B(E2; $0^+_1 \rightarrow 2^+_1$) evaluation for even-even nuclides of Z=24-30 (Cr, Fe, Ni and Zn)

Presented by B. Singh (McMaster)

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Participants

- Boris Pritychenko: NNDC, BNL: Project Leader: data gathering, evaluation, database management (http://www.nndc.bnl.gov/be2).
- Mihai Horoi: Central Michigan University: Shell-model Theory
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  data gathering and evaluation

Purpose of this exercise

- Update of Raman et al., evaluation (2001Ra27) published in ADNDT 78, 1; with a cutoff date of Nov 2000.
- Significant amount of new data in the last 10 years, many experiments using radioactive ion beam facilities. Currently an active area of nuclear structure research as evidenced by a large number if papers presented at international conferences e.g. INPC at Vancouver in 2010. Update of Raman's work is needed.
- Pilot project started in Nov 2009 to update an important region of Z~N~28 (Cr, Fe, Ni, Zn) nuclei . This set of nuclides is completed and a paper to ADNDT has been submitted.
- We seek feedback from the research community and data network members.

Evaluation Policy

There are several classes of B(E2)↑ measurements:

- Model-independent measurements: lifetime(τ), Coulomb Excitation (including intermediate-energy), (γ,γ')
- Somewhat model-dependent measurements: (e,e′), muonic x-rays, Mössbauer
- Model-dependent measurements: inelastic scattering of light- and heavy-ions

Evaluation policy:

- Deduce model-independent B(E2) ↑ values
- Deduce combined B(E2) ↑ values : model-independent + Somewhat model-dependent
- Compile model-dependent values from inelastic scattering data

Adopted (Recommended) Values

Adopted values for Cr, Fe, Ni and Zn nuclei have been produced:

- Model-independent and combined B(E2) ↑ values
- Assigned 5% minimum uncertainty to most experiments.

Example of Cr adopted values (similar tables exist for Fe, Ni and Zn):

- Transition energy in keV
- B(E2) ↑ in e^2b^2 and W.u.
- τ in ps
- Deformation parameter β_2
- Comparison with Raman’s 2001 evaluation

Example: evaluated data for Cr nuclei

Table 1
Adopted (recommended) B(E2)↑-, τ- and β_2-values for Cr, Fe, Ni and Zn isotopes. Model-independent, combined (*) and model-dependent (**) values are compared with S. Raman *et al.* [2] evaluation.

Nuclide	$E_{2_1^+}$ (keV)	B(E2)↑ (e^2b^2)	B(E2)↑ (W.u.)	τ (ps)	β_2	B(E2)↑ [2] (e^2b^2)
^{46}Cr	892.16(10)	0.093(20)	19.0(41)	16.7(36)	0.288(31)	
^{48}Cr	752.19(11)	0.137(15)	26.4(29)	12.4(14)	0.340(19)	0.136(21)
^{50}Cr	783.30(9)	0.1057(23) 0.1034 (26)*	19.32(42) 18.90(48)*	13.10(29) 13.39(34)*	0.2903(32)	0.108(6)
^{52}Cr	1434.094(14)	0.0627(18) 0.0626(16)*	10.88(31) 10.85(27)*	1.073(30) 1.076(27)*	0.2179(31)	0.0660(30)
^{54}Cr	834.855(3)	0.0865(45) 0.0889(40)*	14.27(74) 14.67(66)*	11.63(61) 11.31(51)*	0.0250(65)	0.0870(40)
^{56}Cr	1006.61(20)	0.055(19)	8.7(30)	7.1(25)	0.195(34)	
^{58}Cr	880.7(2)	0.099(28)	14.8(42)	7.8(22)	0.254(37)	
^{60}Cr	646(1)	0.085(18)**	12.3(27)**	43(11)**	0.23(3)**	
^{62}Cr	447(4)	0.122(28)**	16.7(38)**	187(45)**	0.27(3)**	
^{64}Cr	420(7)					

Example: compiled data for Cr nuclei

Table 3
Experimental B(E2↑)-, τ- and β_2-values in Cr, Fe, Ni and Zn isotopes (^{s},^{d} or * - Superseded, duplicate or above the Coulomb barrier [13] experiments). Beam energy units are in MeV or (A)-MeV/nucleon. NSR keynumbers [14] are shown in the reference column.

Nuclide	B(E2) (e^2b^2)	τ (ps)	β_2	Target	Beam	Energy (MeV)	Method	Reference
^{46}Cr	0.093(20)			^{208}Pb	^{46}Cr	44 A	CE*	[2005Ya26]
^{48}Cr		10.6(11)		^{36}Ar	^{14}N	28-35	TRDM	[1979Ek03]
^{48}Cr		16.7(22)		^{34}S	^{16}O	30-36	TRDM	[1975Ha04]
^{48}Cr		9.7(26)		^{40}Ca	^{10}B	19-25	TRDM	[1973Ku10]
^{50}Cr		13.2(4)		^{12}C	^{50}Cr	110-120	CE*	[2000Er01]
^{50}Cr	0.093(5)			^{50}Cr	e-	30-400	EE	[1983Li02]
^{50}Cr	0.102(5)			^{50}Cr	^{32}S	62	CE*	[1975To06]
^{50}Cr		12.6(21)		^{40}Ca	^{16}O	47	TDSA	[1974Br04]
^{50}Cr		12.1(12)		^{40}Ca	^{12}C	28	TRDM	[1973De09]
^{50}Cr		10(2)		^{52}Cr	p	31.4	TDSA	[1972Ra14]
^{50}Cr	0.115(10)			^{50}Cr	^{35}Cl	54	CE	[1972Ra14]
^{50}Cr	0.092(10)			^{50}Cr	^{16}O/^{35}Cl	21-79	CE*	[1971DaZM]
^{50}Cr	0.115(8)			^{50}Cr	^{4}He		CE?	[1961Mc18]
^{52}Cr		1.13(3)		C	^{52}Cr	110-120	CE*	[2000Er01]
^{52}Cr	0.0632(40)			^{52}Cr	e-	30-400	EE	[1983Li02]
^{52}Cr	0.0687(13)			^{52}Cr	γ		GG	[1981Ah02]
^{52}Cr	0.080(8)			^{52}Cr	e-	90, 120, 226	EE	[1978Po04]
^{52}Cr	0.0634(39)			^{52}Cr	e-	40-110	EE	[1976Li19]
^{52}Cr	0.0660(30)			^{52}Cr	^{32}S	60	CE*	[1975To06]
^{52}Cr	0.076(8)			^{52}Cr	e-	50,60,80,90	EE	[1975DeXW]
^{52}Cr		0.86(13)		^{52}Cr	^{16}O/^{35}Cl	21-79	TDSA	[1972WaYZ]
^{52}Cr	0.071(9)			^{52}Cr	e-	150	EE	[1971Pe11]
^{52}Cr		0.99^{+45}_{-25}		^{51}V	^{3}He	11	TDSA	[1971Sp12]
^{52}Cr	0.072(8)			^{52}Cr	^{16}O/^{35}Cl	21-79	CE*	[1971DaZM]
^{52}Cr	0.043(9)			^{52}Cr	^{12}C	36.8	CE*	[1967Af03]
^{52}Cr	0.048(2)			^{52}Cr	^{16}O	31-41	CE*	[1965Si02]
^{52}Cr	0.0520(40)			^{52}Cr	e-	150-180	EE	[1964Be32]
^{52}Cr		1.02(13)		^{52}Cr	γ	0.5-3	GG	[1964Bo22]
^{52}Cr	0.073(7)			^{52}Cr	^{4}He		CE?	[1961Mc18]
^{52}Cr	0.060(15)			^{52}Cr	^{16}O	39	CE*	[1960Ad01]
^{52}Cr		0.8(2)		^{52}Cr	γ	¡2	GG	[1959Of14]
^{54}Cr	0.095(5)			^{54}Cr	e-	30-400	EE	[1983Li02]
^{54}Cr	0.0850(30)			^{54}Cr	^{32}S	62	CE*	[1975To06]
^{54}Cr	0.096(9)			^{54}Cr	^{35}Cl	54	CE	[1970MiZQ]
^{54}Cr	0.106(7)			^{54}Cr	^{4}He		CE?	[1961Mc18]
^{54}Cr	0.057(11)			^{54}Cr	^{14}N	16.3, 26	CE	[1960An07]
^{54}Cr	0.079(20)			^{54}Cr	^{14}N	15.9-35	CE	[1959Al95]
^{56}Cr	0.055(19)			^{197}Au	^{56}Cr	100 A	CE*	[2005Bu29]
^{58}Cr	0.099(28)			^{197}Au	^{58}Cr	100 A	CE*	[2005Bu29]
^{60}Cr			0.23(3)	p	^{60}Cr	63 A	IN-EL	[2009Ao01]
^{62}Cr			0.27(3)	p	^{62}Cr	63 A	IN-EL	[2009Ao01]

Shell-model Calculations

E(2^+) and B(E2; $0^+_1 \rightarrow 2^+_1$) values have been calculated using shell model with **GXPF1A** effective interaction; *pf* shell-valence space; "canonical" effective charges: 0.5e for neutrons and 1.5e for protons.

Ni(A=66-76) and Zn(A=70-78): *fpg* valence space; **JUN45** effective interaction; "canonical" effective charges: 1.1e for neutrons and 1.5e for protons.

Comparison with shell-model calculations for Cr nuclei

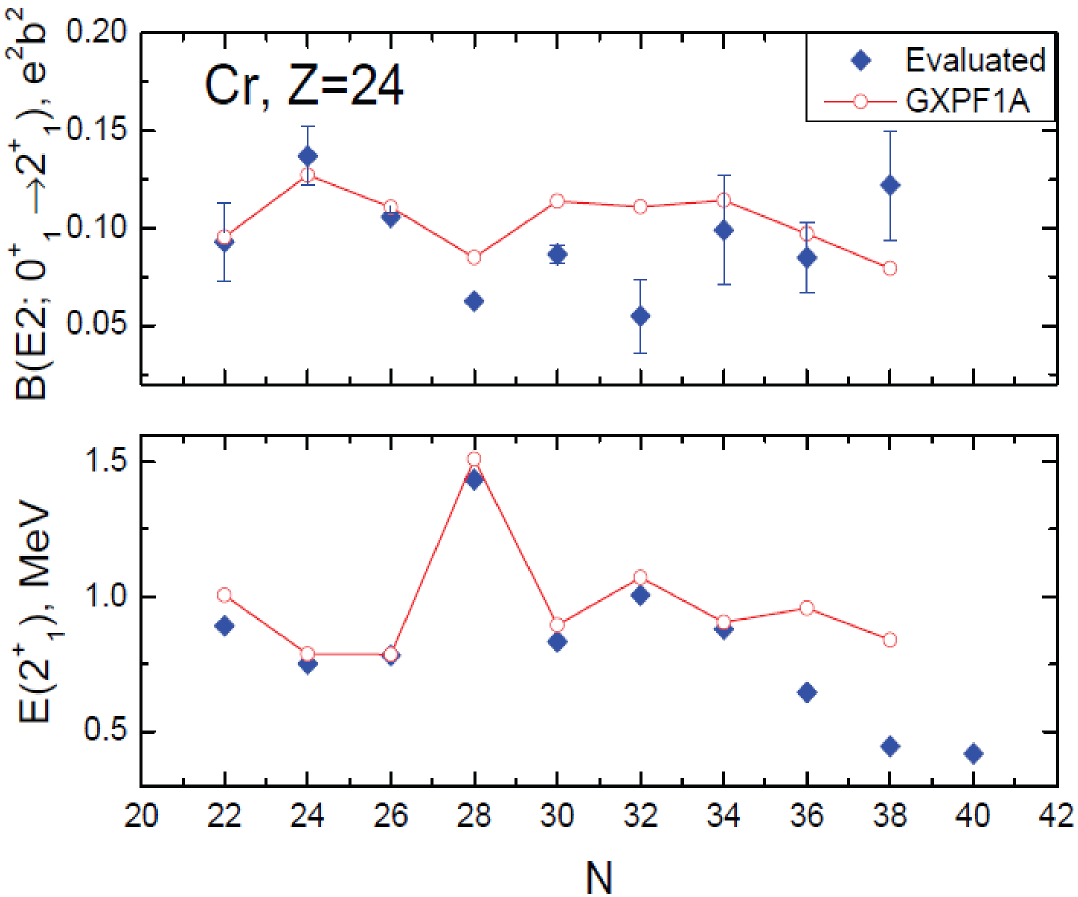

Fig. 1: Shell model calculated and evaluated energies, $E(2_1^+)$, and $B(E; 0_1^+ \rightarrow 2_1^+)$ values for Cr nuclei.

Synopsis

Cr (Z=24), Fe (Z=26), Ni(Z=28), Zn (Z=30):

Out of a total of 38 nuclei, data have been updated or newly included for 33 of these.

- For 18 nuclei: first measurements since 2001Ra27
- For 15 nuclides: newer measurements available since 2001Ra27, thus re-evaluation has been done.

Work is now in progress for Z=4-22 (Be to Ti)

Preprint of Z=24-30 is attached. Comments most welcome.

An Update of B(E2) Evaluation for $0_1^+ \rightarrow 2_1^+$ Transitions in Even-Even Nuclei near N∼Z∼28

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Abstract

An update of B(E2)↑ evaluation for even-even Cr, Fe, Ni and Zn nuclei has been presented. Current update is a continuation of S. Raman work on B(E2) values and was motivated by large numbers of new measurements. It extends the previous evaluation from 20 to 38 nuclei and includes comprehensive shell model analysis. Evaluation policies for analysis of experimental data have been discussed. Future plans for complete B(E2;$0_1^+ \rightarrow 2_1^+$) evaluation of even-even nuclei are outlined.

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Contents

1. Introduction

Quadrupole collectivities (reduced electric quadrupole transition rates) or B(E2) values play an important role in nuclear physics and are in high demand for nuclear model calculations. Originally, these values have been compiled by S. Raman *et al.* at the Oak Ridge Nuclear Data Project program [1, 2]. Presently this work continues within the U.S. Nuclear Data Program (USNDP). In 2005, Brookhaven B(E2)↑ project website (*http://www.nndc.bnl.gov/be2*) was successfully launched [3]; this website currently contains up-to-date compilation of B(E2;$0_1^+ \rightarrow 2_1^+$) experimental results and evaluated values from Raman [2] that are widely used by scientists.

With an advent of rare isotope facilities [4] the whole nuclear landscape has been changing dramatically. These facilities have been producing rare nuclei far from the valley of stability at an increasing rate and providing researchers with unprecedented opportunities to study their properties. In many cases, B(E2) values and energies of the low-lying states have been studied for the first time. Large amounts of new data, especially for A$\leq$100 region, require a new evaluation of quadrupole collectivities for proper interpretation and analysis of the newly-obtained values. A renewed interest in N$\sim$Z$\sim$28 B(E2) values has been expressed by participants of the International Nuclear Physics Conference (INPC 2010) in Vancouver (*http://inpc2010.triumf.ca*) [5].

To answer the need for a new B(E2)$\uparrow$ evaluation and seek comments from the research community, new evaluations of Cr, Fe, Ni and Zn isotopes has been completed. The complete evaluation of B(E2;$0_1^+ \rightarrow 2_1^+$) for all even-even nuclei would follow thereafter based on our experience and the feedback from the users.

2. B(E2) Evaluation Policies

Present evaluation is based on results published prior to January 2011 and includes evaluated B(E2;$0_1^+ \rightarrow 2_1^+$) values in e^2b^2, lifetimes (τ) in ps and deformation parameters (β_2). To introduce an additional measure of collectivity for nuclear excitations, B(E2) values in Weisskopf units (W.u.) are added; not included into current evaluation transition quadrupole moment values Q_0 can be easily deduced by the user as follows

$$Q_0 = [16\pi B(E2) \uparrow /5e^2]^{1/2} \qquad (1)$$

There are several classes of measurements that are often used to deduce B(E2)$\uparrow$ values:

- Model-independent measurements: lifetime(τ), Low-Energy (LE) and Intermediate-Energy (IE) Coulomb excitation and γ,γ'.
- Low model-dependent measurements: e,e$'$, muon x-rays, Mössbauer.
- Model-dependent measurements: inelastic scattering of light and heavy ions.

These measurements were used to produce adopted (recommended) B(E2;$0_1^+ \rightarrow 2_1^+$)values as follows:

1) Compile all measurements of τ, Coulomb, γ,γ', e,e$'$, muon x-rays, Mössbauer, inelastic scattering of light and heavy ions without any changes or modifications.

2) Convert B(E2), τ and β_2 into B(E2)$\uparrow$ in e^2b^2.

3) Analyze B(E2)$\uparrow$ values and assign minimum uncertainty of 5% to experiments with small or no uncertainty. Often such adjustments are made after consultation with the authors.

4) Round uncertainties to two significant digits.

5) Select primary (model-independent) and combined (model-independent and low model-dependent) data sets.

6) Deduce B(E2)$\uparrow$ adopted values with AveTools software package [6] using the selected data sets.

3. Adopted B(E2) values

Current project adopted or recommended values for Cr, Fe and Ni isotopes are shown in Table 1. It includes 16 new recommended values for ^{46,56,58}Cr, ^{50,52,62,64,66}Fe, ^{54,70,74}Ni, ^{72,74,76,78,80}Zn compared to the previous evaluation of S. Raman *et al.* [2].

In the current evaluation we used the latest AveTools averaging procedures [6], Band-Raman calculation of Internal conversion coefficients (α) [7] while S. Raman *et al.* [2] used the older Hager-Seltzer Internal conversion coefficients (HSICC) code [8]. These coefficients, older averaging procedures and the addition of recent experimental results could explain differences between current work and S. Raman *et al.* [2]. These values are interpreted within the shell model and experimental results which are presented in the following sections.

4. Shell Model Calculations

The 2^+ excitation energies and B(E2) for $0_1^+ \rightarrow 2_1^+$ transitions have been calculated in the pf-shell valence space using the GXPF1A effective interaction [9]. GXPF1A is a refinement of the original GXPF1A Hamiltonian [10], which was obtained starting with the G-matrix for the Bonn-C two-body potential and by further fine-tuning its matrix elements to describe the energies of about 700 selected states of pf-shell nuclei. GXPF1 Hamiltonian does not describe very well the 2^+ state in ^{54}Ti (N=34). Therefore, five of its matrix elements were change to fix this discrepancy, leading to the GXPF1A Hamiltonian [9]. GXPF1A predicts the 2^+ state in ^{58}Cr (N=36) at higher energy than that seen in the experimental data, but one would not expect to get reliable energies when the number of neutrons is close to the limits of the pf-shell (N=40). Results for Cr, Fe, Ni and Zn nuclei using the "canonical" effective charges, 0.5e for neutrons and 1.5e for protons, are shown in Table 2 and Fig. 1-4.

The missing values for ^{66}Fe, ^{68,70,74}Ni, ^{72,74,76,78,80}Zn are due to the limitations of the valence space and of the GXPF1A effective interaction. In the pf-shell one cannot have more than 20 valence protons and 20 valence neutrons on top of the ^{40}Ca core. Even when N is too close to the limit (N=40) the result are not reliable, due to the increasing importance of the intruder states ($g_{9/2}$), which create an "island of inversion" [11]. Therefore, for the heavy isotopes of Ni and Zn we performed shell model calculations in the $f_{5/2}, p_{3/2}, p_{1/2}, g_{9/2}$ valence space using the JUN45 effective interaction [12]. Results obtained using the effective charges recommended in Ref. [12] for this model space, e_p=1.5e and e_n=1.1e, are shown in Table 2.

5. Experimental B(E2) values

Experimental values of B(E2), τ and β_2 are shown in Table 3. To create a more comprehensive picture for each experiment we extended the scope of the previous work of S. Raman *et al.* [2] and include target, beam, beam energy and Coulomb barrier height into compilation. A short review of the most recent experimental results that were used for production of new evaluated values is presented below.

5.1. ^{46}Cr, ^{50}Fe, ^{54}Ni:

To complete systematics in the $N = Z = 28$ region, B(E2;$0_1^+ \rightarrow 2_1^+$) values of 0.093(20), 0.140(30) and 0.059(17) e^2b^2 have been reported in intermediate-energy Coulomb excitation of ^{46}Cr, ^{50}Fe, ^{54}Ni [2005Ya26], respectively.

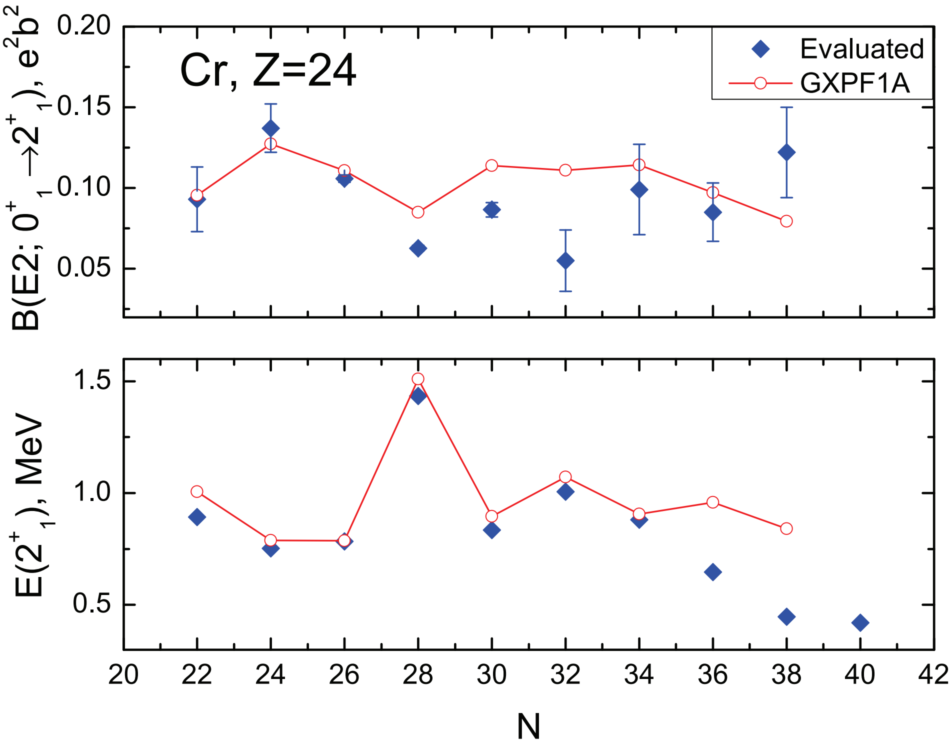

Fig. 1: Shell model calculated and evaluated energies, E(2_1^+), and B(E; $0_1^+ \rightarrow 2_1^+$) values for Cr nuclei.

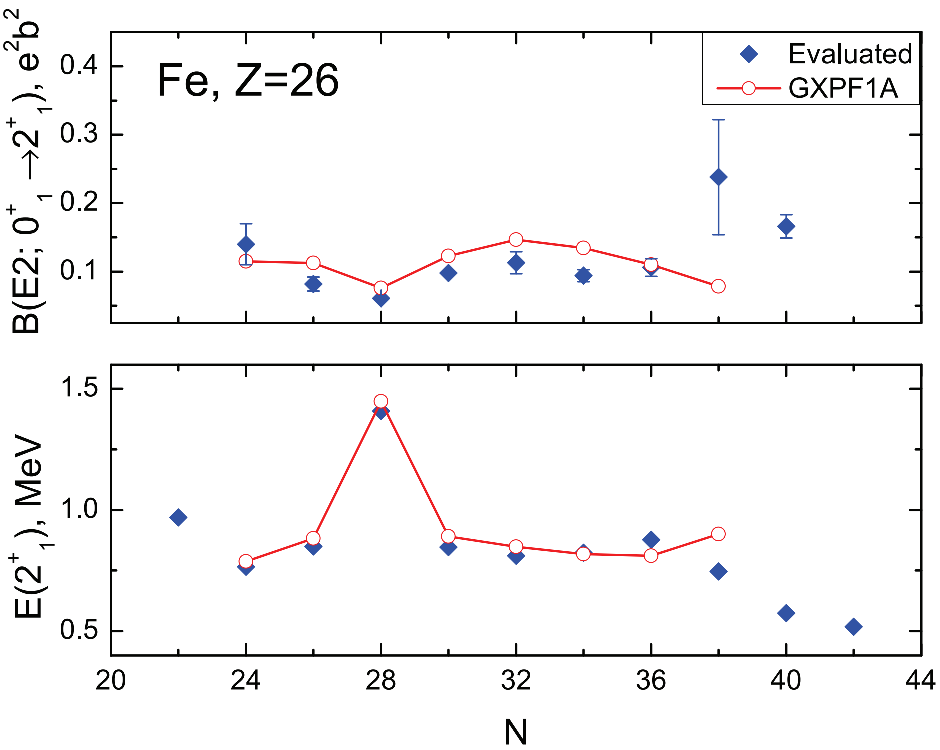

Fig. 2: Shell model calculated and evaluated energies, E(2_1^+), and B(E; $0_1^+ \rightarrow 2_1^+$) values for Fe nuclei.

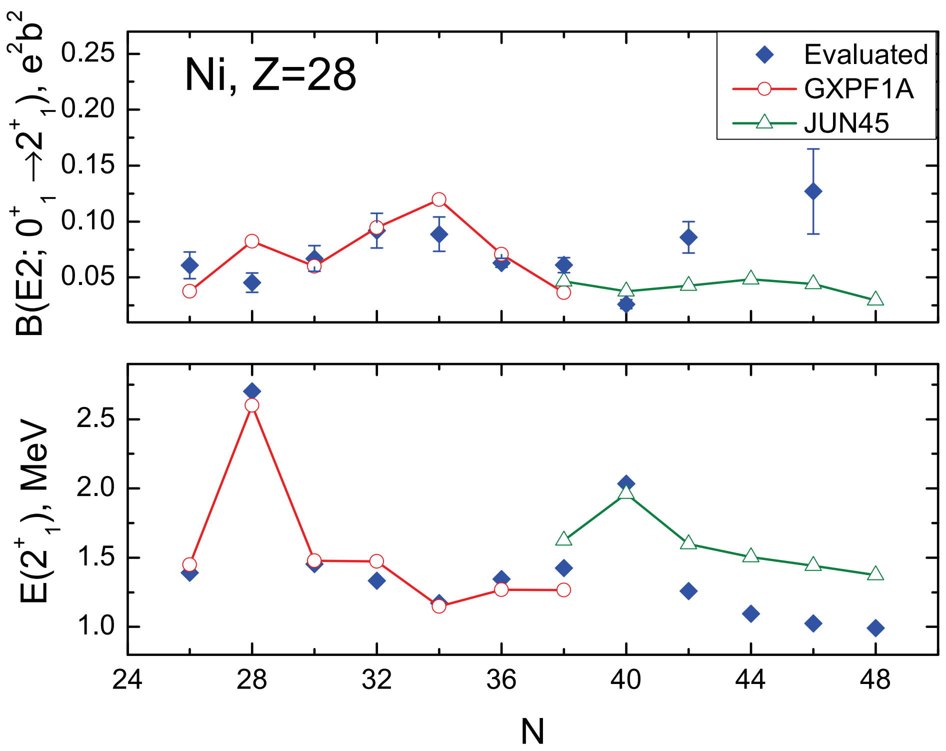

Fig. 3: Shell model calculated and evaluated energies, $E(2_1^+)$, and $B(E; 0_1^+ \rightarrow 2_1^+)$ values for Ni nuclei.

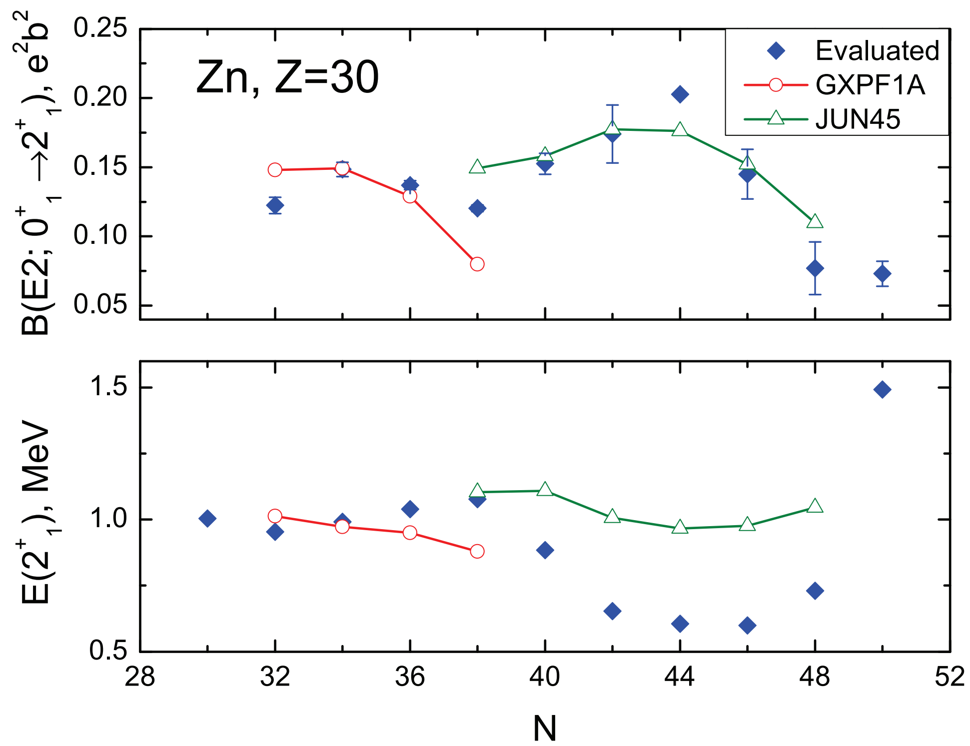

Fig. 4: Shell model calculated and evaluated energies, $E(2_1^+)$, and $B(E; 0_1^+ \rightarrow 2_1^+)$ values for Zn nuclei.

5.2. ^{54,56,58}Cr:

Relativistic Coulomb excitation B(E2) values of ^{54,56,58}Cr are 14.6(0.6), 8.7(3.0) and 14.8(4.2) W.u., respectively, have been measured by the RISING collaboration [2005Bu29]. These results agree well with the shell model calculation based on GXPF1A and GXPF1 effective interactions [9, 10].

5.3. ^{60,62}Cr:

Deformation length and quadrupole deformation parameter have been measured in inelastic scattering of Chromium on Hydrogen [2009Ao01]. These data provide evidence for enhanced collectivity in chromium nuclei.

5.4. ^{52}Fe:

Intermediate-energy Coulomb excitation measurement at MSU [2004Yu07] has produced B(E2;$0^+_1 \rightarrow 2^+_1$) values of 0.082(10) e^{2}b^2. The increase in B(E2) strength with respect to the even-mass neighbor ^{54}Fe agrees with shell model calculations as the magic number N=28 is approached.

5.5. ^{62,64,66}Fe:

The ^{62,64}Fe lifetimes of 7.4(9) and 7.4(26) ps [2010Lj01], have been originally reported by GANIL group using the recoil-distance Doppler shift method after multinucleon transfer reactions in inverse kinematics. These results collaborate with a recent MSU measurement of 8.0(10), 10.3(10), 39.0(40) ps for ^{62,64,66}Fe [2011Ro02], respectively. The deduced B(E2) strengths demonstrate the enhanced collectivity of the neutron-rich Fe isotopes up to $N = 40$. Note that both use plunger method.

5.6. ^{70}Ni:

The reduced transition probabilities B(E2;$0^+_1 \rightarrow 2^+_1$) of 0.086(14) e^{2}b^2 [2006Pe13] for the neutron-rich ^{70}Ni nucleus has been measured by Coulomb excitation in a ^{208}Pb target at intermediate energy. The current B(E2) value for ^{70}Ni is unexpectedly large, which may indicate that neutrons added above $N = 40$ strongly polarize the $Z = 28$ proton core.

5.7. ^{74}Ni:

Deformation length and quadrupole deformation parameter have been measured in inelastic scattering of ^{74}Ni on Hydrogen [2010Ao01]. Results of this experiment indicate that that the magic character of $Z = 28$ or $N = 50$ is weakened in ^{74}Ni.

5.8. ^{72}Zn:

The reduced transition probabilities B(E2;$0^+_1 \rightarrow 2^+_1$) of 0.174(21) e^{2}b^2 [2002Le17] for ^{72}Zn nucleus has been measured by Coulomb excitation at intermediate energy. This result is consistent with the expectations derived from the neighboring nucleus ^{73}Zn and indicates that the behavior of B(E2) strengths around the $N = 40$ sub-shell closure in Zn is very different from the Ni isotopic chains.

5.9. ^{74}Zn:

The reduced transition probabilities B(E2;$0_1^+ \rightarrow 2_1^+$) of 0.204(15) e^2b^2 [2006Pe13] for the neutron-rich ^{74}Zn nucleus has been measured by Coulomb excitation in a ^{208}Pb target at intermediate energy. This result agrees well with 0.201(16) e^2b^2 value measured at REX-ISOLDE [2007Va20].

5.10. $^{76,78,80}Zn$:

The reduced transition probabilities B(E2;$0_1^+ \rightarrow 2_1^+$) of 0.145(18), 0.077(19) and 0.073(9) e^2b^2 for ^{76,78,80}Zn have been reported by REX-ISOLDE group [2007Va20, 2009Va01] using low-energy Coulomb excitation. The present data indicate a need for large-scale shell-model calculations.

6. Conclusion & Outlook

New B(E2) evaluation of even-even Cr, Fe, Ni and Zn isotopes has been performed under the auspices of the USNDP with an intention to update B(E2;$0_1^+ \rightarrow 2_1^+$) values and collect nuclear data user feedback. It is a continuation of S. Raman work on transition probabilities from the ground to the first-excited 2^+ state of even-even nuclides [1, 2]. The update is based on all published data prior to January 2011 and includes new experimental B(E2) values for 33 out of 38 nuclei. It extends evaluated data in the N$\sim$Z$\sim$28 region from 20 to 38 nuclei. These results are compared with the large-scale shell model calculations. A complete evaluation of quadrupole collectivities based on best nuclear data evaluation practices and user responses will follow.

7. Acknowledgments

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Explanation of Tables

Table 1. Adopted (recommended) B(E2)↑-, τ- and β_2-values for Cr, Fe, Ni and Zn isotopes.

(Throughout this table, bracketed numbers refer to the uncertainties in the last digits of the quoted values.)

Nuclide	The even Z, even N nuclide studied
E(level)	Energy of the first excited 2^+ state in keV either from a compilation or from current literature
$B(E2)\uparrow$	Reduced electric quadrupole transition rate for the ground state to 2^+ state transition in units of e^2b^2
τ	Mean lifetime of the state in ps $\tau = 40.81 \times 10^{13} E^{-5} [B(E2)\uparrow /e^2b^2]^{-1}(1+\alpha)^{-1}$, where α - Band-Raman internal conversion coefficients
β_2	Quadrupole deformation parameter $\beta_2 = (4\pi/3ZR_0^2)[B(E2)\uparrow /e^2]^{1/2}$, where $R_0^2 = (1.2 \times 10^{-13} A^{1/3} \mathrm{cm})^2$ $= 0.0144 A^{2/3}$b

Table 2. Shell model E(2_1^+)-, B(E2↑)-values for Cr, Fe, Ni and Zn isotopes.

Nuclide	The even Z, even N nuclide studied
E(level)	Energy of the first excited 2^+ state in MeV
$B(E2)\uparrow$	Reduced electric quadrupole transition rate for the ground state to 2^+ state transition in units of e^2b^2

Table 3. Experimental B(E2↑)-, τ- and β_2-values in Cr, Fe, Ni and Zn isotopes.

(Throughout this table, bracketed numbers refer to the uncertainties in the last digits of the quoted values.)

Nuclide	The even Z, even N nuclide studied
$B(E2)\uparrow$	Reduced electric quadrupole transition rate for the ground state to 2^+ state transition in units of e^2b^2
τ	Mean lifetime of the state in ps
β_2	Quadrupole deformation parameter
Target	Target nuclide
Beam	Incident beam
Energy	Incident beam energy
Method	CE: Coulomb excitation
	CE*: Coulomb excitation with beam energy above the Coulomb barrier
	Inel. Scatt.: Inelastic scattering of light and heavy ions
	TDSA: Doppler shift attenuation
	TCS: Time coincidences
	γ,γ': Resonance fluorescence
	e,e′: Inelastic electron scattering
Reference	NSR database [14] keynumber

Table 1
Adopted (recommended) B(E2)↑-, τ- and β_2-values for Cr, Fe, Ni and Zn isotopes. Model-independent, combined (*) and model-dependent (**) values are compared with S. Raman *et al.* [2] evaluation.

Nuclide	$E_{2_1^+}$ (keV)	**B(E2)↑** (e^2b^2)	(W.u.)	τ (ps)	β_2	**B(E2)↑** [2] (e^2b^2)
^{46}Cr	892.16(10)	0.093(20)	19.0(41)	16.7(36)	0.288(31)	
^{48}Cr	752.19(11)	0.137(15)	26.4(29)	12.4(14)	0.340(19)	0.136(21)
^{50}Cr	783.30(9)	0.1057(23) 0.1034 (26)*	19.32(42) 18.90(48)*	13.10(29) 13.39(34)*	0.2903(32)	0.108(6)
^{52}Cr	1434.094(14)	0.0627(18) 0.0626(16)*	10.88(31) 10.85(27)*	1.073(30) 1.076(27)*	0.2179(31)	0.0660(30)
^{54}Cr	834.855(3)	0.0865(45) 0.0889(40)*	14.27(74) 14.67(66)*	11.63(61) 11.31(51)*	0.0250(65)	0.0870(40)
^{56}Cr	1006.61(20)	0.055(19)	8.7(30)	7.1(25)	0.195(34)	
^{58}Cr	880.7(2)	0.099(28)	14.8(42)	7.8(22)	0.254(37)	
^{60}Cr	646(1)	0.085(18)**	12.3(27)**	43(11)**	0.23(3)**	
^{62}Cr	447(4)	0.122(28)**	16.7(38)**	187(45)**	0.27(3)**	
^{64}Cr	420(7)					
^{48}Fe	969.5(5)					
^{50}Fe	765.0(10)	0.140(30)*	25.6(55)*	11.1(24)*	0.308(33)	
^{52}Fe	849.45(10)	0.082(10)*	14.2(18)*	11.3(14)*	0.230(14)	
^{54}Fe	1408.19(19)	0.0608 (31) 0.0542(18)*	10.0(5) 8.94(30)*	1.21(6) 1.36(5)*	0.193(5)	0.062(5)
^{56}Fe	846.776(5)	0.0981(20) 0.0954(27)*	15.4(3) 15.0(4)*	9.56(19) 9.83(28)*	0.239(2)	0.0980(40)
^{58}Fe	810.7662(20)	0.113(16) 0.0932(76)*	16.9(24) 14.0(11)*	10.4(15) 12.5(10)*	0.250(18)	0.1200(40)
^{60}Fe	823.63(15)	0.0938(88)	13.4(13)	11.5(11)	0.224(10)	0.096(18)

Table 1 Adopted (recommended) B(E2)↑-, τ- and β_2-values for Cr, Fe, Ni and Zn isotopes (continued).

Nuclide	$E_{2_1^+}$ (keV)	**B(E2)↑** (e^2b^2)	(W.u.)	τ (ps)	β_2	**B(E2)↑** [2] (e^2b^2)
^{62}Fe	876.8(3)	0.1028(90)	14.1(12)	7.67(67)	0.229(10)	
^{64}Fe	746.40(10)	0.178(17)	23.4(22)	9.93(97)	0.295(15)	
^{66}Fe	574.4(10)	0.166(17)	21.0(21)	39.4(40)	0.280(15)	
^{68}Fe	517(6)?					
^{54}Ni	1392.3(4)	0.061(12)	10.0(20)	1.28(25)	0.179(18)	
^{56}Ni	2700.6(7)	0.0453(86) 0.0502(70)*	7.1(13) 7.9(11)*	0.062(13) 0.057(8)*	0.151(14)	0.060(12)
^{58}Ni	1454.21(9)	0.0669(12) 0.0647(10)*	10.04(17) 9.75(15)*	0.938(16) 0.966(15)*	0.1794(15)	0.0695(20)
^{60}Ni	1332.518(5)	0.0919(16) 0.0892(16)*	13.17(22) 12.78(23)*	1.057(18) 1.090(20)*	0.2055(17)	0.0933(15)
^{62}Ni	1172.91(9)	0.0887(15) 0.08793(89)*	12.17(21) 12.07(12)*	2.073(36) 2.091(21)*	0.1975(17)	0.0890(25)
^{64}Ni	1345.75(5)	0.063(4) 0.066(3)*	8.3(5) 8.7(4)*	1.47(9) 1.40(6)*	0.163(5)	0.076(8)
^{66}Ni	1424.8(10)	0.0611(67)	7.71(85)	1.14(12)	0.157(9)	0.062(9)
^{68}Ni	2034.07(17)	0.0260 (40)	3.15(49)	0.451(69)	0.101(8)	0.026(6)
^{70}Ni	1259.6(2)	0.086(14)	10.0(16)	1.50(24)	0.179(15)	
^{72}Ni	1096.0(20)					
^{74}Ni	1024(1)	0.127(38)**	13.8(41)**	2.86(85)**	0.21(3)**	
^{76}Ni	992(2)					

Table 1 Adopted (recommended) B(E2)↑-, τ- and β_2-values for Cr, Fe, Ni and Zn isotopes (continued).

Nuclide	$E_{2_1^+}$ (keV)	**B(E2)↑** (e^2b^2)	(W.u.)	τ (ps)	β_2	**B(E2)↑** [2] (e^2b^2)
^{60}Zn	1003.9(2)					
^{62}Zn	954.0(4)	0.1224(59) 0.1224(59)*	16.79(81) 16.79(81)*	4.22(20) 4.22(20)*	0.2166(52)	0.124(9)
^{64}Zn	991.56(5)	0.1484(52) 0.1519(43)*	19.52(68) 19.98(57)*	2.87(10) 2.803(79)*	0.2335(41)	0.160(15)
^{66}Zn	1039.2279(21)	0.1370(33) 0.1389(31)*	17.29(42) 17.53(39)*	2.458(59) 2.424(54)*	0.2198(26)	0.135(10)
^{68}Zn	1077.37(4)	0.1203(25) 0.1198(28)*	14.59(30) 14.53(34))	2.337(49) 2.347(55)*	0.2019(21)	0.124(15)
^{70}Zn	884.46(8)	0.1525(75) 0.169(14)*	17.80(88) 19.7(16)*	4.93(24) 4.45(37)*	0.2229(55)	0.160(14)
^{72}Zn	652.70(5)	0.174(21)	19.6(24)	19.8(24)	0.234(14)	
^{74}Zn	605.9(8)	0.2026(15)	21.96(16)	24.65(18)	0.24761(91)	
^{76}Zn	598.68(10)	0.145(18)	15.2(19)	36.6(45)	0.206(12)	
^{78}Zn	730.2(4)	0.077(19)	7.8(19)	25.5(63)	0.147(18)	
^{80}Zn	1492(1)	0.073(9)	7.1(9)	0.76(9)	0.141(9)	

Table 2
Shell model $E(2_1^+)$-, $B(E2)\uparrow$-values for Cr, Fe, Ni and Zn isotopes.

Nuclide	GXPF1A effective interaction [9]		JUN45 effective interaction [12]	
	$\mathbf{E(2_1^+)}$ **(MeV)**	$\mathbf{B(E2)}\uparrow$ (e^2b^2)	$\mathbf{E(2_1^+)}$ **(MeV)**	$\mathbf{B(E2)}\uparrow$ (e^2b^2)
^{46}Cr	1.0054	0.0955		
^{48}Cr	0.7887	0.1273		
^{50}Cr	0.7872	0.1107		
^{52}Cr	1.5101	0.0849		
^{54}Cr	0.8949	0.1138		
^{56}Cr	1.0715	0.1109		
^{58}Cr	0.9062	0.1143		
^{60}Cr	0.958	0.0972		
^{62}Cr	0.840	0.0793		
^{50}Fe	0.787	0.1151		
^{52}Fe	0.883	0.1124		
^{54}Fe	1.4483	0.0761		
^{56}Fe	0.8903	0.1228		
^{58}Fe	0.8478	0.1468		
^{60}Fe	0.8173	0.1345		
^{62}Fe	0.8114	0.1101		
^{64}Fe	0.9008	0.0784		
^{66}Fe				
^{54}Ni	1.448	0.0375		
^{56}Ni	2.599	0.0823		
^{58}Ni	1.478	0.0599		
^{60}Ni	1.474	0.0946		
^{62}Ni	1.149	0.1195		
^{64}Ni	1.268	0.0706		
^{66}Ni	1.265	0.0365	1.624	0.0464
^{68}Ni			1.963	0.0376
^{70}Ni			1.599	0.0427
^{72}Ni			1.505	0.0483
^{74}Ni			1.442	0.0440
^{76}Ni			1.374	0.0296
^{62}Zn	1.013	0.1479		
^{64}Zn	0.973	0.1492		
^{66}Zn	0.950	0.1290		
^{68}Zn	0.879	0.0799	1.104	0.1493
^{70}Zn			1.109	0.1581
^{72}Zn			1.007	0.1773
^{74}Zn			0.966	0.1763
^{76}Zn			0.976	0.1521
^{78}Zn			1.045	0.1097
^{80}Zn				

Table 3
Experimental B(E2↑)-, τ- and β_2-values in Cr, Fe, Ni and Zn isotopes (^{s},^{d} or * - Superseded, duplicate or above the Coulomb barrier [13] experiments). Beam energy units are in MeV or (A)-MeV/nucleon. NSR keynumbers [14] are shown in the reference column.

Nuclide	**B(E2)** (e^2b^2)	τ (ps)	β_2	**Target**	**Beam**	**Energy** (MeV)	**Method**	**Reference**
^{46}Cr	0.093(20)			^{208}Pb	^{46}Cr	44 A	CE*	[2005Ya26]
^{48}Cr		10.6(11)		^{36}Ar	^{14}N	28-35	TRDM	[1979Ek03]
^{48}Cr		16.7(22)		^{34}S	^{16}O	30-36	TRDM	[1975Ha04]
^{48}Cr		9.7(26)		^{40}Ca	^{10}B	19-25	TRDM	[1973Ku10]
^{50}Cr		13.2(4)		^{12}C	^{50}Cr	110-120	CE*	[2000Er01]
^{50}Cr	0.093(5)			^{50}Cr	e-	30-400	EE	[1983Li02]
^{50}Cr	0.102(5)			^{50}Cr	^{32}S	62	CE*	[1975To06]
^{50}Cr		12.6(21)		^{40}Ca	^{16}O	47	TDSA	[1974Br04]
^{50}Cr		12.1(12)		^{40}Ca	^{12}C	28	TRDM	[1973De09]
^{50}Cr		10(2)		^{52}Cr	p	31.4	TDSA	[1972Ra14]
^{50}Cr	0.115(10)			^{50}Cr	^{35}Cl	54	CE	[1972Ra14]
^{50}Cr	0.092(10)			^{50}Cr	^{16}O/^{35}Cl	21-79	CE*	[1971DaZM]
^{50}Cr	0.115(8)			^{50}Cr	^{4}He		CE?	[1961Mc18]
^{52}Cr		1.13(3)		C	^{52}Cr	110-120	CE*	[2000Er01]
^{52}Cr	0.0632(40)			^{52}Cr	e-	30-400	EE	[1983Li02]
^{52}Cr	0.0687(13)			^{52}Cr	γ		GG	[1981Ah02]
^{52}Cr	0.080(8)			^{52}Cr	e-	90, 120, 226	EE	[1978Po04]
^{52}Cr	0.0634(39)			^{52}Cr	e-	40-110	EE	[1976Li19]
^{52}Cr	0.0660(30)			^{52}Cr	^{32}S	60	CE*	[1975To06]
^{52}Cr	0.076(8)			^{52}Cr	e-	50,60,80,90	EE	[1975DeXW]
^{52}Cr		0.86(13)		^{52}Cr	^{16}O/^{35}Cl	21-79	TDSA	[1972WaYZ]
^{52}Cr	0.071(9)			^{52}Cr	e-	150	EE	[1971Pe11]
^{52}Cr		0.99^{+45}_{-25}		^{51}V	^{3}He	11	TDSA	[1971Sp12]
^{52}Cr	0.072(8)			^{52}Cr	^{16}O/^{35}Cl	21-79	CE*	[1971DaZM]
^{52}Cr	0.043(9)			^{52}Cr	^{12}C	36.8	CE*	[1967Af03]
^{52}Cr	0.048(2)			^{52}Cr	^{16}O	31-41	CE*	[1965Si02]
^{52}Cr	0.0520(40)			^{52}Cr	e-	150-180	EE	[1964Be32]
^{52}Cr		1.02(13)		^{52}Cr	γ	0.5-3	GG	[1964Bo22]
^{52}Cr	0.073(7)			^{52}Cr	^{4}He		CE?	[1961Mc18]
^{52}Cr	0.060(15)			^{52}Cr	^{16}O	39	CE*	[1960Ad01]
^{52}Cr		0.8(2)		^{52}Cr	γ	<2	GG	[1959Of14]
^{54}Cr	0.095(5)			^{54}Cr	e-	30-400	EE	[1983Li02]
^{54}Cr	0.0850(30)			^{54}Cr	^{32}S	62	CE*	[1975To06]
^{54}Cr	0.096(9)			^{54}Cr	^{35}Cl	54	CE	[1970MiZQ]
^{54}Cr	0.106(7)			^{54}Cr	^{4}He		CE?	[1961Mc18]
^{54}Cr	0.057(11)			^{54}Cr	^{14}N	16.3, 26	CE	[1960An07]
^{54}Cr	0.079(20)			^{54}Cr	^{14}N	15.9-35	CE	[1959Al95]
^{56}Cr	0.055(19)			^{197}Au	^{56}Cr	100 A	CE*	[2005Bu29]
^{58}Cr	0.099(28)			^{197}Au	^{58}Cr	100 A	CE*	[2005Bu29]
^{60}Cr			0.23(3)	p	^{60}Cr	63 A	IN-EL	[2009Ao01]
^{62}Cr			0.27(3)	p	^{62}Cr	63 A	IN-EL	[2009Ao01]
^{50}Fe	0.140(30)			Pb	^{50}Fe	41 A	CE*	[2005Ya26]
^{52}Fe	0.082(10)			^{197}Au	^{52}Fe	56.9 A	CE*	[2004Yu07]
^{54}Fe	0.0676(38)			^{54}Fe	^{40}Ca	86*	CE	[1981Le02]
^{54}Fe	0.060(6)			^{54}Fe	e-	50,60,80,90	EE	[1975DeXW]
^{54}Fe		1.10^{+50}_{-32}		^{54}Fe	p	10	TDSA	[1972Mo31]
^{54}Fe		0.95(14)		^{54}Fe	^{16}O/^{35}Cl	21-30; 60-79	TDSA	[1972WaYZ]
^{54}Fe	0.0532(33)			^{54}Fe	e-	150, 225	EE	[1972Li28]
^{54}Fe	0.0595(60)			^{54}Fe	^{16}O/^{35}Cl	21-30; 60-79	CE*	[1971DaZM]
^{54}Fe	0.061(14)			^{54}Fe	^{12}C	36.8	CE*	[1967Af03]
^{54}Fe	0.051(2)			^{54}Fe	^{16}O	38.1	CE*	[1965Si02]
^{54}Fe	0.0533(24)			^{54}Fe	e-	150	EE	[1962Be18]
^{56}Fe	0.1022(55)			^{12}C/^{56}Fe	^{52}Cr	22, 110-120	CE*	[1981Le02]
^{56}Fe		7.9(12)		^{51}V	^{7}Li	25	Recoil	[1974Po15]
^{56}Fe	0.111(6)			^{56}Fe	^{4}He/^{16}O	7.5-30	CE	[1972Ca05]
^{56}Fe	0.0970(20)			^{56}Fe	^{32}S	65	CE*	[1972Le19]
^{56}Fe	0.0678(48)			^{56}Fe	e-	150, 225	EE	[1972Li28]
^{56}Fe	0.0945(45)			^{56}Fe	e-	299.5	EE	[1971He08]
^{56}Fe	0.118(12)			^{56}Fe	^{16}O/^{35}Cl	21-30; 60-79	CE*	[1971DaZM]
^{56}Fe	0.125(27)			^{56}Fe	e-	60.2	EE	[1970Pe15]
^{56}Fe		10.3(20)		^{56}Fe	^{16}O	14-35	TDSA	[1969Sp05]
^{56}Fe		11.3^{+40}_{-24}		^{56}Fe	^{16}O	34	TDSA	[1965Es01]
^{56}Fe	0.097(10)			^{56}Fe	^{16}O	33	CE*	[1964El03]
^{56}Fe		8.5(29)		^{56}Fe	γ	0.5-3	GG	[1964Bo22]
^{56}Fe		9.6(18)		^{56}Fe	γ	0.845-3.2	GG	[1963Be29]

Table 3 (continued)

Nuclide	**B(E2)** (e^2b^2)	τ (ps)	β_2	**Target**	**Beam**	**Energy** (MeV)	**Method**	**Reference**
^{56}Fe	0.0720(35)			^{56}Fe	e-	150	EE	[1962Be18]
^{56}Fe		10.6(17)		^{56}Fe	γ		GG	[1961Me11]
^{56}Fe		8.6(29)		^{56}Fe	γ		GG	[1961Ke06]
^{56}Fe	0.100(20)			^{56}Fe	^{16}O	27	CE	[1960Go08]
^{56}Fe	0.061(12)			^{56}Fe	^{14}N	16.3, 36	CE*	[1960An07]
^{56}Fe	0.100(25)			^{56}Fe	^{16}O	39	CE*	[1960Ad01]
^{56}Fe	0.070(18)			^{56}Fe	N	15.9-35	CE*	[1959Al95]
^{56}Fe	0.100(20)			^{56}Fe	^{4}He	6	CE	[1956Te26]
^{58}Fe	0.1234(36)			^{58}Fe	^{12}C/^{52}Cr	22, 110-120	CE*	[1981Le02]
^{58}Fe		3.4^{+10}_{-9}		^{58}Fe	^{4}He	10	TDSA	[1978Bo35]
^{58}Fe	0.086(5)			^{58}Fe	^{40}Ca	76	CE*	[1974ToZJ]
^{58}Fe	0.094(8)			^{58}Fe	e-	150, 225	EE	[1972Li28]
^{58}Fe	0.110(22)			^{58}Fe	^{14}N	16.3	CE	[1960An07]
^{58}Fe	0.20(5)			^{58}Fe	N	15.9-35	CE*	[1959Al95]
^{60}Fe		11.4(12)		^{64}Ni	^{238}U	6.5 A	Recoil	[2010Lj01]
^{60}Fe		11.6(22)		^{48}Ca	^{15}N/^{18}O	25-55	Recoil	[1977Wa10]
^{62}Fe		8.0(10)		^{197}Au	^{62}Fe	97.8 A	Recoil	[2011Ro02]
^{62}Fe		7.4(9)		^{64}Ni	^{238}U	6.5 A	Recoil	[2010Lj01]
^{64}Fe		10.3(10)		^{197}Au	^{64}Fe	95 A	Recoil	[2011Ro02]
^{64}Fe		7.4(26)		^{64}Ni	^{238}U	6.5 A	Recoil	[2010Lj01]
^{66}Fe		39.4(40)		^{197}Au	^{66}Fe	88.3 A	Recoil	[2011Ro02]
^{54}Ni	0.059(17)			Pb	^{54}Ni	42 A	CE*	[2005Ya26]
^{54}Ni	0.063(17)			^{197}Au	^{54}Ni	70.3 A	CE*	[2004Yu10]
^{56}Ni	0.049(12)			^{197}Au	^{56}Ni	85.8 A	CE*	[2004Yu10]
^{56}Ni			0.144(34)	^{208}Pb	^{56}Ni	70.7 A	CE*	[1998YaZR]
^{56}Ni	0.060(12)			^{1}H	^{56}Ni	101 A	IN-EL	[1995Kr17]
^{56}Ni		0.076^{+49}_{-24}		^{54}Fe	^{3}He	10	TDSA	[1973Sc28]
^{58}Ni	0.0662(50)			^{58}Ni	^{6}Li	240	IN-EL	[2010Kr01]
^{58}Ni	0.0728(50)			^{58}Ni	^{6}Li	240	IN-EL	[2010Kr01]
^{58}Ni		1.00^{+15}_{-10}		Ni	n	1.6,1.8	TDSA	[2008Or02]
^{58}Ni	0.0707(145)			^{197}Au	^{58}Ni	77.8 A	CE*	[2004Yu10]
^{58}Ni		1.27(2)		^{12}C	^{58}Ni	155, 160	TDSA	[2001Ke08]
^{58}Ni	0.0588(40)			^{58}Ni	e-	124, 180	EE	[1983Kl09]
^{58}Ni		0.90(11)		^{58}Ni	γ	0.5-1.65	GG	[1981Ca10]
^{58}Ni		0.92(17)		^{58}Ni	p	8	TDSA	[1973BeYD]
^{58}Ni	0.0660(40)			^{58}Ni	^{16}O	35-60	CE*	[1973Ch13]
^{58}Ni		1.07(8)		^{58}Ni	γ		GG	[1972ArZD]
^{58}Ni	0.0680(20)			^{58}Ni	^{16}O	30,32,34	CE*	[1971ChZF]
^{58}Ni		0.98(9)		^{58}Ni	γ	<4.5	GG	[1970Me18]
^{58}Ni	0.0731(17)			^{58}Ni	^{12}C/^{16}O/^{32}S	21-22, 25-30, 60-70	CE*	[1970Le17]
^{58}Ni	0.0554(30)			^{58}Ni	e-	150, 225	EE	[1969Af01]
^{58}Ni		0.94(12)		^{58}Ni	p	7-9.0	TDSA	[1969Be48]
^{58}Ni	0.0657(11)			^{58}Ni	e-	45-65	EE	[1967Du07]
^{58}Ni		0.62(20)		^{58}Ni	γ	0.5-3.0	GG	[1964Bo22]
^{58}Ni	0.072(7)			^{58}Ni	^{4}He	4.5-8	CE	[1962St02]
^{58}Ni	0.098(13)			^{58}Ni	e-	183	EE	[1961Cr01]
^{58}Ni	0.063(13)			^{58}Ni	^{16}O	34	CE*	[1960Go08]
^{58}Ni	0.080(16)			^{58}Ni	^{14}N	36	CE*	[1960An07]
^{58}Ni	0.071(14)			^{58}Ni	^{4}He		CE?	[1960An07]
^{58}Ni	$0.100(25)^{s}$			^{58}Ni	N	15.9-35	CE	[1959Al95]
^{60}Ni		1.30^{+30}_{-20}		^{60}Ni	n	1.6,1.8	TDSA	[2008Or02]
^{60}Ni		1.31(3)		^{12}C	^{60}Ni	155, 160	TDSA	[2001Ke02]
^{60}Ni		1.30(36)		N/A	N/A	N/A	TCS	[1976Kl04]
^{60}Ni	0.1020(40)			^{60}Ni	e-	30-60	EE	[1974Ye01]
^{60}Ni	0.087(7)			^{60}Ni	e-	45-250	EE	[1974Si01]
^{60}Ni		1.00(7)		^{60}Ni	^{35}Cl	56-68	TDSA	[1973Fi15]
^{60}Ni	0.082(6)			^{60}Ni	γ		GG	[1972ArZD]
^{60}Ni	0.0910(30)			^{60}Ni	^{16}O	30,32,34	CE	[1971ChZF]
^{60}Ni	0.092(12)			^{60}Ni	γ	<4.5	GG	[1970Me18]
^{60}Ni	0.0928(20)			^{60}Ni	γ	1.333	GG	[1970Me08]
^{60}Ni	0.0914(20)			^{60}Ni	^{16}O/^{32}S	28-70	CE*	[1969Cl05]
^{60}Ni	0.0603(28)			^{60}Ni	e-	150, 225	EE	[1969Af01]
^{60}Ni	0.077(8)			^{60}Ni	e-	183,250	EE	[1969To08]
^{60}Ni	0.108(21)			^{60}Ni	γ	1-2.0	GG	[1967Be39]
^{60}Ni	0.0845(9)			^{60}Ni	e-	45-65	EE	[1967Du07]
^{60}Ni	0.091(5)			^{60}Ni	^{4}He	4.5-8	CE	[1962St02]
^{60}Ni	0.123(15)			^{60}Ni	e-	183	EE	[1961Cr01]

Table 3 (continued)

Nuclide	B(E2) (e^2b^2)	τ (ps)	β_2	Target	Beam	Energy (MeV)	Method	Reference
^{60}Ni	0.11(1)			^{60}Ni	^{14}N	36	CE*	[1960An07]
^{60}Ni	0.120(24)			^{60}Ni	^{16}O	34	CE*	[1960Go08]
^{60}Ni		1.0(3)		^{60}Ni	γ	133	GG	[1959Bu12]
^{60}Ni	0.160(40)			^{60}Ni	^{14}N	15.9-35	CE	[1959Al95]
^{60}Ni		1.1(2)		^{60}Ni	γ	1.33,1.17	GG	[1956Me59]
^{62}Ni		2.01(7)		^{12}C	^{62}Ni	155, 160	TDSA	[2001Ke02]
^{62}Ni		2.15(42)		^{62}Ni	γ	0.5-1.65	GG	[1981Ca10]
^{62}Ni		1.55(25)		^{59}Co	^{4}He	10	TDSA	[1978Ke11]
^{62}Ni		1.55(25)^d		^{59}Co	^{4}He	10	TDSA	[1978KlZR]
^{62}Ni		1.7(5)		^{59}Co	^{4}He	8	TDSA	[1977OhZX]
^{62}Ni		2.1(5)^d		^{62}Ni	γ	0.5-1.65	GG	[1977Ca14]
^{62}Ni	0.102(10)			^{62}Ni	e-	50,60,80,90	EE	[1975DeXW]
^{62}Ni	0.0618(42)			^{62}Ni	e-	150225	EE	[1972Li28]
^{62}Ni	0.0880(30)			^{62}Ni	^{16}O	30, 32, 34	CE	[1971ChZF]
^{62}Ni	0.0899(28)			^{62}Ni	^{12}C/^{16}O/^{32}S	70	CE*	[1970Le17]
^{62}Ni	0.084(5)			^{62}Ni	^{28}Si	70	CE*	[1969Ha31]
^{62}Ni	0.0877(11)			^{62}Ni	e-	45-65	EE	[1967Du07]
^{62}Ni		2.28(18)		^{62}Ni	^{16}O	36	TDSA	[1965Es01]
^{62}Ni	0.083(8)			^{62}Ni	^{4}He	4-8.0	CE	[1962St02]
^{62}Ni	0.085(17)			^{62}Ni	^{14}N	36	CE*	[1960An07]
^{62}Ni	0.140(35)			^{62}Ni	^{14}N	15.9-35	CE	[1959Al95]
^{64}Ni		1.57(5)		^{12}C	^{64}Ni	155, 160	TDSA	[2001Ke08]
^{64}Ni	0.0744(20)			^{64}Ni	e-	147.4-356	EE	[1988Br10]
^{64}Ni		2.5^{+5}_{-2}		^{64}Ni	^{4}He	30	TDSA	[1977Mo20]
^{64}Ni		0.40(15)		^{64}Ni	^{4}He	13	TDSA	[1974Iv01]
^{64}Ni	0.0650(40)			^{64}Ni	^{16}O	30,32,34	CE	[1971ChZF]
^{64}Ni	0.0650(34)			^{64}Ni	e-	150, 225	EE	[1969Af01]
^{64}Ni	0.087(17)			^{64}Ni	^{14}N	36	CE*	[1960An07]
^{64}Ni	0.077(15)			^{64}Ni	^{4}He		CE?	[1960An07]
^{64}Ni	0.090(18)^s			^{64}Ni	N	15.9-35	CE	[1959Al95]
^{66}Ni	0.06(1)			^{208}Pb	^{66}Ni	0.3 c	CE*	[2002So03]
^{66}Ni	0.09(1)			^{58}Ni	^{70}Ni	65.9 A	CE*	[2000LeZZ]
^{68}Ni	0.028(11)			^{108}Pd	^{68}Ni	2.9 A	CE*	[2008Br18]
^{68}Ni	0.0255(60)			^{208}Pb	^{66}Ni	0.3 c	CE*	[2002So03]
^{68}Ni	0.029(7)			^{58}Ni	^{70}Ni	65.9 A	CE*	[2000LeZZ]
^{70}Ni	0.086(14)			^{208}Pb	^{70}Ni	0.28 c	CE*	[2006Pe13]
^{74}Ni			0.21(3)	p	^{74}Ni	81 A	IN-EL	[2010Ao01]
^{62}Zn		4.2(7)		^{63}Zn	C	0.35 c	RDM	[2007St16]
^{62}Zn		4.3(3)		^{62}Zn	Fe	160	TDSA	[2002Ke02]
^{62}Zn		4.20(30)		^{6}Li	^{58}Ni	15-24	TDSA	[1981Wa09]
^{62}Zn		2.5^{+10}_{-20}		^{4}He	^{61}Ni	30	TDSA	[1977BrYO]
^{64}Zn		2.85(9)		^{64}Zn	C	180	TDSA	[2005Le12]
^{64}Zn		2.70(8)		^{64}Zn	Fe, C	160	TDSA	[2002Ke02]
^{64}Zn	0.112(6)			p	^{64}Zn	2-4.5	CE*	[1998Si25]
^{64}Zn	0.168(4)			^{4}He/^{16}O/^{18}O	^{64}Zn	8,35,30	CE	[1988Sa32]
^{64}Zn		2.97(25)		γ	^{64}Zn	1.65	GG	[1981Ca10]
^{64}Zn		3.00(30)^s		γ	^{64}Zn	1.65	GG	[1977Ca14]
^{64}Zn		4.0(10)		^{16}O	^{51}V	49	RDM	[1977Al14]
^{64}Zn	0.162(9)			e-	^{64}Zn	100-275	EE	[1977Ne05]
^{64}Zn	0.155(9)			e-	^{64}Zn	40-112	EE	[1976Ne06]
^{64}Zn		2.9(7)		^{4}He	^{61}Ni	6.4,8	TDSA	[1976Ch11]
^{64}Zn	0.161(12)			^{4}He	^{64}Zn	3-5.0	CE	[1975Th01]
^{64}Zn	0.176(21)			^{35}Cl	^{64}Zn	56-68	CE	[1973Fi15]
^{64}Zn	0.155(11)			γ	^{64}Zn		GG	[1972ArZD]
^{64}Zn	0.170(16)			e-	^{64}Zn	150, 225	EE	[1970Af04]
^{64}Zn	0.108(5)			γ	^{64}Zn		GG	[1965Ta13]
^{64}Zn	0.162(10)			^{4}He	^{64}Zn	4.5-8	CE	[1962St02]
^{64}Zn	0.110(22)			^{14}N	^{64}Zn	36	CE*	[1960An07]
^{64}Zn	0.110(22)			^{4}He	^{64}Zn	6-7.0	CE	[1956Te26]
^{66}Zn		2.5(1)		^{66}Zn	C	180	TDSA	[2006Le24]
^{66}Zn	0.144(9)			^{66}Zn	Pb	274.2	CE*	[2003Ko51]
^{66}Zn		2.43(5)		^{66}Zn	Fe, C	160	TDSA	[2002Ke02]
^{66}Zn	0.135(8)			p	^{66}Zn	2-4.5	CE*	[1998Si25]
^{66}Zn		2.71(23)		γ	^{66}Zn	1.65	GG	[1981Ca10]
^{66}Zn		2.0(10)		^{4}He	^{63}Cu	10, 16.7	TDSA	[1981Zh07]
^{66}Zn		2.70(20)^s		γ	^{66}Zn	1.65	GG	[1977Ca14]
^{66}Zn	0.141(8)			e-	^{66}Zn	100-275	EE	[1977Ne05]

Table 3 (continued)

Nuclide	**B(E2)** (e^2b^2)	τ (ps)	β_2	**Target**	**Beam**	**Energy** (MeV)	**Method**	**Reference**
^{66}Zn		2.5^{+5}_{-2}		^{4}He	^{64}Ni	27, 30	TDSA	[1977Mo20]
^{66}Zn	0.137(10)			e-	^{66}Zn	40-112	EE	[1976Ne06]
^{66}Zn	0.154(13)			^{4}He	^{66}Zn	3-5.0	CE	[1975Th01]
^{66}Zn	0.180(15)			e-	^{66}Zn	225	EE	[1973Li24]
^{66}Zn	0.155(13)			^{35}Cl	^{66}Zn	56-68	CE	[1973Fi15]
^{66}Zn		2.2(9)		^{4}He	^{66}Zn	25	TDSA	[1972Yo01]
^{66}Zn	0.153(21)			γ	^{66}Zn	1.037	GG	[1972Ka22]
^{66}Zn	0.138(16)			γ	^{66}Zn		GG	[1972ArZD]
^{66}Zn	0.145(15)			e-	^{66}Zn	150, 225	EE	[1970Af04]
^{66}Zn	0.15(6)			γ	^{66}Zn	1-2.0	GG	[1967Be39]
^{66}Zn	0.145(13)			^{4}He	^{66}Zn	4-8.0	CE	[1962St02]
^{66}Zn	0.110(22)			^{14}N	^{66}Zn	36	CE*	[1960An07]
^{66}Zn	0.087(17)			^{4}He	^{66}Zn	6-7.0	CE	[1956Te26]
^{68}Zn		2.32(5)		^{68}Zn	C	180	TDSA	[2005Le12]
^{68}Zn	0.129(8)			^{68}Zn	Pb	276	CE*	[2004Ko03]
^{68}Zn		2.32(7)		^{68}Zn	Fe, C	160	TDSA	[2002Ke02]
^{68}Zn	0.105(7)			p	^{68}Zn	2-4.5	CE*	[1998Si25]
^{68}Zn		$2.71(23)^{s}$		γ	^{68}Zn	1.65	GG	[1981Ca10]
^{68}Zn	0.125(11)			e-	^{68}Zn	100-275	EE	[1977Ne05]
^{68}Zn	0.105(8)			γ	^{68}Zn	1.65	GG	[1977Ca14]
^{68}Zn	0.111(8)			e-	^{68}Zn	40-112	EE	[1976Ne06]
^{68}Zn		1.3(3)		^{4}He	^{68}Zn	13	TDSA	[1974Iv01]
^{68}Zn	0.126(13)			^{35}Cl	^{68}Zn	56-68	CE	[1973Fi15]
^{68}Zn	0.108(14)			e-	^{68}Zn	225	EE	[1973Li24]
^{68}Zn	0.140(16)			γ	^{68}Zn		GG	[1972ArZD]
^{68}Zn	0.125(11)			^{4}He	^{68}Zn	4-8.0	CE	[1962St02]
^{68}Zn	0.110(22)			^{14}N	^{68}Zn	36	CE*	[1960An07]
^{70}Zn	0.164(28)			^{70}Zn	^{58}Ni	65.9 A	CE*	[2002So03]
^{70}Zn		5.3(3)		^{70}Zn	Fe, C	160	TDSA	[2002Ke02]
^{70}Zn	0.235(25)			p	^{70}Zn	2-4.5	CE*	[1998Si25]
^{70}Zn	0.205(19)			e-	^{70}Zn	40-112	EE	[1976Ne06]
^{70}Zn	0.160(14)			^{4}He	^{70}Zn	4-8.0	CE	[1962St02]
^{72}Zn	0.174(21)			^{72}Zn	Pb	35 A	CE*	[2002Le17]
^{74}Zn	0.201(16)			^{74}Zn	^{108}Pd,^{120}Sn	2.87 A	CE*	[2007Va20]
^{74}Zn	0.204(15)			^{74}Zn	^{208}Pb	0.28 c	CE*	[2006Pe13]
^{76}Zn	0.145(18)			^{76}Zn	^{108}Pd,^{120}Sn	2.83 A	CE*	[2007Va20]
^{78}Zn	0.077(19)			^{78}Zn	^{108}Pd,^{120}Sn	2.87 A	CE*	[2007Va20]
^{80}Zn	0.073(9)			^{80}Zn	^{108}Pd,^{120}Sn	2.79 A	CE*	[2009Va01, 2007Va20]

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