)\uparrow$ is related to this value [13].

$$B(E2, J_i \to J_f)\downarrow = B(E2, J_f \to J_i)\uparrow x\ g \tag{8}$$

with $$g = \frac{(2J_f+1)}{(2J_i+1)} \tag{9}$$

B(E2) in units of Weisskopf single particle transition (W.u) [14].

$$B(E2)e^2b^2 = 5.94 \times A^{4/3} \times B(E2)_{w.u} \tag{10}$$

For the low-lying levels of even-even nuclei decay with more than one gamma transition, $T^{\gamma}_{1/2}$ is related to half-life, $T_{1/2}$ by the following equation [8].

$$T^{\gamma}_{1/2}(k) = T_{1/2}\sum_{i=1}^{n}\frac{I_i(1+\alpha_{i\,tot})}{I_k} \tag{11}$$

where the summation is taken over the intensity (I_i) of all gamma transition from the exciting level, I_k is the intensity of k_{th} (E2) transition.

RESULTS AND DISCUSSION

We have calculated binding energy, neutron excess parameter, Coulomb barrier, projectile-like fragments energy, Q-value, and systematic B(M2)↓ values of even-even nuclei from ^{76}Ni to ^{94}Pd for N = 48, which are presented in the table 1. It is shown that binding energy increases with atomic number increases and the neutron excess values are decreases with atomic number increases. The calculated Q-values of ^{76}Ni, ^{78}Zn, ^{90}Mo, ^{92}Ru, and ^{94}Pd indicate endothermic and ^{80}Ge, ^{82}se, ^{84}Kr, ^{86}Sr and ^{88}Zr are exothermic reaction. Moreover, calculated projectiles like fragments (PLFs) in deep-inelastic collision and half-lives of 8^+ levels are in good agreement with experimental values. The transition energies between 8^+ and 6^+ with those of reduced transition probabilities, one can safely assign the E2-type for isomeric transitions based on selection rules.

Table 1. Binding energy, Neutron excess parameter, Coulomb barrier, Q-value, Projectile like fragments and B(E2) ↓ values, half-lives in even-even nuclei with N= 48 and Z = 28-46.

Nuclei	B.E. (MeV)	η neutron excess parameter	Vc (MeV)	Q value	PLFs (Th.)	*PLFs (Ex.)	**B(E2) ↓	$T_{1/2}$	***$T_{1/2}$
				MeV	MeV	MeV	e^2b^2	Cal. ns	Expt. ns
^{76}Ni	633.12	0.263	260.45	-35.43			0.0013	608.9	590(20)
^{78}Zn	663.31	0.230		-14.07			0.0024	319.6	319(9)
^{80}Ge	690.11	0.200		1.09			0.0009	3.0	2.9(1)
^{82}Se	712.84	0.171		10.34			0.0012	8.6	6.6(4)

^{84}Kr	732.28	0.143		13.59	370.8	362(10)	0.0051	1.8 s	1.8(1) s
^{86}Sr	748.93	0.116		13.68	369.4	304(8)	0.0064	0.5 s	0.46(1) s
^{88}Zr	762.61	0.091		7.61			0.0041	1.3 s	1.3(1) s
^{90}Mo	773.73	0.067		-3.34			0.0070	2.0 s	1.1(1) s
^{92}Ru	782.55	0.043		-18.72			0.0041	100.2	100(14)
^{94}Pd	789.07	0.021		-38.46			0.0030	5.1	5

*Ref.[9, 10]

** Ref. [7,8]

***Ref.[4, 8, 11, 12]

Figure 1 shows the systematic excitation levels of 8^+, 6^+, 4^+, 2^+, and 0^+ states are plotted as a function of atomic number of even-even ^{76}Ni to ^{94}Pd nuclei for N = 48. It is shown that 2^+ levels and 4^+ levels of all presented nuclei indicate parallel S shape. The excitation levels up to 4^+ levels quite similar in even-even ^{76}Ni to ^{94} Pd nuclei. From the literature the transition energies of even-even ^{76}Ni to ^{94}Pd nuclei are calculated from 8^+ to 6^+ states, which are 114, 147.4, 460.76, 347, 63.5, 96.68, 63.15, 161.9 and 324 keV [8,9]. The energy from 8^+ to 6^+ level are known as E2 transition whose are increases from Z = 28 to 32, and then decreases until Z= 36, then again increases to even atomic number Z = 40, after those are continuously increases up to Z = 46. But the energy of 8^+ level increases towards atomic number up to Z= 34, and then decreases up to Z = 46. The maximum isomeric level is 3236 KeV for ^{82}Se nucleus and minimum isomeric level is 2440 keV for ^{76}Ni nucleus. It is found that the maximum value of B(E2) is 0.0069 e^2b^2 for ^{90}Mo nucleus, while the minimum value is 0.0.0009 e^2b^2 for ^{80}Ge nucleus. The B(E2) values as well as E2 transitions of ground states band up to 8^+ states do not show any correlation as a function of atomic number Z. The $B(E2)\downarrow$ values, E2 transitions of ground state band of even-even nuclei from ^{76}Ni to ^{94}Pd for N = 48 isotones with Z ≤ 38 differ significantly from those with Z ≥ 38. The discrepancy comes from the orbital occupied by valence proton; the nuclei of atomic number Z = 28 to 38 the valence proton mainly occupies the *f p* orbital while in the nuclei of atomic number Z > 38 occupy the $g_{9/2}$ orbital.

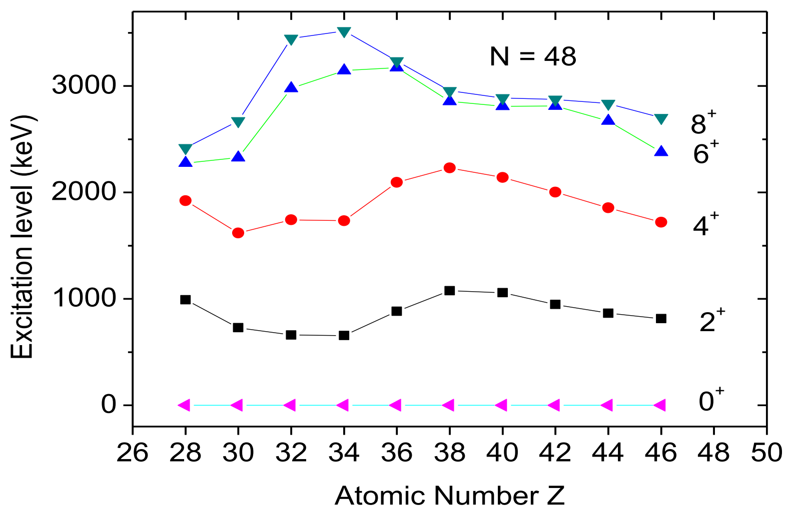

Figure 1. Systematic 2^+, 4^+, 6^+, 8^+ levels in $g_{(9/2)}^{-2}$ configurations of even-even nuclei ^{76}Ni to ^{94}Pd.

CONCLUSIONS

This paper presented the isomeric properties of V $g_{9/2})^{-2}$ configuration in even-even nuclei ^{76}Ni to ^{94}Pd. We calculated half-lives, reduced transition probabilities, Q-value, projectiles-like fragments energies, binding energy, neutron excess parameter and Coulomb barrier. Calculated PLFs and half-lives are in good agreements with experimental values. Moreover, systematic 2^+, 4^+, 6^+, 8^+ levels in $g_{(9/2)}^{-2}$ configurations of even-even nuclei ^{76}Ni to ^{94}Pd are investigated.

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