Proceedings of the Pakistan Academy of Sciences 50 (4): 335–338 (2013)

ISSN: 0377 - 2969 (print), 2306 - 1448 (online)

Pakistan Academy of Sciences

Research Article

Calculation of $\nu g_{(9/2)}{}^{+}$ Isomers in ^{65}Ni, ^{67}Zn, ^{69}Ge and ^{71}Se Nuclei

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Abstract: We have calculated the reduced transition probabilities B(M2, $9/2^+ \rightarrow 5/2^-$) of odd ^{65}Ni, ^{67}Zn, ^{69}Ge, and ^{71}Se nuclei with neutron number N=37. The theoretical calculations of the reduced transition probabilities are compared with the experimental values. The width of isomeric levels, mean-life of isomers, and Weisskopf hindrance factors of those nuclei were calculated. The systematic isomeric levels are plotted as a function of odd mass number and indicated that isomeric level decreases with an increase in the mass number.

Keywords: Reduced transition probabilities, isomeric levels, hindrance factors, width of isomeric levels

1. INTRODUCTION

Nuclear shell model has explained the nuclear isomers in the vicinity of the closed shells. It convinces that the quadrupole de-excitation of single particle is very important in this field. Particle's transition is governed by the single particle when the nuclear excitation is due to only one nucleon [1]. Isomers which are the long-lived excited state of an atom's nucleus usually belong to shell closure or magic number. The features of subshell closure in ^{68}Ni with neutron number N=40 was established by Broda et al. [2]. A study of the excited states and their decay pattern for the odd-even and even-odd nuclei gives the information of nuclear structure for a single particle state.

In odd ^{65}Ni to ^{71}Se nuclei the neutron number is N=37, the atomic number is even from Z= 28 to 34. The M2 ($9/2^+$ to $5/2^-$) transitions of those nuclei were established due to $\nu g(_{9/2})^n$ configuration [3-6]. Theoretically and experimentally, the M2 transitions of odd-even nucleus between $9/2^+$ and $5/2^-$ states were observed in odd As isotopes from A = 67-79 [7,8]. The calculation of odd-even Arsenic nuclei of $\pi g(_{9/2})^n$ configuration raised the possibility to calculate the isomerism of even-odd nuclei $\nu g(_{9/2})^n$ configuration such as ^{65}Ni, ^{67}Zn, ^{69}Ge and ^{71}Se. Moreover, the systematic mean lives, reduced transition probabilities, width of isomeric levels, and Weisskopf hindrance factors in odd ^{65}Ni to ^{71}Se nuclei are not investigated yet. It would give the good information about the strength of shell closure for N=40. It is very interesting to study systematically by theoretical calculations of ^{65}Ni, ^{67}Zn, ^{69}Ge and ^{71}Se nuclei in details.

Received, November 2012; Accepted, October 2013
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2. MATERIALS AND METHODS

2.1 Reduced Transition Probability B(M2)

The reduced transition probabilities B(M2) are defined for the γ-ray transitions with certain multipolarity as follows,

$B(M2; I_i \rightarrow I_f) = 7.381 \times 10^{-8}$

$E_\gamma^{-5} P_\gamma (M2; I_i \rightarrow I_f)$ (1)

The partial γ-ray transition probability Pγ(Mλ) can be obtained from the total transition probability of the level,

$$P_\gamma \left(\frac{M}{E}\lambda\right) = P(level) \frac{I\gamma(\frac{M}{E}\lambda)}{I_{total}} \quad (2)$$

$P(level) = \frac{1}{\tau(level)}$ and $\tau(level)$ is the measured mean life of the level of interest.

2.2 Width of Isomeric Levels, Γ_γ

It can be calculated by,

$$\frac{1}{\tau_\gamma} = \frac{\Gamma_\gamma}{\hbar} \quad (3)$$

Where; γ = mean life

$\hbar$= h/2; h is the Plank constant

2.3 Mean-life Time, $\tau\gamma$

Based on the radioactive relation, the half-life $T_{1/2}$ that gives,

$$T_{1/2} = \frac{ln2}{\lambda} = \frac{0.693}{\lambda} \equiv 0.693\tau \quad (4)$$

so, $\tau\gamma = \frac{T_{1/2}}{0.693}$

where, $T_{1/2}$ = Half-life

2.4 Weisskopf Hindrance Factor, F_w

$$F_w = \frac{B(M)w}{B(M)theoretical} \quad (5)$$

Where; $B(M)w = 1.65\, A^{2/3}$

3. RESULTS AND DISCUSSION

Calculations of the reduced transition probabilities B(M2), isomeric levels, mean life, width of the isomeric levels of odd ^{65}Ni to ^{71}Se nuclei are presented in Table 1 [9]. The available experimental uncertainties are presented by first bracket in the Table 1.

3.1 Isomeric levels

Fig. 1 shows the isomeric levels plotted versus odd mass number of ^{65}Ni to ^{71}Se nuclei. It is shown that the isomeric level $9/2^+$ of odd nuclei ^{65}Ni to ^{71}Se is decreasing with the increase of the mass number monotonically. The energy spectra of the N=37 isotones significantly decreases as the valance protons increases to the f-p shell in ^{65}Ni, ^{67}Zn, ^{69}Ge, and ^{71}Se nuclei.

3.2 Systematic reduced transition probabilities B(M2)

The reduced transition probabilities of the ^{65}Ni, ^{67}Zn, ^{69}Ge, and ^{71}Se nuclei were calculated according to equation (1) and showed that M2-type has been assigned between $9/2^+$ to $5/2^-$ based on selection rules. Fig. 2 shows the comparison of B(M2) between the theoretical and experimental data. It is shown that the calculated and experimental reduced

Table 1. Properties of isomers of ^{65}Ni, ^{67}Zn, ^{69}Ge, and ^{71}Se nuclei.

Nucl.	Isomeric levels $g_{9/2}^+$ (keV)	$^*T_{1/2\,(exp)}$	Mean-life (ns)	B(M2)		Γ_γ (eV)	F_w	Ref.
				*W.u $_{(Exp)}$	W.u $_{(present)}$			
^{65}Ni	1017.01 (10)	25.6 (11)ns	36.94		0.069	178.66	14.59	[3]
^{67}Zn	604.48 (50)	333 ns	480.52	0.054	0.067	13.74	14.37	[4]
^{69}Ge	397.94 (18)	2.81 (5)µs	4054.83	0.066 (1)	0.065	1.63	15.28	[5]
^{71}Se	260.48 (10)	19.0 (5)µs	27417.03	0.076 (2)	0.079	0.24	12.66	[6]

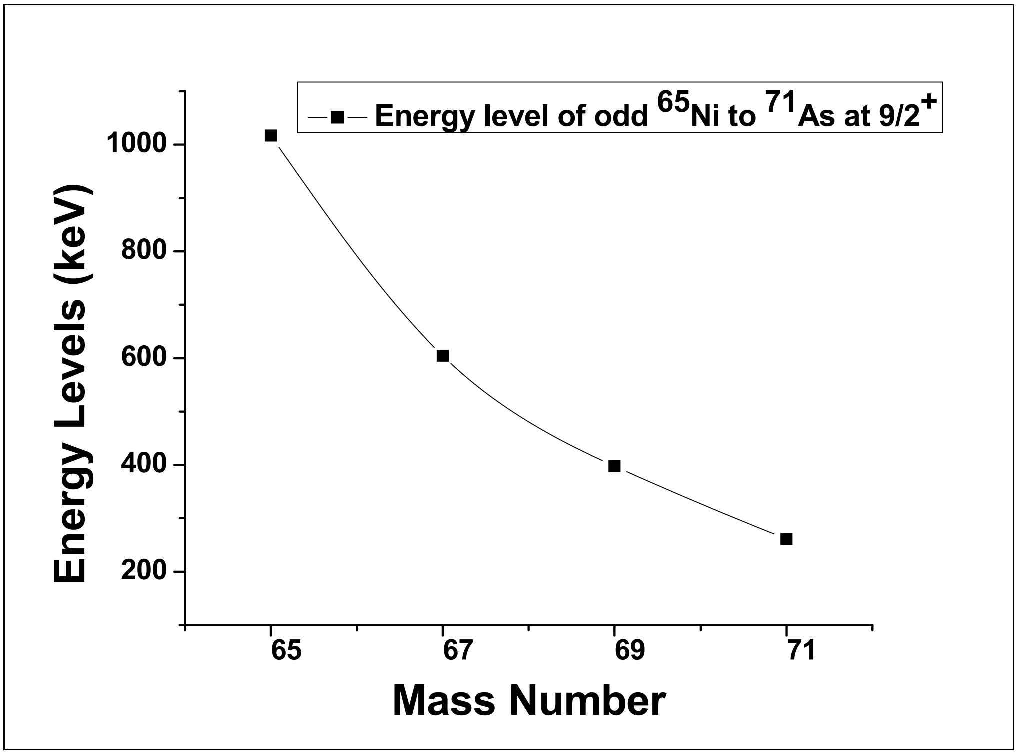

Fig.1. Isomeric levels ($9/2^{+}$) versus odd mass number of ^{65}Ni to ^{71}Se nuclei for N=37 isotones.

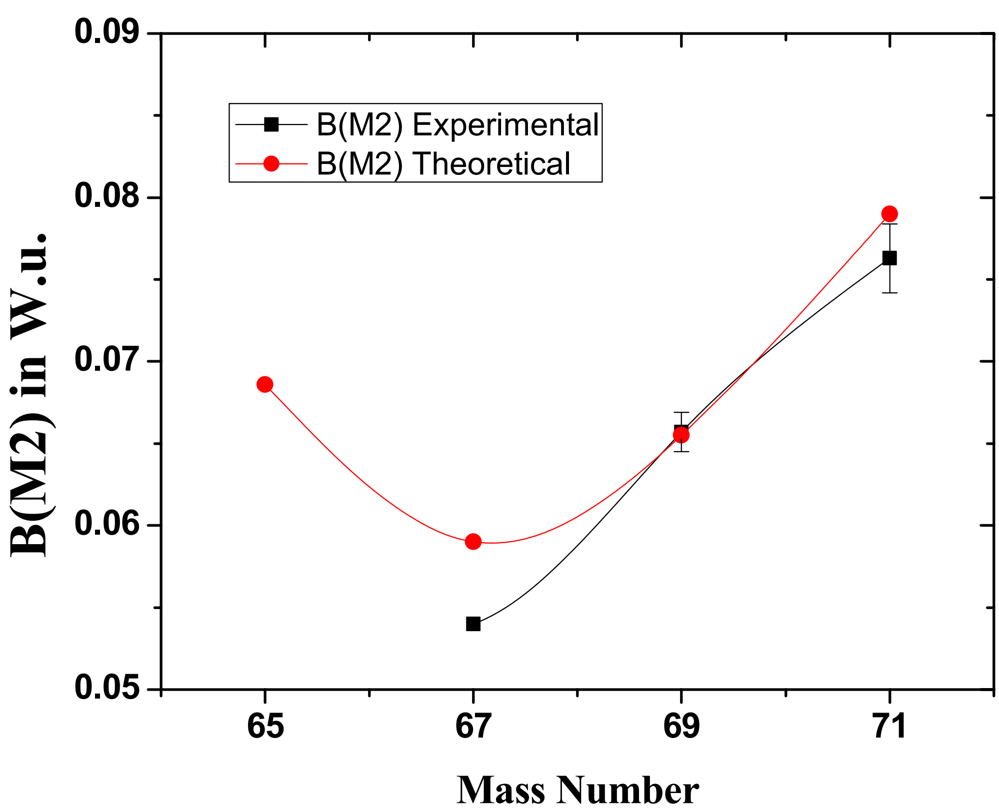

Fig. 2. B(M2) values in W.u. versus odd mass number of ^{65}Ni to ^{71}Se nuclei.

transition probabilities B(M2) as a function of mass number are close to each other except ^{67}Zn. It is essential to note that $\nu g_{(9/2)}$+ to $\nu f_{(5/2)}$- state in ^{67}Zn is not pure B(M2) transition. There is a mixing ratio with B(E3) transition according to selection rules. The experimental values of B(M2) is 0.05% compared to B(E3) values. B(E3) reduced transition probabilities are dominated in ^{67}Ni. The uncertainty of experimental data of ^{67}Ni is not found in the literature [4]. There is a discrepancy of calculated and experimental B(M2) values in ^{67}Zn which is due to mixing ratio. The theoretical calculations of the reduced transition probabilities B(M2) are in good agreement with the previous experimental results.

3.3 Width of isomeric levels (Γ_γ)

The width of the isomeric levels are calculated from equation (3). The width indicates the thickness of the gamma rays produced from the transition. The values of the widths of the isomeric levels are 178.66, 13.74, 1.63 and 0.24 eV of ^{65}Ni, ^{67}Zn, ^{69}Ge, and ^{71}Se nuclei respectively. It indicates that the width of the gamma rays decreases with the increase of the neutrons of ^{65}Ni, ^{67}Zn, ^{69}Ge, and ^{71}Se isomers.

3.4 Weisskopf Hindrance Factor, F_w

The Weisskopf Hindrance Factor, Fw of ^{65}Ni, ^{67}Zn, ^{69}Ge, and ^{71}Se were calculated according to equation (4). The values of the hindrance factor are 14.59, 14.37, 15.28 and 12.66 of ^{65}Ni, ^{67}Zn, ^{69}Ge, and ^{71}Se respectively. The maximum value of hindrance factor is 15.28 for ^{67}Zn.

4. CONCLUSIONS

The systematic mean life, reduced transition probabilities B(M2), width of isomeric level, and Weisskopf hindrance factor are calculated in odd ^{65}Ni to ^{71}Se isomers. The theoretical calculations of the reduced transition probabilities B(M2) are in good agreement with the previous experimental results.

5. ACKNOWLEDGEMENTS

The authors thank to King Abdulaziz University for supporting this work. Authors would also like to thank for the financial support of Ministry of Higher Education (MOHE), Malaysia/Universiti, Teknologi, Malaysia (UTM) for supporting a research studentship.

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