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Explanation of the Near Equality of Isoscalar and
Electromagnetic Transition Rates in Neutron-Excess
Nuclei; Representation of the Data in Terms of $\beta_{\alpha\alpha'}/\beta_{em}$

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The ratios of isoscalar and electromagnetic transition rates to the lowest 2^+ state in neutron-excess nuclei are compared to predictions based on the ratios of isovector and isoscalar transition strengths determined from microscopic effective-charge theory in which giant-quadrupole core-polarization contributions are included with a schematic model. The near equality of the isoscalar (determined from (α, α')) and electromagnetic transition rates is explained, and it is shown that shell effects may be large but that they are compensated for in part by core-polarization effects. A comparison to data for single-closed-shell nuclei is consistent with the schematic-model prediction that the remaining shell effects are systematically different for neutron- versus proton-valence nuclei.

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There have been many studies of the systematics of the lowest 2^+ level of even-even nuclei. For example, by Coulomb-excitation experiments one obtains the values of $B(E2) = |M_p|^2$, where M_p is the proton multipole matrix element as defined in Appendix A. The inelastic scattering of strongly interacting projectiles such as neutrons, protons, alpha particles, etc., are of interest because these probes interact with both neutrons and protons and therefore offer the additional possibility of obtaining the neutron multipole matrix element M_n (see Appendix A for definition). Measurement of M_n and M_p is equivalent to separate measurements of the isoscalar and isovector parts of the electromagnetic transition rate.

Because of the spin and isospin character of the α particle, its interaction with nuclei is simplified. Furthermore, it is strongly absorbed which means that only the surface region of the nucleus contributes so that the magnitude of the (α, α') cross section is proportional to $|M_n + M_p|^2$. Therefore, a comparison of (α, α') cross sections to $B(E2)$ values can lead to a determination of the ratio of M_n and M_p . Such a comparison has been made,¹ and for neutron-excess nuclei the results were considered surprising because they did not show any significant shell effects but were mostly within 30% of a ratio which is the pure collective-model result and corresponds to $M_n/M_p = N/Z$ (or equivalently $\beta_{\alpha\alpha'}/\beta_{em} = 1$, see Appendix A. In this Letter we offer an explanation for these results based on microscopic effective-charge theory which shows that the expected deviations from the pure collective-model results are typically 10 to 40%. Furthermore, they are systematic in that $M_n/M_p > N/Z$ ($\beta_{\alpha\alpha'}/\beta_{em} > 1$) for single-closed-shell (SCS) neutron-valence nuclei and $< N/Z$ ($\beta_{\alpha\alpha'}/\beta_{em} < 1$) for SCS proton-valence nuclei.

In practice inelastic scattering data are often parameterized by the collective deformation-parameter β which in the usual first-order one-fluid collective model is independent of how the nucleus is excited. The difference between neutron and proton inelastic scattering due to deforming the Lane potential is attributed to the neutron excess so that the scattering cross section is always greater for (p,p') than for (n,n'). This is contrary to expectation from pure valence considerations for a nucleus with a neutron closed shell. Shell effects, which in the primitive shell model would give extreme differences in transition strength for different projectiles, are moderated^{2,3} by core-polarization effects due to mixing with giant-quadrupole resonances. The expectation for the remaining shell effects is that $\beta_{pp'} < \beta_{em}$ for SCS proton-valence nuclei, and $\beta_{pp'} > \beta_{em}$ for SCS neutron-valence nuclei; the general trend of the data supports the predictions.²

For the case of α scattering, a pure isoscalar external field, the core-polarization effects should also depend on whether the valence particles are neutrons or protons for neutron-excess nuclei. This is true both because the neutron-proton polarizing interaction V_{np} is greater than the neutron-neutron V_{nn} or proton-proton V_{pp} interaction and because there are more neutrons than protons to polarize. The result of Ref. 2 for the ratio of $\beta_{\alpha\alpha'}$ to β_{em} is

$$\frac{\beta_{\alpha\alpha'}}{\beta_{em}} = \frac{1}{1 - \xi \left(\frac{\beta_1}{\beta_0} - 1 \right)}, \quad (1)$$

where $\xi = \frac{N-Z}{A}$. The ratio β_1/β_0 of the deformation parameters for isovector and isoscalar parts of the optical potential is taken as proportional to the isovector and isoscalar transition operator strengths. The connection² to the corresponding ratios in microscopic-effective-charge theory can be made for SCS nuclei since in that case the isospin operator acting on the valence nucleons has a definite value which is opposite for neutrons and protons. If the giant quadrupole states were pure in isospin, the neutron and proton core-polarization contribution would be equal as expected for a pure isoscalar vibration. The lack of purity in the giant-quadrupole states, which is due to the neutron excess, makes the core polarization due to valence protons greater than that due to valence neutrons and corresponds to the presence of an isovector component.

If there were no core-polarization effects in Eq. (1), then $\beta_1/\beta_0 \xi = \pm 1$ for neutron-(upper sign) and proton-(lower sign) valence nuclei. Correspondingly, $\beta_{\alpha\alpha'}/\beta_{em}|_n \approx 1/\xi \gg 1$ (actually β_{em} would be zero for pure neutron-valence particles, which is inconsistent with the approximate form used here), and $\beta_{\alpha\alpha'}/\beta_{em}|_p \approx \frac{1}{2+\xi} < 0.5$. The change from these extreme values of the β ratios which attribute the β differences exclusively to shell effects is a result of the core-polarization contributions which are opposite for $\beta_{\alpha\alpha'}$ and β_{em} . If the main contribution comes from the polarization of unlike nucleons, the direction of the effect is such as to restore $\beta_{\alpha\alpha'}/\beta_{em}$ to one for both cases.

It is instructive to rewrite the β ratio of Eq. (1) for valence neutrons as

$$\left. \frac{\beta_{\alpha\alpha'}}{\beta_{em}} \right|_n \approx \left(\frac{Z}{A} \right) \frac{1 + \delta^{nn} + \delta^{pn}}{\delta^{pn}}, \quad (2)$$

and for valence protons as

$$\left. \frac{\beta_{\alpha\alpha'}}{\beta_{em}} \right|_p \approx \left(\frac{Z}{A} \right) \frac{1 + \delta^{pp} + \delta^{np}}{1 + \delta^{pp}}, \quad (3)$$

where δ^{xy} is a polarization parameter³ corresponding to core x's polarized by valence y's. The results of Eqs. (2) and (3) might have been written down intuitively. The factor Z/A comes about because the β 's are collective and the δ 's are microscopic parameters, and the isoscalar transition involves all the nucleons whereas the electromagnetic transition involves that fraction of all the nucleons that is protons. The β ratios presented in Eqs. (2) and (3) are within a few percent of our actual schematic-model results.

In order to get some indication from the schematic model³ as to whether $\beta_{\alpha\alpha'}/\beta_{em}$ is expected to be greater or less than one, it is useful to look at the ratios of the polarization parameters in Eqs. (2) and (3) in the light of some simplifying assumptions. The results from the core-polarization model³ in the limit that the isovector state is at ∞ and that the interaction is purely isoscalar is

$$\frac{\delta^{np}}{\delta^{pp}} = \frac{\delta^{nn}}{\delta^{pn}} \approx \frac{N}{Z} \left[1 - \frac{2}{3} \xi \right] \quad (4)$$

Without the $-(2/3) \xi$ term, Eq. (4) states that the polarizations are just proportional to the number of nucleons of each kind to be polarized. The $-(2/3) \xi$ term means that the neutrons are polarized in a ratio less than N/Z , which follows directly from the constraint made in Ref. 3 that the neutron and proton mean square radii are equal and, therefore, that $\hbar\omega_n > \hbar\omega_p$. In the extreme opposite choice of $\hbar\omega_n = \hbar\omega_p$ the $-(2/3) \xi$ gets replaced by $+(2/3) \xi$. Actual nuclei are probably somewhere in between, and the compromise choice of dropping the $(2/3) \xi$ term is reasonable, introducing at most a 20% error. In any case it is instructive to do so; accordingly we take $\delta^{nn}/\delta^{pn} = \delta^{np}/\delta^{pp} = N/Z$ and obtain for Eqs. (2) and (3)

$$\left. \frac{\beta_{\alpha\alpha'}}{\beta_{em}} \right|_n \approx \frac{\delta^{pn} + Z/A}{\delta^{pn}} > 1, \quad (5)$$

and

$$\left. \frac{\beta_{\alpha\alpha'}}{\beta_{em}} \right|_p \approx \frac{Z/A + \delta^{pp}}{1 + \delta^{pp}} < 1, \quad (6)$$

which is the direction of the effect we see experimentally. However, the ratios $\delta^{nn}/\delta^{pn} = \delta^{np}/\delta^{pp} = N/Z$ correspond only to the neutron excess and do not take into account that V_{np} is greater than V_{nn} or V_{pp} . Similar approximations in the limit that the isoscalar and isovector resonances are at the same energy and taking⁴ $V_{np} = 3V_{nn}$ yield $\delta^{np}/\delta^{pp} \approx 3N/Z$ and $\delta^{nn}/\delta^{pn} \approx N/(3Z)$. If these ratios are used in Eqs. (2) and (3), the results

for both valence types are brought closer to unity and, indeed, are not restricted to values greater or less than one, respectively. Of course, even in the schematic model things are not as simple as this intuitive picture which has been obtained from the unrealistic placement of the giant states. The actual calculations using the schematic model³ place the energies of the isoscalar and isovector quadrupole collective states at $60/A^{1/3}$ MeV and $120/A^{1/3}$ MeV, respectively. Further, the effects of the spreading of the isoscalar giant resonance is taken into account in an approximate way in a one-parameter-schematic model (OPSM) with the one parameter free to be determined by empirical electromagnetic effective charges. The extreme values of the δ ratios presented above do not have these features built in.

Calculations for the available SCS neutron-excess nuclei have been made using the OPSM and the no-parameter-schematic model (NPSM). The schematic model has been designed to describe trends in the periodic table for neutron-excess nuclei, and it contains some features that satisfy our intuition about the effects of valence particles, but the actual numbers should not be taken too seriously for magnitudes such as δ^{xy} . (Although ratios such as $\beta_{\alpha\alpha}/\beta_{em}$ are less sensitive to model assumptions.) The OPSM is idealized in that it is designed to take into account the spreading of the isoscalar state, but no account is taken of the spreading in the isovector state, and when one includes a parameter to take this into account, it can be shown that the results are further modified. Nevertheless it is interesting to compare the extreme ratios described above with those calculated with the OPSM.⁵ For the proton-valence nuclei the values for δ^{np}/δ^{pp} always

fall between the extremes of N/Z and $3N/Z$. An example of this type is ^{92}Mo with $\delta^{np}/\delta^{pp} = 1.84$ to be compared with $N/Z = 1.19$ and $3N/Z = 3.57$.

For the neutron-valence nuclei values of δ^{nn}/δ^{pn} lie between N/Z and $N/(3Z)$ for the lighter nuclei, but for ^{62}Ni , the Sn isotopes, and ^{206}Pb $\delta^{nn}/\delta^{pn} < N/(3Z)$. An example of a neutron-valence nucleus is ^{60}Ni with $\delta^{nn}/\delta^{pn} = 0.589$ to be compared with $N/Z = 1.14$ and $N/(3Z) = 0.381$.

The ratio of the neutron and proton multipole matrix elements M_n and M_p (see Appendix) can be written in terms of the δ parameters using Eqs. (2) and (3). The ratio for neutron-valence nuclei is

$$\left. \frac{M_n}{M_p} \right|_n \approx \frac{1 + \delta^{nn}}{\delta^{pn}}, \quad (7)$$

and for proton-valence nuclei it is

$$\left. \frac{M_n}{M_p} \right|_p \approx \frac{\delta^{np}}{1 + \delta^{pp}}. \quad (8)$$

The experimental values^{1,6-15} of M_n/M_p for SCS nuclei are presented in Fig. 1 as compared to the schematic model predictions and to the simple collective-model values of N/Z . It is evident that the values of M_n/M_p are larger than N/Z for neutron-valence nuclei and less than N/Z for proton-valence nuclei with the effects ranging from 10 to 60%.¹⁶ This tendency is seen in all but one out of 18 data points and with 2/3 of the points being different from N/Z by more than the quoted errors. The predictions of the NPSM and the OPSM are in qualitative agreement with the trend of the data which is as much as should be expected. The use of empirical effective

charges in the OPSM is seen to move the predictions systematically closer to N/Z compared to the NPSM. The data can be equivalently represented in terms of $\beta_{\alpha\alpha}/\beta_{em}^{17}$ (Eq. A9) which for neutron (proton) SCS nuclei is greater (less) than one. A similar trend has been previously observed for β_{pp}/β_{em} which is also consistent with the schematic-model predictions.²

The near equality of isoscalar $B(IS)$ and electromagnetic $B(E2)$ transition rates ($M_n/M_p \approx N/Z$) for neutron-excess nuclei has been a long standing puzzle.¹ A solution of this puzzle for SCS nuclei is found in the application² of microscopic effective-charge theory³ to the differences between isoscalar and isovector parts of the collective deformation-parameter β . Although valence shell effects are present and may be large, they are compensated for by core-polarization effects from giant-quadrupole vibrations which as a result of isoscalar enhancement and isovector retardation act in the direction of restoring the pure-collective-model results. The evidence from the data and the calculations is that the compensation is incomplete, and shell effects do persist which are different for neutron versus proton SCS nuclei. It is emphasized that the actual numbers as predicted by the schematic model should not be taken too seriously, but the explanation of the trend in the data is expected to be valid.

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Appendix A

In this appendix we shall define the neutron and proton multipole matrix elements. The proton transition density is given by

$$\rho_{fi}^{(p)}(r) \equiv \left\langle \psi_f \parallel \sum_{\text{protons}} Y_{\ell}(\Omega) \parallel \psi_i \right\rangle, \quad (\text{A1})$$

where ψ represents the A-body wave functions of the initial and final states, and ℓ is the angular momentum transfer ($\ell = 2$ for $0^+ \rightarrow 2^+$ transitions). The proton multipole matrix element is given by

$$M_p = \int_0^{\infty} r^{\ell+2} \rho_{fi}^{(p)}(r) dr, \quad (\text{A2})$$

and the B(EL) value (all transition rates are upward) is given by

$$B(\text{EL}) = |M_p|^2. \quad (\text{A3})$$

The corresponding quantities for neutrons are obtained by taking the sum over neutrons in Eq. (A1).

The usual definitions of the isoscalar (IS) and isovector (IV) transition rates are

$$\left. \begin{array}{l} B(\text{IS}) \\ B(\text{IV}) \end{array} \right\} = \left| \frac{M_n \pm M_p}{2} \right|^2. \quad (\text{A4})$$

Note that when $M_n = M_p$, $B(\text{EL}) = B(\text{IS})$ and $B(\text{IV}) = 0$; i.e. the electromagnetic rate is pure isoscalar. In Ref. 1 a modified IS transition rate $\tilde{B}(\text{IS})$ was defined as

$$\tilde{B}(\text{IS}) = \left| \frac{Z}{A} (M_n + M_p) \right|^2. \quad (\text{A5})$$

This definition is useful when one considers the usual first-order one-fluid collective models (rotational or vibrational) in which neutrons and protons move in phase and retain the equilibrium density ratios. For this model

$$\rho_{fi}^{(p)}/Z = \rho_{fi}^{(n)}/N = \beta R \rho'(r)/\hat{\ell} \quad , \quad (A6)$$

where $\rho'(r)$ is the derivative of the ground-state density distribution (assumed to be the same for neutrons and protons), R is the half-density radius, and β is the RMS amplitude of vibration (in the vibrational model) or the static deformation parameter (in the rotational model). For this case

$$M_n/N = M_p/Z = \beta R/\hat{\ell} \left(\int \rho'(r) r^{\ell+2} dr \right) \equiv \beta R I/\hat{\ell} \quad , \quad (A7)$$

and

$$\tilde{B}(\text{IS}) = B(\text{EL}) = (Z\beta R I/\hat{\ell})^2 \quad , \quad (A8)$$

where $\hat{\ell} = \sqrt{2\ell + 1}$. We note the equality of $\tilde{B}(\text{IS})$ and $B(\text{EL})$ for this model.

If we had used the usual definition of IS and IV transition rates given by Eq. (A4), then in the collective model $B(\text{IS}) = (A\beta R I/2\hat{\ell})^2 \neq B(\text{EL})$ and

$$B(\text{IV}) = \left| \left(\frac{N-Z}{2} \right) \beta R I/\hat{\ell} \right|^2 \quad \text{so that the first-order collective model for}$$

$N > Z$ nuclei has both an IS and an IV part. Furthermore, the modified IS definition is convenient since the ratio of $\tilde{B}(\text{IS})/B(\text{EL})$ then measures deviations from the one-fluid collective model. For example, if $\tilde{B}(\text{IS})/B(\text{EL}) = 1$, one knows $M_n/M_p = N/Z$. In this paper we present M_n/M_p obtained from the ratio

$$\tilde{B}(\text{IS})/B(\text{EL}) = \left(\frac{Z}{A}\right)^2 \left|1 + M_n/M_p\right|^2 \equiv \left(\beta_{\alpha\alpha'}/\beta_{\text{em}}\right)^2 \quad . \quad (\text{A9})$$

To obtain M_n/M_p from the experimental data the positive value of the square root has been used. This is consistent with the collective nature of the first 2^+ states in nuclei, where M_n and M_p are in phase. In Ref. 1 the values of $\tilde{B}(\text{IS})$ as obtained from (α, α') experiments are tabulated. Note that when $\tilde{B}(\text{IS})/B(\text{EL}) > 1$, then $M_n/N > M_p/Z$, and conversely when $\tilde{B}(\text{IS})/B(\text{EL}) < 1$, then $M_n/N < M_p/Z$.

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4. F. Petrovich, H. McManus, V. A. Madsen and J. Atkinson, *Phys. Rev. Letters*, 22 (1969) 895.
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13. F. R. Metzker, to be published in *Phys. Rev. C*, June 1977.
14. R. P. Singhal et al., *Nucl. Phys.* A218 (1974) 189.
15. J. H. Barker and J. C. Hiebert, *Phys. Rev.* C6 (1972) 1795.
16. These percent differences are larger than those of Ref. 1 because of new data, primarily that of Ref. 15.

Figure 1 M_n/M_p for single-closed-shell (SCS) nuclei. The theoretical predictions for the no-parameter-schematic model (NPSM) are shown with a dashed line, and the one-parameter-schematic-model (OPSM) are shown with solid lines. The heavy solid lines are N/Z which is the prediction of the simple collective model. The data shown with error bars are from Refs. 1, 6 - 15. The SCS neutron (proton) -valence nuclei are plotted to the left (right).

Fig. 1

Appendix B

This appendix is composed of Table I - III and Fig. 2. Table I is a compilation of the isoscalar and electromagnetic transition rates with references for the data presented in Figs. 1 and 2. Tables II and III give the various core-polarization parameters discussed in the text and the quantities plotted in Figs. 1 and 2 for neutron- and proton- valence nuclei, respectively. Figure 2 is a representation of the data in terms of $\beta_{\alpha\alpha}/\beta_{em}$.

TABLE I ISOSCALAR AND ELECTROMAGNETIC UPWARD TRANSITION RATES TO THE LOWEST 2^+ STATES FOR SINGLE-CLOSED-SHELL NEUTRON AND PROTON VALENCE NUCLEI

Neutron-Valence Nuclei			Proton-Valence Nuclei		
Isotope	$\tilde{G}$ (IS)	G (EM)	Isotope	$\tilde{G}$ (IS)	G (EM)
^{42}Ca	11.0 ± 1.7^a	9.4 ± 0.4^b	^{50}Ti	6.1 ± 0.9^a	6.0 ± 0.4^g
^{44}Ca	11.0 ± 2.2^a	10.2 ± 0.4^b	^{52}Cr	7.6 ± 1.1^a	11.6 ± 0.5^g
^{58}Ni	16.4 ± 1.6^c	10.9 ± 0.2^d	^{54}Fe	6.1 ± 1.0^a	8.4 ± 0.8^h
^{60}Ni	19.6 ± 2.0^c	13.3 ± 0.2^d	^{88}Sr	7.9 ± 1.0^a	7.6 ± 0.4^i
^{62}Ni	20.3 ± 2.0^c	12.3 ± 0.4^d	^{90}Zr	5.2 ± 0.5^c	5.6 ± 0.5^j
^{64}Ni	18.2 ± 1.8^c	8.5 ± 0.5^b	^{92}Mo	8.0 ± 2.4^a	8.8 ± 1.4^h
^{116}Sn	20.6 ± 3.1^e	11.6 ± 0.4^f	^{138}Ba	5.6 ± 1.1^k	10.4 ± 0.4^b
^{118}Sn	19.1 ± 2.9^e	11.6 ± 0.4^f	^{140}Ce	7.4 ± 0.8^k	13.4 ± 1.9^h
^{120}Sn	20.6 ± 3.1^e	11.2 ± 0.2^f	^{144}Sm	7.0 ± 1.1^k	11.2 ± 1.8^h

a. A.M. Bernstein, *Advances in Nucl Phys* 3 (1969) 325, M. Baranger and E. Vogt, editors, Plenum Press, N.Y.

b. A. Christy and O. Häusser, *Nuclear Data Table II* (1972) 281

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h. C.K. Ross and R.K. Bhaduri, *Nucl Phys A* 196 (1972) 369

i. F.R. Metzker, to be published in *Phys Rev C*, June 1977

j. R.P. Singhal et.al., *Nucl Phys A* 218 (1974) 189

k. J.H. Barker and J.C. Hiebert, *Phys Rev C* 6 (1972) 1795

TABLE II CORE-POLARIZATION PARAMETERS AND COMPARISON OF M_n/M_p AND $\beta_{\alpha\alpha'}/\beta_{em}$ WITH THEORY FOR SINGLE-CLOSED-SHELL NEUTRON-VALENCE NUCLEI TRANSITION RATES ARE TO THE LOWEST 2^+ STATE

Isotope	e_n^a	N/Z	N/3Z	δ^{nn}/δ^{pn}	M_n/M_p			$\beta_\alpha \alpha'/\beta_{em}$		
					OPSM	NPSM	OPSM	DATA ^f	NPSM	OPSM
⁴² Ca	2.08 ^b	1.10	0.367	0.739	1.57	1.21	1.27 ± 0.18	1.22	1.05	1.08 ± 0.09
⁴⁴ Ca	1.49 ^b	1.20	0.400	0.661	1.61	1.32	1.28 ± 0.23	1.19	1.05	1.04 ± 0.11
⁵⁸ Ni	1.90 ^c	1.07	0.357	0.698	1.56	1.22	1.54 ± 0.13	1.24	1.07	1.23 ± 0.06
⁶⁰ Ni	1.34 ^c	1.14	0.381	0.589	1.58	1.32	1.60 ± 0.13	1.21	1.08	1.21 ± 0.06
⁶² Ni	0.911 ^c	1.21	0.405	0.397	1.61	1.46	1.84 ± 0.15	1.18	1.11	1.28 ± 0.07
⁶⁴ Ni	0.972 ^c	1.29	0.429	0.470	1.64	1.47	2.34 ± 0.19	1.16	1.08	1.46 ± 0.08
¹¹⁶ Sn	0.72 ^d	1.32	0.440	0.255	1.66	1.59	2.09 ± 0.24	1.15	1.12	1.33 ± 0.10
¹¹⁸ Sn	0.745 ^d	1.36	0.453	0.301	1.68	1.60	2.03 ± 0.24	1.14	1.10	1.28 ± 0.10
¹²⁰ Sn	0.727 ^d	1.40	0.467	0.295	1.70	1.62	2.25 ± 0.25	1.12	1.09	1.36 ± 0.10
²⁰⁶ Pb	0.86 ^e	1.51	0.504	0.474	1.76	1.61		1.10	1.03	

^a Effective charge of the valence neutrons

^b B.A. Brown, D.B. Fossan, J.M. McDonald, and K.A. Snover, Phys Rev C9, (1974) 1033

^c Calculated from Table VI of L.S. Kisslinger and R.A. Sorensen, Rev of Modern Physics 35, (1963) 853

^d Calculated from cloud-nucleon strength parameters and experimental B(E2) of S. Yoshida, Nucl Phys 38, (1962) 380

^e J. Blomquist in proceedings of the International Conference on Nuclear Moments and Nuclear Structure, edited by H. Horne and K. Sugimoto, (Physical Society of Japan, Osaka, 1972) P.223

^f See Table I for isoscalar and electromagnetic data components with references

TABLE III CORE-POLARIZATION PARAMETERS AND COMPARISON OF M_n/M_p AND $\beta_{\alpha\alpha'}/\beta_{em}$ WITH THEORY FOR SINGLE-CLOSED-SHELL PROTON-VALENCE NUCLEI. TRANSITION RATES ARE TO THE LOWEST 2^+ STATE

Isotope	e_p^a	N/Z	3N/Z	δ^{np}/δ^{pp}		M_n/M_p		$\beta_{\alpha\alpha'}/\beta_{em}$		
				OPSM	NPSM	OPSM	DATA ^h	NPSM	OPSM	DATA ^h
⁵⁰ Ti	1.55 ^b	1.27	3.82	2.39	0.77	0.89	1.29 ± 0.19	0.778	0.832	1.01 ± 0.08
⁵² Cr	1.92 ^b	1.17	3.50	1.81	0.72	0.89	0.75 ± 0.13	0.794	0.870	0.81 ± 0.06
⁵⁴ Fe	1.93 ^b	1.08	3.23	1.74	0.68	0.84	0.77 ± 0.17	0.810	0.888	0.85 ± 0.08
⁸⁸ Sr	1.65 ^c	1.32	3.95	2.22	0.79	0.93	1.36 ± 0.16	0.772	0.832	1.02 ± 0.07
⁹⁰ Zr	2.4 ^d	1.25	3.75	1.60	0.76	0.96	1.17 ± 0.14	0.781	0.873	0.96 ± 0.06
⁹² Mo	1.9 ^e	1.19	3.57	1.84	0.73	0.89	1.09 ± 0.35	0.791	0.865	0.95 ± 0.16
¹³⁸ Ba	1.79 ^f	1.46	4.39	2.12	0.86	1.02	0.81 ± 0.18	0.753	0.819	0.73 ± 0.07
¹⁴⁰ Ce	2.0 ^g	1.41	4.24	1.89	0.83	1.01	0.79 ± 0.16	0.759	0.834	0.74 ± 0.07
¹⁴⁴ Sm	2.0 ^g	1.32	3.97	1.84	0.79	0.97	0.84 ± 0.21	0.771	0.848	0.79 ± 0.09

^a Effective charge of the valence protons

^b B.G. Bezzeti, J. Phys Soc Jpn Suppl 34, (1973) 338

^c T.A. Hughes, Phys Rev 181, (1969) 1586

^d W.G. Love and G.R. Satchler, Nucl Phys A101, (1967) 424

^e Chosen arbitrarily a characteristic of proton nuclei in this mass region

^f D. Larson, S.M. Austin, and B.H. Wildenthal, Physics Letters 42B, (1972) 153

^g M. Waroquier and K. Heyde, Nuclear Phys A 164, (1971) 113

^h See Table I for isoscalar and electromagnetic data components with reference

Figure 2 $\beta_{\alpha\alpha}/\beta_{em}$ for single-closed-shell (SCS) nuclei. The theoretical predictions for the no-parameter-schematic model (NPSM) are shown with a dashed line, and the one-parameter-schematic model (OPSM) are shown with solid lines. The data shown with error bars are from Refs. 6-16. The SCS neutron (proton)-valence nuclei are plotted to the left (right).

Fig. 2

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