B(E2) Evaluation for 0\textsuperscript{+} \rightarrow 2\textsuperscript{+} Transitions in Even-Even Nuclei

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A collaborative study by Brookhaven-McMaster-Central Michigan is underway to evaluate B(E2)\textsuperscript{↑} for 0\textsuperscript{+} \rightarrow 2\textsuperscript{+} transitions. This work is a continuation of a previous USNDP evaluation and has been motivated by a large number of recent measurements and nuclear theory developments. It includes an extended compilation, data evaluation procedures and shell model calculations. The subset of B(E2)\textsuperscript{↑} recommended values for nuclei of relevance to the double-beta decay problem is presented, and evaluation policies of experimental data and systematics are discussed. Future plans for completion of the B(E2;0\textsuperscript{+} \rightarrow 2\textsuperscript{+}) evaluation project are also described.

I. INTRODUCTION

The importance of B(E2)\textsuperscript{↑} values compilation and evaluation was recognized in the 1960s by Stelson and Grodzins [1, 2]. Evaluated quadrupole collectivity (reduced electric quadrupole transition rates) values are essential for nuclear structure physics and in high demand for nuclear model calculations. These nuclear data activities flourished at Oak Ridge National Laboratory at the end of the century under the leadership of Raman, who produced two excellent evaluations [3, 4]. In recent years, this project was transferred to Brookhaven National Laboratory in order to ensure continuation of this important work.

The volume of B(E2)\textsuperscript{↑} data is rapidly increasing due to the general availability of supercomputers and nuclear radioactive beam facilities. These facilities have been producing rare nuclei far from the valley of stability at an increasing rate, 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 the A \leq 100 region, require a new evaluation of quadrupole collectivities for proper interpretation and analysis of the newly-obtained values.

Access to these data is of paramount importance for the SciDAC ad FRIB collaborations [5, 6]. To satisfy the evolving needs of theoretical and experimental nuclear physics, a new B(E2)\textsuperscript{↑} evaluation has been launched [7]. This work broadens the previous evaluation of even-even nuclei [4] along the nuclear landscape, and includes many new experimental and evaluated quantities. It consists of an updated set of compiled experimental parameters, comprehensive data analysis and evaluation and large-scale shell model calculations. It extends the list of evaluated nuclei from 53 to 68 and from 20 to 38 in the Z=2-22 and Z=24-30 regions, respectively. More details are given in the following sections.

II. COMPILATION AND EVALUATION OF EXPERIMENTAL DATA

The quadrupole collectivity data compilation at Brookhaven was accompanied by the online service http://www.nndc.bnl.gov/be2 [8] and later evolved into a collaborative data evaluation project. The B(E2)\textsuperscript{↑} project Web Interface is shown in Fig. 1.

This compilation is based on the previous evaluation [4], XUNDL and NSR database content [9, 10].

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and the original research papers. All measurements were separated into three classes: model independent, low model dependent and model dependent [4, 7]. The recommended $B(E2)$ values were deduced using model-independent or traditional, combined (model-independent and low model-dependent), and model-dependent datasets with the AveTools software package [11] using the selected datasets. The final results were analyzed using the shell model predictions. A subset of evaluated and calculated data for Ni nuclei is shown in Fig. 2.

FIG. 2. Brookhaven-McMaster-Central Michigan evaluated $B(E2)$ values and $2^+_1$ energies vs. shell-model calculations for Ni [7].

As an example, consider a non-traditional application of $B(E2)^+$ evaluation. In recent years a considerable amount of effort has been dedicated to the search for double-beta decay transitions to the first excited states [12]. Two-neutrino double-beta decay half-lives for the transitions to the first excited $2^+$ and $0^+$ states are often computed on the basis of a second Quasi Random Phase Approximation (QRPA) and Hartree-Fock-Bogoliubov models [13, 14]. The deformed QRPA using the realistic Bonn-CD nucleon-nucleon interaction approach has been applied recently for the neutrinoless mode [15]. The reliability of these calculations has been tested by comparing theoretically calculated results for a number of spectroscopic properties such as reduced transition probabilities with evaluated data. To facilitate such calculations, two subsets of evaluated nuclear structure data for $2\beta^-$-decay and $2\beta^+$-, $\epsilon \beta^+$- and $2\epsilon$-decay candidates [16] are shown in Tables I and II respectively. These tables reflect current progress and indicate future work.

III. CONCLUSIONS

The $B(E2)^+$ evaluation is proceeding under the auspices of the U.S. Nuclear Data Program. This effort is continuation of the previous works of Stelson, Grodzins and Raman [14]. This procedure includes the broadened nuclear structure data sets supported by shell model calculations for all known even-even nuclei.

The subset of the latest quadrupole collectivity data relevant to double-beta decay problem has been noted [10]. These well-established data could provide some guidance for theoretical calculations of double-beta decay rates for nuclei of interest where information on Gamow-Teller transitions is lacking.

The data evaluation for the $Z\sim 28$ nuclei [7] is publicly
TABLE II. Recommended $B(E2; 0^+ \rightarrow 2^+)$ and $\beta_2$ values for $2\beta^+$, $\epsilon\beta^+$ and $2\epsilon$ candidates.

| Parent | $E(2^+_1)$, keV | $B(E2)$, W.u. | $\beta_2$ | Daughter | $E(2^+_2)$, keV | $B(E2)$, W.u. | $\beta_2$ |
|--------|------------------|---------------|-----------|----------|-----------------|---------------|-----------|
| $^{56}$Cr | 783.3(9) | 19.32(42) | 0.2903(32) | $^{90}$Ti | 1553.778 (7) | 5.04(30) | 0.1617(48) |
| $^{58}$Ni | 1454.21(9) | 10.04(17) | 0.1794(15) | $^{58}$Fe | 810.7662(20) | 16.9(24) | 0.250(18) |
| $^{64}$Zn | 991.56(5) | 19.52(68) | 0.2335(41) | $^{64}$Ni | 1345.75(5) | 8.3(5) | 0.163(5) |
| $^{74}$Se | 634.74(6) | 38.7(21) | 0.2902(80) | $^{74}$Ge | 595.850(6) | 32.68(+90-81) | 0.2832(+39-35) |
| $^{78}$Kr | 455.033(23) | 64.0(16) | 0.3524(44) | $^{78}$Se | 613.727(3) | 34.6(12) | 0.2744(49) |
| $^{84}$Sr | 793.22(6) | 26.7(21) | 0.2156(84) | $^{84}$Kr | 881.615(3) | 11.60(+44-25) | 0.1500(+29-16) |
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