

Ground State neutron Spectroscopic Factors for $Z=3-24$ isotopes

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Abstract

Past measurements of the angular distributions for (d,p) and (p,d) reactions on targets with $Z=3-24$ leading to the ground states have been analyzed systematically using the theory of Johnson-Soper adiabatic approximation and Distorted-Wave Born-Approximation, adopting nucleon-nucleus global optical model potentials as input. In all, the ground state neutron spectroscopic factors (SF) for 80 nuclei have been obtained. The consistency of the method is evaluated by comparing spectroscopic factors obtained separately in (p,d) and (d,p) reactions. The values also correlate strongly with Endt's compilation when available, but the current method of extracting spectroscopic factors is more general and the values obtained are more consistent.

I. Introduction

The spectroscopic factors describe the overlap between the initial and final state in the reaction channels and yield important information about single-particle orbitals in many nuclei [1-5]. Single nucleon transfer reactions such as (d,p) or (p,d) reactions have been used extensively to extract the spectroscopic information of the single nucleon orbits [1-6]. Specifically, these measurements allow the extraction of the spectroscopic factors by taking the ratios of the experimental cross-sections to the predicted cross-sections from a reaction model. The most common model used is the Distorted Wave Born Approximation (DWBA) theory [3-5]. For (p,d) and (d,p) transfer reactions involving deuteron, the effects from deuteron break up can be significant at high energy and the correction is generally taken into account using the Johnson-Soper adiabatic approximation [7].

Some of the difficulties in the past extractions of spectroscopic factors have been associated with different parameterizations used in the reaction models, different normalizations, and different assumptions used in the analysis [8, 9]. It is not unusual to find spectroscopic factors for a particular nucleus that fluctuate by factors of 2-3. Recently, it has been shown that systematic and consistent analysis of the angular distributions for the $^{12}\text{C}(\text{d,p})^{13}\text{C}$ and $^{13}\text{C}(\text{p,d})^{12}\text{C}$ reactions yield the ground state spectroscopic factors to within 15% over a range of equivalent deuteron incident energy from 12 to 60 MeV [9]. There is an abundant amount of transfer reaction data collected in the past 40 years. These data, if analyzed in a consistent manner, may provide a systematic view of the spectroscopic factors over the nuclear chart and may shed insight as to how to extract the spectroscopic information about the valence orbitals for unstable nuclei far from the valley of beta stability [10-12].

II. Reaction model

In the present work, we follow the algorithm developed in ref. [9] and use a modified version of the code TWOFNR [13] to perform the transfer reaction model calculations using the same input parameters labeled as CH in ref. [9]. The transfer cross-sections are calculated within the Johnson-Soper (JS) adiabatic approximation [7] to the neutron, proton, and target three-body system using the phenomenological nucleon nucleus optical model potentials [14]. This calculation includes the effects of breakup of

the deuteron in the field of the target. The valence neutron binding potential is Woods-Saxon in shape with fixed a radius parameter of 1.25 fm and a diffuseness parameter of 0.65 fm [9]. The depth of the potential is normalized to the experimental binding energy. All calculations make the local energy approximation (LEA) for finite range effects [15] using the Zero-range strength ($D_0^2=150006.25 \text{ fm}^3$) and range ($\beta=0.7457 \text{ fm}$) parameters of the Reid soft-core 3S_1 - 3D_1 neutron-proton interaction [16]. Nonlocality corrections with range parameters of 0.85 fm and 0.54 fm are included in the proton and deuteron channels, respectively [17]. The same set of input parameters is used throughout in the present work to extract the spectroscopic factors [18].

III Compilation and digitization of angular distribution data

For the present work, we mainly focus on the transfer reactions $A(d,p)B$ and its inverse reaction $B(p,d)A$ where the nucleus A is considered to be composed of the core B plus the valence neutron n. Table 1 contains 423 reactions that we have examined. For clarity, we include shorthand literature references [19-239] in the table.

Nearly all the angular distributions listed in Table 1 have been digitized from the published figures. The few exceptions are those found in the Nuclear Science References (NSR) database of the National Nuclear Data Center (NNDC) [240]. The data from NSR are in tabulated form and the sources of these data came from the Former Soviet Union or Japan whose journals are not widely available in the United States. These non-US and non-European data complement our search in the Physical Review Journals, Nuclear Physics and occasionally in Physics Letters. While we make an effort to search out nearly all the relevant experiments that published the absolute differential cross-sections, we may have missed some reactions especially if the incident energy is below 10 MeV and above 70 MeV. Except when noted, the table does not include reactions with cross-sections published in arbitrary units. The data and calculations will be posted in a website [241]. Eventually, we hope all the digitized data used in this work will be adopted by the NSR.

By checking some of the data carefully and sometimes repeating the digitization several times, we estimate the uncertainties introduced by the digitization process to be less than 10%. For illustration, we use the data for the reaction ${}^{14}\text{N}(d,p){}^{15}\text{N}$ at $E_d=12 \text{ MeV}$ [21, 82]. This set of data was first published in tabulated form in ref [21]. The tabulated

data are plotted as closed points in Figure 1. Later the authors in ref. [82] plotted the data in a figure. We digitized the data in [82] and compare our digitized data (open points) with the tabulated data (closed points) in Figure 1. We see a difference of less than 10% between the two sets of data. Of course, the digitization errors also depend on the actual size of the graphs available in the original literature. As described later, generally, errors introduced by digitization are small compared to the uncertainties in the absolute cross-section measurements.

IV. Extraction of spectroscopic factors

For nearly all the nuclei we study, we use the ground state ℓ values determined from the angular distributions and the j^π values of the valence neutron ground states found in the isotope tables [242]. In general, the experimental angular distributions at the backward angle are more sensitive to the effects of inelastic couplings and other higher-order effects and are not well reproduced by most reaction models. Furthermore, discrepancies between the shapes from calculations and experiment are much worse in the valley. Thus, we follow the procedures developed in ref. [9] and others that the spectroscopic factor is extracted by fitting the reaction model predictions to the angular distribution data at the first peak, with emphasis on the maximum. The accuracy in absolute cross-section measurements near the peak is most important. When possible, we take the mean of as many points near the maximum as we can to extract the spectroscopic factors. We will use the angular distributions of $^{14}\text{N}(d,p)^{15}\text{N}$ shown in Fig 1 to illustrate the procedure we adopt to extract the spectroscopic factors.

In Figure 1, the first 3 data points with $\theta_{\text{cm}} < 25^\circ$ have been used to determine the ratios of the measured and calculated differential cross-sections. The mean of these three ratios is adopted as the spectroscopic factor. For example, for the two sets of data plotted in Figure 1, the spectroscopic factors are 1.2 and 1.1 for digitized [82] data and tabulated data [21] respectively. The difference in the spectroscopic factors represents the uncertainties introduced by digitizations. The theoretical angular distributions, obtained from TWOFNR, multiplied by the spectroscopic factor 1.1, are plotted as solid curve in the figure.

In cases when a “first peak” is not obvious or that the angular distributions of the forward angles are nearly flat, e.g. in the reaction of $^{44}\text{Ca}(p,d)^{43}\text{Ca}$ at $E_p=40$ MeV [174]

as shown in Figure 2, we found that fitting the shoulder gives more consistent results. This observation is probably related to the fact that due to quantum tunneling, the very forward angle data cannot be described well by classical calculations [243].

In general, the agreement of the shape of the angular distributions of the first peak or shoulder to reaction calculations gives some indication to the quality of the data. The numbers of data points in the fit region, which can be described well by the predicted angular distributions are included as statistical weights in Table 1 when the mean spectroscopic factors for an isotope are computed.

V. Evaluation of the angular distribution measurements

Even though most papers state the uncertainties of their cross-section measurements to be 10-20%, the actual disagreements between experiments are often larger than the quoted uncertainties. An example is illustrated in the reactions $^{11}\text{B}(d,p)^{12}\text{B}$ reactions. From the conventional literature, we found two measurements at deuteron incident energy of 11.8 MeV [45] and 12 MeV [21]. Since the incident deuteron energy is nearly the same, one would expect the angular distributions plotted in Figure 3 to be the same within experimental error. Ref. [21] stated that the accuracy of the absolute cross-section measurements is 15% while ref. [45] quoted an error of 6%, which is smaller than the closed symbols in Fig 3. Not only do the cross-sections differ sometimes by a factor of two, the shapes of the distributions (especially the first peak) are not even the same. In this case, the shape of the angular distributions in ref. [45] agrees with the calculations better than that measured in ref. [21]. Fortunately for this reaction, we were able to find another measurement in the NNDC database [46]. This latter angular distribution agrees with ref. [45]. Data in ref. [45] was measured nearly 40 years later than data in ref. [21]. Naively, one might expect newer measurements to be better as beam quality and detection systems tend to improve with time. However, when another reaction, $^{12}\text{C}(d,p)^{13}\text{C}$ at $E_d=11.8$ MeV from ref. [45] (closed circles) is compared to three other published angular distributions at $E_d=11.8$ MeV (closed diamonds) [30], 12 MeV (open circles) [21], 12 MeV (open diamonds) [59], the cross-sections in the first peak measured in ref. [45] is consistently low. No uncertainties in the measurements are given in ref. [30] and ref. [59] but it is clear that data in ref. [45] do not agree with other measurements.

Cross comparisons of angular distributions sometimes help to establish common systematic problems when one set of measurements was performed by the same group with the same set up. An example is illustrated in the $^{40}\text{Ca}(d,p)^{41}\text{Ca}$ reactions in ref. [181] where the ground state angular distributions of ^{41}Ca at $E_d=7, 8, 9, 10, 11$ and 12 MeV have been measured. Figure 5 shows the extracted spectroscopic factors as a function of incident deuteron energy for all the $^{40}\text{Ca}(d,p)^{41}\text{Ca}$ reactions. For clarity in presentation, no uncertainties are plotted. The extracted spectroscopic factors from ref. [181] (open circles) are consistently larger than the spectroscopic factors extracted from different experiments with the same reactions at the same energy. Detailed comparisons of the angular distribution data show essentially the same effect, that the differential cross-sections measured in ref. [181] are systematically higher than the other measurements. Clearly, there must be some problems in the determination of the absolute cross-sections in ref. [181]. Since it is not possible to find the cause after so many years. In our review of the data, we ignore spectroscopic factor values determined from ref. [181].

Similarly we include the weight of only one spectroscopic factor at 11 MeV determined using the data in ref. [29] for the $^9\text{Be}(d,p)^{10}\text{Be}$ reaction as most of the data in ref. [29] are low when compared to the available data from other measurements. To also include data from $E_d=10$ and 10.5 MeV for the reaction $^9\text{Be}(d,p)^{10}\text{Be}$ will increase the weights of these measurements in the mean values. All the SF values not used are listed in Column 5. In general, a brief comment follows in the last column of Table I if the data set is considered to be problematic.

The disagreements between data sets suggest that it is not reliable to use the quoted uncertainties by the experimenters. Rather, we have found that the most important aspect of quality control of the data is to have as many independent measurements as possible. Comparisons of different measurements help to weed out bad ones. The large number of measurements compiled in Table I provide some assurance of the quality of the spectroscopic factors extracted in the present work.

VI. Transfer reactions at high and low energy

When Q-value and the transverse and angular momentum transferred are not well-matched as in the transfer reactions induced by very low or high (> 50 MeV) beam energy, the shape comparisons are also poor. Figure 6 shows the angular distributions of

the protons emitted from the $^{40}\text{Ca}(d,p)^{41}\text{Ca}$ (g.s) reaction from $E_d=7.2$ to 56 MeV. Only one angular distribution is presented for each energy. The agreement between data and prediction for the first peak improves with increasing energy. At very low incident or excitation energy, the comparisons are bad. This phenomenon is also seen in other reactions. The spectroscopic factors as a function of incident energy are shown in Figure 5. The increase of spectroscopic factors observed at $E_d < 10$ MeV has been observed before [9, 21] and has been attributed to the resonance structures in the elastic scattering of the deuterons [244]. If the open points based on the data from ref. [181] are ignored, between 10 to 56 MeV, the mean spectroscopic factor, 0.99 ± 0.055 as shown by the solid line in Figure 1, is independent of incident energy within experimental errors.

In reactions which have large negative Q values such as $^{12}\text{C}(p,d)^{11}\text{C}$ ($Q = -16.5$ MeV), the center of mass energy available in the exit channel is very small even at ~ 20 MeV proton incident energy [38]. The validity of the calculated angular distribution is questionable at these energies and we discard these data. For other reactions measured at low incident energy (< 10 MeV), the data could be dominated by compound nucleus emissions, or resonances in the low energy deuteron elastic scattering [244]. When possible, we exclude spectroscopic factors obtained with incident beam energy less than 10 MeV. These “excluded” spectroscopic factors are listed in Column 5 of Table 1.

Even though we exclude data with incident energy lower than 10 MeV from the calculation of the mean SF, these low energy data are still valuable. In cases where very few (sometimes only one) measurements with incident energy greater than 10 MeV are available, they provide checks for consistency of the measurements. Examples are $^{49}\text{Ti}(p,d)^{48}\text{Ti}$ and $^{48}\text{Ti}(d,p)^{49}\text{Ti}$ reactions [146, 211, 217, 218]. In the $^{43}\text{Ca}(d,p)^{44}\text{Ca}$ reaction, only 8.5 MeV data [201] are available. Similarly, only 7.5 MeV data for $^{50}\text{V}(d,p)^{51}\text{V}$ reaction [220] and 7.83 MeV data for $^{23}\text{Na}(d,p)^{24}\text{Na}$ reaction [110] are found. We adopted these results nonetheless.

At high energy, momentum transferred and angular momentum are mismatched so the conditions may not be optimized to extract spectroscopic factors for the ground state valence neutrons. Furthermore, the global nucleon-nucleus potentials (CH89) [14] are good to 65 MeV for protons and 26 MeV for neutrons. Thus, we do not include high energy reactions in this work. Above 100 MeV per nucleon, knockout reactions

dominate. In examining data over a wide range of d or p incident energy, we find that the optimum beam energy to study transfer reactions lies between 10-20 MeV per nucleon.

VII. Nuclei with small spectroscopic factors

For the $^{50}\text{Cr}(p,d)^{49}\text{Cr}$ reactions, there are two measurements at beam energy of 17.5 and 55 MeV [223, 224]. In each case, the predicted and measured angular distributions are different as shown in Figure 10. From the magnitude of the measured cross-sections, a spectroscopic factor value of 0.11 is derived. The extracted spectroscopic factor is very low especially for an even-even nucleus. It is reasonable to speculate that there is considerable configuration mixing of the valance nucleus. When very low SF values (compared to values predicted by the Independent Particle Model [3-5]) are obtained, data quality is generally poor and the predicted shape of the angular distributions may not agree well with that of the data. Other examples are ^{20}F , ^{21}Ne , ^{22}Ne , ^{24}Mg , ^{35}Cl , ^{45}Sc , ^{48}Ti , ^{50}Cr , ^{51}Cr , and ^{51}V nuclei.

In the case of $^{46}\text{Ti}(d,p)^{47}\text{Ti}$ reactions [214, 215], both measurements at $E_d=7$ and 10 MeV are very different from the predicted cross-sections and disagree with each other in shape and absolute cross-sections. We did not extract spectroscopic factors for the nucleus of ^{47}Ti .

VIII. Comparison of Spectroscopic factors obtained from (p,d) and (d,p) reactions

The neutron pickup (d,p) and neutron stripping (p,d) reactions are inverse reactions, both of which connect the ground states of the target and projectile nuclei. They should yield the same values of the spectroscopic factors. From Table I, we select the nuclei, which have been studied reasonably well by both neutron pick-up and stripping reactions from and to the ground state. The averaged SF values are listed in the 2nd and 4th column of Table II. The numbers of measurements contributing to the averages are listed right next to the mean values in the 3rd and 5th columns.

There are strong correlations between the spectroscopic factors determined from the (p,d) and (d,p) reactions as shown in Figure 8. The solid line indicates perfect agreement. As these are independent measurements determined from similar procedure outlined above, the scatter of the data points could be used to determine the error bars. Assuming the uncertainties of each of the measurement are the same, x%. By requiring the chi-square per degree of freedom to be unity, x can be determined and in this case x=20%.

The obtained uncertainty of 20% is consistent with analysis with large number of measurements such as $^{12}\text{C}(d,p)^{13}\text{C}$ and $^{40}\text{Ca}(d,p)^{41}\text{Ca}$. Examinations of large number of measurements in Table I suggest that the uncertainties in the extraction of the spectroscopic factors are largely limited by the agreement between measurements.

In Table II, we have excluded measurements for ^7Li , ^{34}S and ^{10}Be nuclei due to large uncertainties associated with either the associated (p,d) or (d,p) measurements. Including these 3 measurements increase x to 30%.

Finally, we can compute the spectroscopic factor values and the associated uncertainties. The SF values are obtained from the weighted average of independent measurements from both the (p,d) and (d,p) reactions listed in Table 1 from which the low energy (<10 MeV) and “bad” (nominally marked with asterisks) data are excluded. For values determined by only one measurement when no other independent measurement is available for consistency checks, an associated uncertainty of 30% is assigned. For values determined by N measurements, the associated uncertainties are determined by $20\%/\sqrt{N}$.

IX. Comparison with Endt’s “best values”

In 1977, Endt compiled a list of the “best” spectroscopic factor values for the sd-shell nuclei [8]. For the neutron spectroscopic factors, Endt compiled the published spectroscopic factors from (d,t), (p,d), ($^3\text{He},\alpha$) and (d,p) reactions. An uncertainty of 25% is assigned to the values. (When only the (p,d) and (d,p) reactions are studied, Endt assigned a 50% uncertainties.) Endt’s best values are listed in Table 3. Figure 9 compares the spectroscopic factors determined by Endt and the present work. There are strong correlations between the two procedures even though the values scatter around the dashed line, which indicates perfect agreement. From the consistency check with (p,d) and (d,p) reactions, our values should have smaller uncertainties. We believe our values are better than Endt’s because we use a systematic approach to extract the SF values directly from the measured angular distributions while Endt’s compilation depended on the analysis of different authors and relied on the communication with the authors concerning the analysis and normalizations of the spectroscopic factors. Of course, we also have the advantage that our data set in Table 1 include many more measurements than those available in Endt’s compilations.

X. $^{14}\text{C}(\text{d,p})^{15}\text{C}$ reactions

The $^{14}\text{C}(\text{d,p})^{15}\text{C}$ reaction is interesting because ^{15}C has a loosely bound halo neutron. It is an important reaction to provide good cross-comparisons between the spectroscopic factors obtained from one-nucleon knock-out and transfer reactions [245]. In addition, this reaction is a good candidate to extract spectroscopic factors using the combined asymptotic normalization coefficient (ANC) method [246].

For the $^{14}\text{C}(\text{d,p})^{15}\text{C}$ reaction, there are three references [71, 74 and 75] with $E_d > 10$ MeV. When data from these references are plotted in Figure 8, the data do not agree with each other within a factor of two. However, in each case, the spectroscopic factors quoted in the original references are within 20% of each other (0.88 [74], 1.03 [71], 0.99 [75]). The near agreement of the published SF values, even though the measured cross-sections are very different, illustrates the problem when spectroscopic factors of desired values could be obtained by choosing different input parameters in the analysis. It underscores the importance of analysis with a systematic and consistent approach as studied here.

Since data with first peak or forward angle peak missing are generally not used in our analysis, we exclude ref. [71, 75]. The predicted angular distribution shape (curve) shows good agreement with ref. [74] with data less than 15° and we choose to adopt the extracted SF from this data set. The value of 1.1 is about 35% higher compared with the SF's values extracted at low energy.

XI. Dependence of spectroscopic factors on neutron separation energy

Recent measurements of spectroscopic factors from single-nucleon “knock-out” reactions with radioactive and stable nuclei show increasing quenching of the spectroscopic factor values with respect to large basis shell model predicted values with nucleon separation energy [247, 248]. The wide range of isotopes studied in this work includes nuclei with neutron-separation energies ranging from 0.5 to 19 MeV as listed in Table III. To examine any quenching trend, we compute the neutron spectroscopic factors using Oxbash, a large basis shell model code [249, 250]. The interactions used in the calculations are listed in Table 3. Due to the amount of CPU times involved, we cannot compute the SF values from Oxbash for every nucleus. As discussed in detail in ref. [18], excluding the deformed nuclei and nuclei with small SF values, most of the extracted

spectroscopic factors agree well with the predicted values from large basis shell model to 20%.

Figure 11 shows the ratio of the experimental SF values to the LB-SM values from Oxbash as a function of the neutron separation energy. Within the experimental uncertainties, we do not see any systematic quenching of the spectroscopic factors with increasing nucleon separation energy as in the nucleon knockout reactions induced by radioactive beams. Rather, there seems to be some indication that the trend is the opposite, i.e., the SF's values are smaller than the predicted values for nuclei with small neutron separation energy. (This trend persists in a smaller subset of the nuclei such as the Ca isotopes plotted as solid stars in Figure 11.)

The structures of the neutron rich nuclei with small neutron separation energy are of general interest. For loosely bound nuclei, knockout reactions with radioactive beams suggest no quenching. In our data set, there are seven nuclei with $S_n < 4$ MeV, ${}^8\text{Li}$, ${}^9\text{Be}$, ${}^{11}\text{Be}$, ${}^{12}\text{B}$, ${}^{15}\text{C}$, ${}^{16}\text{N}$, and ${}^{19}\text{O}$. Except for ${}^{15}\text{C}$, which was discussed in previous section, the fit and quality of the data are typical as compared to all the data we have examined. However, the experimental SF values are consistently smaller than the large basis shell model predictions as shown in Figure 11. (If we relax the criterion to $S_n < 5$ MeV, the conclusion is similar.) Excluding ${}^{15}\text{C}$, the average quenching factor is 0.6. To be sure, we do not have many nuclei and they are all light nuclei with $Z \leq 8$. Furthermore, the quenching ratios vary from 0.44 to 0.77 for the six nuclei we examined. However, as a group, the SF values do not agree with the LB-SM predictions. The results suggest that the standard global potential [14] may not be appropriate to describe the scattering of these weakly bound nuclei with diffuse surfaces. Further study with improved theoretical inputs is needed to understand these nuclei with loosely bound neutrons.

XII. Summary

Using angular distributions from past (p,d) and (d,p) transfer reactions data and minimum assumptions used in the conventional Johnson-Soper adiabatic and distorted-wave theories, we obtain a set of neutron ground state spectroscopic factors for nuclei ranging from Li to Cr isotopes. Endt's compilation of $A > 40$ nuclei in 1977 provide some values for comparison. Our spectroscopic factors correlate strongly with Endt's best values. Based on the comparisons between spectroscopic factors obtained from (p,d) and

(d,p) reactions, most extracted values have uncertainties less than 20%, mainly coming from experimental measurements. The present compilation of the neutron ground state spectroscopic factors of 80 nuclei would provide important reference points to future analysis on spectroscopic factors especially for rare nuclei. They also provide testing grounds for more sophisticated theoretical work on transfer reactions and development in nuclear structure model. At the very least, the simple theory with minimum assumption presented in this paper predicts the shape of the first peak of the angular distributions quite reliably. Such knowledge is useful in planning future transfer experiments with radioactive beams.

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References

- [1] M. H. Macfarlane and J. B. French, *Rev. Mod. Phys.* **32**, 567 (1960).
- [2] M. H. Macfarlane and J. P. Schiffer, *Nuclear Spectroscopy and Reactions* (Academic, New York, London, 1974), Vol. 40B, pp. 170-194.
- [3] N. Austern, *Direct Nuclear Reaction Theories*, John Wiley & Sons, New York, 1970.
- [4] G. R. Satchler, *Direct Nuclear Reactions*, Oxford University Press, Oxford, 1983.
- [5] Norman K Glendenning, *Direct Nuclear Reactions*, World Scientific Publishing, 2004.
- [6] S. T. Butler, *Proc. R. Soc. London, Ser. A* **208**, 559 (1951).
- [7] R. C. Johnson and P. J. R. Soper, *Phys. Rev. C* **1**, 976 (1970).
- [8] P. M. Endt, *Atomic Data and Nuclear Data Tables* **19**, 23 (1977).
- [9] X. D. Liu et al., *Phys. Rev. C* **69**, 064313 (2004).
- [10] W. N. Catford, *Nucl. Phys.* **A701**, 1c (2002). [ISI]
- [11] N. Keely et al., *Phys. Rev. C* **69**, 064604 (2004)
- [12] K. L. Jones et al., *Phys. Rev. C* **70**, 067602 (2004).
- [13] M. Igarashi et al., *Computer Program TWOFNR* (Surrey University version).
- [14] R. L. Varner et al., *Phys. Rep.* **201**, 57 (1991).
- [15] P. J. A. Buttle and L. J. B. Goldfarb, *Proc. Phys. Soc. London* **83**, 701 (1964).
- [16] L. D. Knutson, J. A. Thomson, and H. O. Meyer, *Nucl. Phys.* **A241**, 36 (1975).
- [17] F. Perey and B. Buck, *Nucl. Phys.* **32**, 353 (1962).
- [18] M.B. Tsang, H. C. Lee and W. G. Lynch, to be published.
- [19] L. A. Kull, *Phys. Rev.* **163**, 1066 (1967).
- [20] D. L. Powel et al., *Nucl. Phys.* **A147**, 65 (1970).
- [21] J. P. Schiffer et al., *Phys. Rev.* **164**, 1274 (1967).
- [22] D.W.Devins et al, *Nucl. Phys.* **A126**, 261 (1969).
- [23] A.H.Wuosmaa et al., *Phys. Rev. Lett.* **94**, 082502 (2005).
- [24] G. M. Hudson et al., *Nucl. Phys.* **A184**, 175 (1972).
- [25] F. D. Becchetti et al., *Phys. Rev. C* **24**, 2401 (1981).
- [26] D. L. Auton, *Nucl. Phys.* **A157**, 305 (1970).
- [27] D. G. Montague et al., *Nucl. Phys.* **A199**, 433 (1973).
- [28] J. W. Verba et al., *Phys. Rev.* **153**, 1127 (1967).

- [29] L.N.Generalov et al., *Izv. Rossiiskoi Akademii Nauk, Ser.Fiz.* Vol.64, 440 (2000).
- [30] U.Schmidt-rohr, R.Stock and P. Turek, *Nucl. Phys.* 53, 77 (1964).
- [31] O.I.Vasileva et al., *Yadern Fiz.* 45,312,(1987).
- [32] S. E. Darden, G. Murillo and S. Sen, *Nucl. Phys.* A266, 29 (1976).
- [33] N.S.Zelenskaya et al., *Yadern Fiz.* 64, 1995 (2001).
- [34] R. E. Anderson et al., *Nucl. Phys.* A236, 77 (1974).
- [35] R. J. Slobodrian, *Phys. Rev.* 126, 1059 (1962).
- [36] X. D. Liu, Ph.D Thesis , Michigan State University, (2005)
<http://www.nsl.msui.edu/ourlab/library/publications>
- [37] B. Zwiaglinski et al., *Nucl. Phys.* A315, 124 (1979).
- [38] J. S. Winfield et al., *Nucl. Phys.* A683, 48 (2001).
- [39] L. A. Kull and E. Kashy, *Phys. Rev.* 167, 963 (1968).
- [40] G. T. A. Squier et al., *Nucl. Phys.* A141, 158 (1970).
- [41] William R. Smith and Eugene V. Ivash, *Phys. Rev.* 131, 304 (1963).
- [42] S.Hinds, R.Middleton, *Nucl. Phys.* 38, 114 (1962).
- [43] H.W.Barz, R.Fulle, D.Netzband, R.Reif, K.Schlott, J.Slotta, *Nucl. Phys.* 73, 473 (1965).
- [44] James C. Legg, *Phys. Rev.* 129, 272 (1963).
- [45] Z. H. Liu et al., *Phys. Rev. C* 64, 034312 (2001).
- [46] D.Fick, *J,NUK*,19,693 (1974),
<http://www.nndc.bnl.gov/exfor/servlet/X4sGetSubent?subID=150326002&master=ND>
- [47] E. K. Warburton and H. O. Funsten, *Phys. Rev.* 128, 1810 (1962).
- [48] N. S. Chant, P. S. Fisher and D. K. Scott, *Nucl. Phys.* A99, 669 (1967).
- [49] C. D. Kavaloski, G. Bassani, and Norton M. Hintz, *Phys. Rev.* 132, 813 (1963).
- [50] J. R. Comfort and B. C. Karp, *Phys. Rev. C* 21, 2162 (1980).
- [51] P. G. Roos et al., *Nucl. Phys.* A255, 187 (1975).
- [52] K. Hosono et al., *Nucl. Phys.* A343, 234 (1980).
- [53] A.Gallman, P.Fintz, P.E.Hodgson, *Nucl. Phys.* 82, 161 (1966).
- [54] T. W. Bonner et al., *Phys. Rev.* 101, 209 (1956).
- [55] H. Guratzsch, G. Hofmann, H. Müller and G. Stiller, *Nucl. Phys.* A129, 405 (1969).
- [56] N. I. Zaika et al., *Soviet Phys. JETP* 12, 1 (1961)*JETP* 12, 1 (1960)
- [57] D.Robson, *Nucl. Phys.* 22, 34 (1961).

- [58] E. W. Hamburger, Phys. Rev. 123, 619 (1961).
- [59] J. Lang et al., Nucl. Phys. A477, 77 (1988).
- [60] J. N. McGruer, E. K. Warburton, and R. S. Bender, Phys. Rev. 100, 235 (1955).
- [61] S. E. Darden et al., Nucl. Phys. A208, 77 (1973).
- [62] S. Morita et al., J. Phys. Soc. Jap 15, 550 (1960).
- [63] R. van Dantzig and W. Tobocman, Phys. Rev. 136, B1682 (1964).
- [64] H. Ohnuma et al., Nucl. Phys. A448, 205 (1986).
- [65] K. Hatanaka et al., Nucl. Phys. A419, 530 (1984).
- [66] H. Toyokawa et al., Phys. Rev. C 51, 2592 (1995).
- [67] J. R. Campbell et al., Nucl. Phys. A470, 349 (1987).
- [68] H. Taketani, J. Muto, H. Yamaguchi and J. Kokame, Phys. Lett. B 27, 625 (1968).
- [69] S. K. Datta, G. P. A. Berg and P. A. Quin, Nucl. Phys. A312, 1 (1978).
- [70] T. H. Curtis et al., Nucl. Phys. A165, 19 (1971).
- [71] F. E. Cecil et al., Nucl. Phys. A255, 243 (1975).
- [72] M. Yasue et al., Nucl. Phys. A509, 141 (1990).
- [73] John B. Nelson, William R. Smith, Nucl. Phys. A96, 671 (1967).
- [74] J. D. Goss et al., Phys. Rev. C 12, 1730 (1975).
- [75] G. Murillo et al., Nucl. Phys. A579, 125 (1994)
- [76] E. F. Bennett, Phys. Rev. 122, 595 (1961).
- [77] Y. Aoki et al., Nucl. Phys. A322, 117 (1979).
- [78] R. L. Kozub, L. A. Kull and E. Kashy, Nucl. Phys. A99, 540 (1967).
- [79] W. Kretschmer, G. Pröbstle and W. Stach, Nucl. Phys. A333, 13 (1980).
- [80] Y. Aoki, S. Kunori, K. Nagano, Y. Toba and K. yagi, Nucl. Phys. A382, 269 (1982).
- [81] E. K. Warburton and J. N. McGruer, Phys. Rev. 105, 639 (1957).
- [82] E. F. Hefter, E. T. Boschitz, V. Heidt and Ch. Weddigen, Nucl. Phys. A275, 212 (1977).
- [83] J. L. Snelgrove and E. Kashy, Phys. Rev. 187, 1259 (1969).
- [84] J. L. Snelgrove and E. Kashy, Phys. Rev. 187, 1246 (1969).
- [85] O. Dietzsch et al., Nucl. Phys. A114, 330 (1968).
- [86] I. M. Naqib and L. L. Green, Nucl. Phys. A112, 76 (1968).
- [87] H. Cords, G. U. Din and B. A. Robson, Nucl. Phys. A134, 561 (1969).
- [88] D. C. Kocher, P. J. Bjorkholm and W. Haeberli, Nucl. Phys. A172, 663 (1971).

- [89] K. W. Corriga et al., Nucl. Phys. A188, 164 (1972).
- [90] J. L. Alty et al., Nucl. Phys. A97, 541 (1967).
- [91] E.L.Keller, Phys. Rev. 121, 820 (1961).
- [92] M. D. Cooper, W. F. Hornyak and P. G. Roos, Nucl. Phys. A218, 249 (1974).
- [93] J.Testoni and S.Mayo, Nucl. Phys. 50, 479 (1964).
- [94] G. B. Crinean et al., Nucl. Phys. A244, 77 (1975).
- [95] R. Mendelson, J. C. Hardy and J. Cerny, Phys. Lett. B 31, 126 (1970).
- [96] T.K.Li, D.Dehnhard, R.E.Brown, P.J.Ellis, Phys. Rev. C13, 55 (1976).
- [97] H. F. Lutz et al., Nucl. Phys. A101, 241 (1967).
- [98] M. Pignanelli et al., Phys. Rev. C 10, 445 (1974).
- [99] E. J. Stephenson, B. P. Hichwa and J. D. Hutton, Nucl. Phys. A331, 269 (1979).
- [100] S. Sen, S. E. Darden, H. R. Hiddleston and W. A. Yoh, Nucl. Phys. A219, 429 (1974).
- [101] J. C. Armstrong and K. S. Quisenberry, Phys. Rev. 122, 150 (1961).
- [102] J. M. Delbrouck-Habaru and G. Robaye, Nucl. Phys. A337, 107 (1980).
- [103] H. T. Fortune and R. R. Betts, Phys. Rev. C 10, 1292 (1974).
- [104] B. H. Wildenthal et., Phys. Rev. C 6, 21 (1972).
- [105] S. K. Datta et al., Nucl. Phys. A332, 125 (1979).
- [106] A. J. Howard, J. O. Pronko and C. A. Whitten, Jr. , Nucl. Phys. A152, 317 (1970).
- [107] A. J. Howard, J. G. Pronko and R. G. Hirko, Nucl. Phys. A150, 609 (1970).
- [108] H. F. Lutz et al., Nucl. Phys. A95, 591 (1967).
- [109] A. J. Howard, J. G. Pronko, and C. A. Whitten, Jr., Phys. Rev. 184, 1094 (1969).
- [110] C.Daum, Nucl. Phys. 45, 273 (1963).
- [111] P. D. Kunz, E. Rost, and R. R. Johnson, Phys. Rev. 177, 1737 (1969).
- [112] R. L. Kozub, Phys. Rev. 172, 1078 (1968).
- [113] D. W. Miller et al., Phys. Rev. C 33, 22 (1986).
- [114] A.Gallmann et al., Nucl. Phys. 88, 654 (1966)
- [115] U. Scheib, A. Hofmann, G. Philipp and F. Vogler, Nucl. Phys. A203, 177 (1973).
- [116] F. Meurders and G. De Korte, Nucl. Phys. A249, 205 (1975).
- [117] T. A. Schmick et al., Phys. Rev. C 10, 556 (1974).
- [118] H.F.Lutz, S.F.Eccles, Nucl. Phys. 88, 513 (1966).
- [119] M. Burlein, K. S. Dhuga, and H. T. Fortune, Phys. Rev. C 29, 2013 (1984).

- [120] H. F. R. Arciszewski et al., Nucl. Phys. A430, 234 (1984).
- [121] J. Kroon et al., Nucl. Phys. A172, 99 (1971).
- [122] P. W. F. Alons et al., Nucl. Phys. A351, 77 (1981).
- [123] R. J. Peterson et al., Phys. Rev. C 38, 2026 (1988).
- [124] J. Silverstei et al., Phys. Rev. 136, B1703 (1964).
- [125] F. Meurders and A. Van Der Steld, Nucl. Phys. A230, 317 (1974).
- [126] J. Kroon, B. Hird, and G. C. Ball, Nucl. Phys. A204, 609 (1973).
- [127] D. L. Show et al., Nucl. Phys. A263, 293 (1976).
- [128] S. Chen, J. Rapaport, H. Enge and W. W. Buechner, Nucl. Phys. A197, 97 (1972).
- [129] T. P. G. Carola and J. G. Van Der Baan, Nucl. Phys. A173, 414 (1971).
- [130] J. V. Maher et al., Phys. Rev. C 5, 1313 (1972).
- [131] G. D. Jones, R. R. Johnson and R. J. Griffiths, Nucl. Phys. A107, 659 (1968).
- [132] D. P. Gurd, G. Roy and H. G. Leighton, Nucl. Phys. A120, 94 (1968).
- [133] U. Strohbush, W. Bakowsky and H. Lacek, Nucl. Phys. A149, 605 (1970).
- [134] A. El-Naiem and R. Reif, Nucl. Phys. A189, 305 (1972).
- [135] R. J. Peterson et al., Nucl. Phys. A408, 221 (1983).
- [136] M. C. Mermaz et al., Phys. Rev. C 4, 1778 (1971).
- [137] F. Pellegrini et al., Phys. Rev. C 2, 1440 (1970).
- [138] A. M. Baxter and S. Hinds, Nucl. Phys. A211, 7 (1973).
- [139] N. J. Davis and J. M. Nelson, Nucl. Phys. A468, 357 (1987).
- [140] H. Mackh et al., Nucl. Phys. A202, 497 (1973).
- [141] R. C. Haight, I. D. Proctor, H. F. Lutz and W. Bartolini, Nucl. Phys. A241, 285 (1975).
- [142] B. H. Wildenthal et al., Nucl. Phys. A108, 49 (1968).
- [143] Š. Piskoř . Pisko et al., Nucl. Phys. A662, 112 (2000).
- [144] J. J. M. Van Gasteren et al., Nucl. Phys. A210, 29 (1973).
- [145] F. J. Eckle et al., Nucl. Phys. A501, 413 (1989).
- [146] B. Mayer, J. Gosset, J. L. Escudie and H. Kamitsubo, Nucl. Phys. A177, 205 (1971).
- [147] J. G. Van Der Baan and B. R. Sikora, Nucl. Phys. A173, 456 (1971).
- [148] D. J. Crozier, Nucl. Phys. A198, 209 (1972).
- [149] A. Moalem and B. H. Wildenthal, Phys. Rev. C 11, 654 (1975).
- [150] J. G. Van Der Baan and H. G. Leighton, Nucl. Phys. A170, 607 (1971)

- [151] R. Abegg and S. K. Datta, Nucl. Phys. A287, 94 (1977).
- [152] Š. Piskoř, P. Franc, J. Kemének and W. Schäferlingová, Nucl. Phys. A414, 219 (1984).
- [153] C. E. Thorn et al., Phys. Rev. C 30, 1442 (1984).
- [154] B. Vignon, J. P. Longequeue and I. S. Towner, Nucl. Phys. A189, 513 (1972).
- [155] P. Decowski, Nucl. Phys A169, 513 (1971).
- [156] Š. Piskoř, P. Franc, W. Schäferlingová and J. Kemének, Nucl. Phys. A481, 269 (1988).
- [157] B. M. Preedom, J. A. Rice and B. H. Wildenthal, Nucl. Phys. A239, 189 (1975).
- [158] J. Rapaport, W. W. Buechner, Nucl. Phys. 83, 80 (1966).
- [159] C. L. Fink and J. P. Schiffer, Nucl. Phys. A225, 93 (1974).
- [160] R. R. Johnson and R. J. Griffiths, Nucl. Phys. A108, 113 (1968).
- [161] S. Sen, C. L. Hollas, and P. J. Riley, Phys. Rev. C 3, 2314 (1970).
- [162] S. Sen, W. A. Yoh, and M. T. McEllistrem, Phys. Rev. C 10, 1050 (1974).
- [163] D. R. Goosman, P. D. Parker and A. J. Howard, Nucl. Phys. A250, 309 (1975).
- [164] S. Sen, C. L. Hollas, C. W. Bjork, and P. J. Riley, Phys. Rev. C 5, 1278 (1972).
- [165] W. Fitz, R. Jahr and R. Santo, Nucl. Phys. A114, 392 (1968).
- [166] J. F. Tonn et al., Phys. Rev. C 16, 1357 (1977).
- [167] S. Sen, S. E. Darden, W. A. Yoh and E. D. Berners, Nucl. Phys. A250, 45 (1975).
- [168] B. H. Wildenthal and J. A. Rice, B. M. Preedom, Phys. Rev. C 10, 2184 (1974).
- [169] W. Savin et al., Nucl. Phys. A213, 317 (1973).
- [170] J. Lichtenstadt et al., Nucl. Phys. A311, 61 (1978).
- [171] U. Lynen, H. Oeschler, R. Santo and R. Stock, Nucl. Phys. A127, 343 (1969).
- [172] C. Glashauser, M. Kondo, M. E. Riskey, and E. Rost, Phys. Lett. 14, 113 (1965).
- [173] P. E. Cavanagh et al., Nucl. Phys. 50, 49 (1964).
- [174] P. Martin, M. Buenerd, Y. Dupont and M. Chabre, Nucl. Phys. A185, 465 (1972).
- [175] M. Matoba et al., Phys. Rev. C 48, 95 (1993).
- [176] S. Rusk, C. M. Class, Nucl. Phys. 61, 209 (1965).
- [177] H. G. Leighton, G. Roy, D. P. Gurd and T. B. Grandy, Nucl. Phys. A109, 218 (1968).
- [178] D. C. Kocher and W. Haeberli, Nucl. Phys. A172, 652 (1971).
- [179] E. Friedman, A. Moalem, and D. Suraqui, S. Mordechai, Phys. Rev. C 14, 2082 (1976).
- [180] T. A. Belote, W. E. Dorenbusch and J. Rapaport, Nucl. Phys. A120, 401 (1968).
- [181] L. L. Lee et al., Phys. Rev. 136, B971 (1964).

- [182] S. A. Andersen and Ole Hansen, Nucl. Phys. A120, 421 (1968).
- [183] G. Brown, A. Denning and J. G. B. Haigh, Nucl. Phys. A225, 267 (1974).
- [184] Syohei Kato et al., Nucl. Phys. 64, 241 (1965).
- [185] Kamal K. Seth, J. Picard, G.R. Satchler, Nucl. Phys. A140, 577 (1970).
- [186] W. P. Alford et al., Nucl. Phys. A302, 12 (1978).
- [187] C. C. Foster, W. E. Maddox, and D. W. Miller, Phys. Rev. 181, 1529 (1969).
- [188] W. P. Alford et al., Phys. Rev. C 14, 946 (1976).
- [189] P. O. Tjøm et al., Nucl. Phys. A243, 100 (1975).
- [190] H. Niewodniczanski et al., Phys. Rev. 146, 799 (1966).
- [191] Sven A. Hjorth, J. X. Saladin and G. R. Satchler, Phys. Rev. 138, B1425 (1965).
- [192] F. J. Eckle et al., Nucl. Phys. A506, 159 (1990).
- [193] Y. Uozumi et al., Phys. Rev. C 50, 263 (1994).
- [194] C. Ellegaard et al., Phys. Lett. B 40, 641 (1972).
- [195] S. M. Smith and A. M. Bernstein, Nucl. Phys. A113, 303 (1968).
- [196] W. E. Dorenbusch, T. A. Belote, and Ole Hansen, Phys. Rev. 146, 734 (1966).
- [197] Y. Dupont, P. Martin, and M. Chabre, Phys. Rev. C 7, 637 (1973).
- [198] J. H. Bjerregaard and Ole Hansen, Phys. Rev. 155, 1229 (1967).
- [199] T. W. Conlon, B. F. Bayman, and E. Kashy, Phys. Rev. 144, 941 (1966).
- [200] J. Rapaport, W. E. Dorenbusch and T. A. Belote, Phys. Rev. 156, 1255 (1967).
- [201] J. H. Bjerregaard, Ole Hansen, and G. Sidenius, Phys. Rev. 138, B1097 (1965).
- [202] R. J. Peterson, Phys. Rev. 170, 1003 (1968).
- [203] G. Roy and J. J. W. Bogaards, Nucl. Phys. A160, 289 (1971).
- [204] E. Kashy, A. Sperduto, H. A. Enge, and W. W. Buechner, Phys. Rev. 135, B865 (1964).
- [205] R. Abegg, J. D. Hutton and M. E. Williams-Norton, Nucl. Phys. A303, 121 (1978).
- [206] W. D. Metz, W. D. Callender, and C. K. Bockelman, Phys. Rev. C 12, 827 (1975).
- [207] Y. Uozumi et al., Nucl. Phys. A576, 123 (1994).
- [208] Edwin Kashy, Phys. Rev. 134, B378 (1964).
- [209] J. Rapaport, A. Sperduto, and W. W. Buechner, Phys. Rev. 151, 939 (1966).
- [210] J. N. Roy, A. R. Majumder, and H. M. Sen Gupta, Phys. Rev. C 46, 144 (1992).
- [211] E. Kashy and T. W. Conlon, Phys. Rev. 135, B389 (1964).
- [212] G. D. Jones, R. R. Johnson and J. H. Jett, Nucl. Phys. A111, 449 (1968).

- [213] P. J. Plauger and E. Kashy, Nucl. Phys. A152, 609 (1970).
- [214] T.A.Belote, W.E.Dorenbusch, O.Hansen, J.Rapaport, Nucl. Phys. 73, 321 (1965).
- [215] D. C. Kocher and W. Haeberli, Nucl. Phys. A196, 225 (1972).
- [216] V.V.Tokarevskij, V.N.Shcherbin, Yadern Fiz. 25,16 (1977).
- [217] P. D. Barne et al., Phys. Rev. 159, 920 (1967).
- [218] J. L. Yntema, Phys. Rev. 131, 811 (1963).
- [219] P. D. Barnes et al., Phys. Rev. 136, B438 (1964).
- [220] M. E. de López et al., Nucl. Phys. A94, 673 (1967).
- [221] J. C. Legg and E. Rost, Phys. Rev. 134, B752 (1964).
- [222] H. Ohmura, T. Ishimatsu, M. Niwano and N. Kumagai, Phys. Lett. B 73, 145 (1978).
- [223] C. A. Whitten, Jr and L. C. McIntyre, Phys. Rev. 160, 997 (1967).
- [224] Y. Fujita et al., Nucl. Phys. A435, 7 (1985).
- [225] V.P.Bochin et al., Nucl. Phys. 51, 161 (1964).
- [226] J. E. Robertshaw et al., Phys. Rev.170, 1013 (1968).
- [227] A.E.Macgregor, G.Brown, Nucl. Phys. A198, 237 (1972).
- [228] M. S. Chowdhury, A. R. Majumder and H. M. Sen Gupta, Nucl. Phys. A282, 87 (1977).
- [229] J.C.Legg, H.D.Scott, M.K.Mehta, Nucl. Phys. 84, 398 (1966).
- [230] E.J.Stephenson, W.Haeberli, Nucl. Phys. A277, 374 (1977).
- [231] M. N. Rao, J. Rapaport, A. Sperduto and D. L. Smith, Nucl. Phys. A121, 1 (1968).
- [232] J.L.Alty, L.L.Green, G.D.Jones, J.F.Sharpey-Schafer, Nucl. Phys. 86, 65 (1966).
- [233] N. Rohrig and W. Haeberli, Nucl. Phys. A206, 225 (1973).
- [234] W. P. Alford et al., Nucl. Phys. A277, 119 (1977).
- [235] R.Bock, H.H.Duhm, S.Martin, R.Rudel, R.Stock, Nucl. Phys. 72, 273 (1965).
- [236] A. A. Debenham et al., Nucl. Phys. A167, 289 (1971).
- [237] M. Masaki et al., Nucl. Phys. A573, 1 (1994).
- [238] D. M. Rosalky et al., Nucl. Phys. A142, 469 (1970).
- [239] T. Taylor and J. A. Cameron, Nucl. Phys. A337, 389 (1980).
- [240] <http://www.nndc.bnl.gov/nsr>
- [241] http://groups.nsl.msu.edu/nsl_library/pddp/database.html
- [242] Richard B. Firestone, Virginia S. Shirley, Table of Isotopes, Wiley-Interscience; 2 Vols. 8th edition (December 4, 1998), <http://www.nndc.bnl.gov/>

- [243] Herman Feshbach, Theoretical Nuclear: Physics Nuclear Reactions, John Wiley & Sons, INC (1992).
- [244] G.G. Ohlsen and R.E. Shamu, Nucl. Phys. 45, 523 (1963).
- [245] J. R. Terry, D. Bazin, B. A. Brown, J. Enders, T. Glasmacher, P. G. Hansen, B. M. Sherrill, and J. A. Tostevin Phys. Rev. C **69**, 054306 (2004)
- [246] A. M. Mukhamedzhanov and F. M. Nunes, Phys. Rev. C 72, 017602 (2005).
- [247] A. Gade et. al., Phys. Rev. Lett. 93, 042501 (2004).
- [248] P.G. Hansen and J.A. Tostevin, Ann. Rev. Nucl. Part. Sci. **53**, 219 (2003).
- [249] B. A. Brown and B. H. Wildenthal, Ann. Rev. of Nucl. Part. Sci. 38, 29 (1988).
- [250] B. A. Brown et al., Computer program,
<http://www.nscl.msu.edu/~brown/resources/obash-augsut-2004.pdf>

Table I: List of reactions studied in this work. SF stands for spectroscopic factors. Not all the SF values extracted are used in computing the averages of the spectroscopic factor for a specific nucleus. The extracted values not used are listed in the 5th column. Most of these include reactions at low beam energy ($E_{\text{beam}} < 10$ MeV). Those values marked with * are obtained from data which are determined to be problematic. Listed in the last column are abbreviated comments, BS (bad shape), BD (bad data), AU (arbitrary unit), No (Normalization problem), NP (missing first peak), and QV (low Q-values).

Isotope	Reaction	E_{beam} (MeV)	References	SF(not used)	SF	<SF>	# of points	Comment
⁶ Li	⁶ Li(p,d) ⁵ Li	33.6	PR163(1967)1066		1.08	1.08		
⁷ Li	⁶ Li(d,p) ⁷ Li	4.5	NPA147(1970)65	1.56			2	
⁷ Li	⁶ Li(d,p) ⁷ Li	4.75	NPA147(1970)65	1.77			2	
⁷ Li	⁶ Li(d,p) ⁷ Li	5	NPA147(1970)65	1.85			2	
⁷ Li	⁶ Li(d,p) ⁷ Li	5.25	NPA147(1970)65	1.74			3	
⁷ Li	⁶ Li(d,p) ⁷ Li	5.5	NPA147(1970)65	1.66			3	
⁷ Li	⁶ Li(d,p) ⁷ Li	12	PR164(1967)1274		1.82	1.82	2	
⁷ Li	⁷ Li(p,d) ⁶ Li	30.3	NPA126(1969)261	0.34*			2	BS
⁷ Li	⁷ Li(p,d) ⁶ Li	33.6	PR163(1967)1066		0.83	0.83	3	
⁸ Li	⁷ Li(d,p) ⁸ Li	12	PR164(1967)1274		0.61	0.61	3	
⁹ Li	⁸ Li(d,p) ⁹ Li	19.1	PRL94(2005)082502		0.98	0.98	5	
⁹ Be	⁹ Be(p,d) ⁸ Be	5	NPA184(1972)175	0.43			3	
⁹ Be	⁹ Be(p,d) ⁸ Be	6	NPA184(1972)175	0.46			7	
⁹ Be	⁹ Be(p,d) ⁸ Be	7	NPA184(1972)175	0.44			4	
⁹ Be	⁹ Be(p,d) ⁸ Be	8	NPA184(1972)175	0.5			3	
⁹ Be	⁹ Be(p,d) ⁸ Be	9	NPA184(1972)175	0.52			3	
⁹ Be	⁹ Be(p,d) ⁸ Be	10	NPA184(1972)175		0.45		2	BS
⁹ Be	⁹ Be(p,d) ⁸ Be	11	NPA184(1972)175		0.45		2	BS
⁹ Be	⁹ Be(p,d) ⁸ Be	14.3	PRC24(1981)2401		0.4		2	BS
⁹ Be	⁹ Be(p,d) ⁸ Be	15	NPA157(1970)305		0.4		3	BS
⁹ Be	⁹ Be(p,d) ⁸ Be	17	NPA199(1973)433		0.5		3	BS
⁹ Be	⁹ Be(p,d) ⁸ Be	21	NPA199(1973)433		0.49		2	BS
⁹ Be	⁹ Be(p,d) ⁸ Be	25	NPA199(1973)433		0.43		2	BS
⁹ Be	⁹ Be(p,d) ⁸ Be	26.2	PRC24(1981)2401		0.35		1	BS
⁹ Be	⁹ Be(p,d) ⁸ Be	29.1	NPA199(1973)433		0.47		2	BS
⁹ Be	⁹ Be(p,d) ⁸ Be	33.6	PR163(1967)1066		0.43		1	BS
⁹ Be	⁹ Be(p,d) ⁸ Be	46	PR153(1967)1127		0.48	0.445	1	BS
¹⁰ Be	⁹ Be(d,p) ¹⁰ Be	4.5	NPA147(1970)65	2.14			1	
¹⁰ Be	⁹ Be(d,p) ¹⁰ Be	4.75	NPA147(1970)65	2.06			3	
¹⁰ Be	⁹ Be(d,p) ¹⁰ Be	5	NPA147(1970)65	2.1			2	
¹⁰ Be	⁹ Be(d,p) ¹⁰ Be	5.25	NPA147(1970)65	2.02			3	
¹⁰ Be	⁹ Be(d,p) ¹⁰ Be	5.5	NPA147(1970)65	1.98			2	
¹⁰ Be	⁹ Be(d,p) ¹⁰ Be	5.75	NPA147(1970)65	1.79			3	
¹⁰ Be	⁹ Be(d,p) ¹⁰ Be	6	NPA147(1970)65	1.98			3	

¹⁰ Be	⁹ Be(d,p) ¹⁰ Be	6.5	J,IZV,64,440,2000	1.51			5	
¹⁰ Be	⁹ Be(d,p) ¹⁰ Be	7	J,IZV,64,440,2000	1.44			4	
¹⁰ Be	⁹ Be(d,p) ¹⁰ Be	7.5	J,IZV,64,440,2000	1.04			2	
¹⁰ Be	⁹ Be(d,p) ¹⁰ Be	8	J,IZV,64,440,2000	1.03			1	
¹⁰ Be	⁹ Be(d,p) ¹⁰ Be	8.5	J,IZV,64,440,2000	1.08			2	
¹⁰ Be	⁹ Be(d,p) ¹⁰ Be	9	J,IZV,64,440,2000	1.07			2	
¹⁰ Be	⁹ Be(d,p) ¹⁰ Be	9.5	J,IZV,64,440,2000	1.00			2	
¹⁰ Be	⁹ Be(d,p) ¹⁰ Be	10	J,IZV,64,440,2000	1.06*			2	
¹⁰ Be	⁹ Be(d,p) ¹⁰ Be	10.5	J,IZV,64,440,2000	1.14*			2	
¹⁰ Be	⁹ Be(d,p) ¹⁰ Be	11	J,IZV,64,440,2000	1.13*			2	BD
¹⁰ Be	⁹ Be(d,p) ¹⁰ Be	11.8	PR164(1967)1274	2.00*			3	BD
¹⁰ Be	⁹ Be(d,p) ¹⁰ Be	11.8	NPA53(1964)77		1.42		2	
¹⁰ Be	⁹ Be(d,p) ¹⁰ Be	12.5	J,YF,45,312,(1987)		1.65		4	
¹⁰ Be	⁹ Be(d,p) ¹⁰ Be	15	NPA266(1976)29		1.69		4	
¹⁰ Be	⁹ Be(d,p) ¹⁰ Be	15.3	J,YF,64,1995,2001		1.36	1.53	4	
¹⁰ Be	⁹ Be(d,p) ¹⁰ Be	17.3	NPA236(1974)77	0.97*			3	BS
¹⁰ Be	⁹ Be(d,p) ¹⁰ Be	28	PR126(1962)1059	2.19 *			2	BS
¹⁰ Be	¹⁰ Be(p,d) ⁹ Be	49.8	Liu, thesis (2005)	2.87 *			10	BD
¹¹ Be	¹⁰ Be(d,p) ¹¹ Be	12	NPA157(1970)305		0.43		3	
¹¹ Be	¹⁰ Be(d,p) ¹¹ Be	25	NPA315(1979)124		0.51	0.476	4	
¹¹ Be	¹¹ Be(p,d) ¹⁰ Be	35.3	NPA683(2001)48		0.56	0.56	2	
¹⁰ B	¹⁰ B(p,d) ⁹ B	33.6	PR167(1968)963		0.55		3	
¹⁰ B	¹⁰ B(p,d) ⁹ B	49.5	NPA141(1970)158		0.42	0.485	3	
¹¹ B	¹⁰ B(d,p) ¹¹ B	4.5	NPA147(1970)65	1.08			2	
¹¹ B	¹⁰ B(d,p) ¹¹ B	4.75	NPA147(1970)65	1.03			3	
¹¹ B	¹⁰ B(d,p) ¹¹ B	5	NPA147(1970)65	0.82			2	
¹¹ B	¹⁰ B(d,p) ¹¹ B	5.25	NPA147(1970)65	0.82			2	
¹¹ B	¹⁰ B(d,p) ¹¹ B	5.5	NPA147(1970)65	0.77			2	
¹¹ B	¹⁰ B(d,p) ¹¹ B	8.2	PR131(1963)304	0.06				AU
¹¹ B	¹⁰ B(d,p) ¹¹ B	10.1	NP38(1962)114	0.96*			4	BD
¹¹ B	¹⁰ B(d,p) ¹¹ B	12	PR164(1967)1274		1.21		4	
¹¹ B	¹⁰ B(d,p) ¹¹ B	13.5	NP73(1965)473		1.60		5	
¹¹ B	¹⁰ B(d,p) ¹¹ B	15.5	PR131(1963)304	1.51*			4	
¹¹ B	¹⁰ B(d,p) ¹¹ B	21.5	PR131(1963)304	1.53*			9	
¹¹ B	¹⁰ B(d,p) ¹¹ B	28	PR126(1962)1059		1.48	1.436	2	
¹¹ B	¹⁰ B(d,p) ¹¹ B	28	PR131(1963)304	1.50*				
¹¹ B	¹¹ B(p,d) ¹⁰ B	19	PR129(1963)272	3.06*			3	BD
¹¹ B	¹¹ B(p,d) ¹⁰ B	33.6	PR167(1968)963		1.25	1.25	3	
¹¹ B	¹¹ B(p,d) ¹⁰ B	45	Liu, thesis (2005)	1.02*			2	BD
¹² B	¹¹ B(d,p) ¹² B	11.8	PRC64(2001)034312		0.43		5	
¹² B	¹¹ B(d,p) ¹² B	12	J,NUK,19,693,1974		0.47	0.445	3	
¹² B	¹¹ B(d,p) ¹² B	12	PR164(1967)1274	0.42*			1	BS
¹² C	¹² C(p,d) ¹¹ C	19.3	PR128(1962)1810					QV

¹² C	¹² C(p,d) ¹¹ C	19.5	PR128(1962)1810					QV
¹² C	¹² C(p,d) ¹¹ C	20	PR128(1962)1810					QV
¹² C	¹² C(p,d) ¹¹ C	30.3	NPA99(1967)669		2.58		3	
¹² C	¹² C(p,d) ¹¹ C	39.8	PR132(1963)813	5.28*			4	No
¹² C	¹² C(p,d) ¹¹ C	61	PRC21(1980)2162		3.20		6	
¹² C	¹² C(p,d) ¹¹ C	65	NPA255(1975)187		2.94	2.98	3	
¹² C	¹² C(p,d) ¹¹ C	65	NPA343(1980)234	2.56*			1	BS
¹³ C	¹² C(d,p) ¹³ C	4	NP82(1966)161	0.63			3	
¹³ C	¹² C(d,p) ¹³ C	4.5	NP82(1966)161	0.66			2	
¹³ C	¹² C(d,p) ¹³ C	4.5	PR101(1956)209	0.48			2	
¹³ C	¹² C(d,p) ¹³ C	4.5	NPA129(1969)405	0.42			2	
¹³ C	¹² C(d,p) ¹³ C	7.15	JETP12(1960)1	0.86			4	
¹³ C	¹² C(d,p) ¹³ C	8.9	NP22(1961)34	0.91			6	
¹³ C	¹² C(d,p) ¹³ C	10.2	PR123(1961)619		0.84		3	
¹³ C	¹² C(d,p) ¹³ C	11.8	NP53(1964)77		0.82		3	
¹³ C	¹² C(d,p) ¹³ C	11.8	PRC64(2001)034312		0.62		2	
¹³ C	¹² C(d,p) ¹³ C	12	NPA477(1988)77		0.70		2	
¹³ C	¹² C(d,p) ¹³ C	12	PR164(1967)1274		0.86		3	
¹³ C	¹² C(d,p) ¹³ C	12.4	PR123(1961)619		0.76		4	
¹³ C	¹² C(d,p) ¹³ C	14.7	PR123(1961)619		0.70		3	
¹³ C	¹² C(d,p) ¹³ C	14.8	PR100(1955)235		0.75		1	
¹³ C	¹² C(d,p) ¹³ C	15	NPA208(1973)77		0.68		4	
¹³ C	¹² C(d,p) ¹³ C	16.6	JPSJ 15(1960)550		0.59		4	
¹³ C	¹² C(d,p) ¹³ C	19.6	JPSJ 15(1960)550		0.59		2	
¹³ C	¹² C(d,p) ¹³ C	25.9	PR136(1964)B1682		0.66		6	
¹³ C	¹² C(d,p) ¹³ C	30	NPA448(86)205		0.59	0.704	3	
¹³ C	¹² C(d,p) ¹³ C	51	Liu, thesis (2005)					BD
¹³ C	¹² C(d,p) ¹³ C	56	NPA419(84)530	0.95*			1	NP
¹³ C	¹³ C(p,d) ¹² C	35	PRC51(1995)2592		0.76		2	
¹³ C	¹³ C(p,d) ¹² C	41.3	NPA470(1987)349		0.83		1	
¹³ C	¹³ C(p,d) ¹² C	48.3	Liu, thesis (2005)		0.97		5	
¹³ C	¹³ C(p,d) ¹² C	55	PLB27(1968)625		0.88	0.895	3	
¹³ C	¹³ C(p,d) ¹² C	65	NPA343(1980)234	1.54*			3	NP
¹⁴ C	¹³ C(d,p) ¹⁴ C	12	PR164(1967)1274		1.88		5	
¹⁴ C	¹³ C(d,p) ¹⁴ C	13	NPA312(1978)1		1.54	1.753	3	
¹⁴ C	¹³ C(d,p) ¹⁴ C	56	NPA419(1984)530	2.25*			2	NP
¹⁴ C	¹⁴ C(p,d) ¹³ C	14.5	NPA165(1971)19		0.85		4	
¹⁴ C	¹⁴ C(p,d) ¹³ C	18.5	PR129(1963)272		1.81		3	
¹⁴ C	¹⁴ C(p,d) ¹³ C	27	NPA255(1975)243		0.99		4	
¹⁴ C	¹⁴ C(p,d) ¹³ C	35	NPA509(1990)141		1.59	1.296	5	
¹⁵ C	¹⁴ C(d,p) ¹⁵ C	2	NPA96(1967) 671	1.10			2	
¹⁵ C	¹⁴ C(d,p) ¹⁵ C	2.6	NPA96(1967) 671	0.66			1	
¹⁵ C	¹⁴ C(d,p) ¹⁵ C	3	NPA96(1967) 671	0.72			2	

¹⁵ C	¹⁴ C(d,p) ¹⁵ C	3.4	NPA96(1967) 671	0.78			2	
¹⁵ C	¹⁴ C(d,p) ¹⁵ C	14	PRC12(1975)1730		1.11	1.11	1	
¹⁵ C	¹⁴ C(d,p) ¹⁵ C	16	NPA579(1994)125	0.57*				BS
¹⁵ C	¹⁴ C(d,p) ¹⁵ C	17	NPA255(1975)243	0.40*				BS
¹⁴ N	¹⁴ N(p,d) ¹³ N	14.5	NPA165(1971)19		0.66		7	
¹⁴ N	¹⁴ N(p,d) ¹³ N	18.5	PR122(1961)595		0.74		3	
¹⁴ N	¹⁴ N(p,d) ¹³ N	21	NPA322(1979)117	0.58*			2	NP
¹⁴ N	¹⁴ N(p,d) ¹³ N	30.3	NPA99(1967)540		0.97	0.732	2	
¹⁴ N	¹⁴ N(p,d) ¹³ N	65	NPA255(1975)187	0.46*			2	NP
¹⁵ N	¹⁴ N(d,p) ¹⁵ N	10	NPA333(1980)13					BD
¹⁵ N	¹⁴ N(d,p) ¹⁵ N	10.03	NPA382(1982)269		1.62		2	
¹⁵ N	¹⁴ N(d,p) ¹⁵ N	11.65	NPA382(1982)269					NP
¹⁵ N	¹⁴ N(d,p) ¹⁵ N	12	PR164(1967)1274		1.10		3	
¹⁵ N	¹⁴ N(d,p) ¹⁵ N	14.8	PR105(1957)639		1.52		5	
¹⁵ N	¹⁴ N(d,p) ¹⁵ N	31	NPA275(1977)212		1.13	1.333	4	
¹⁵ N	¹⁴ N(d,p) ¹⁵ N	52	NPA275(1977)212	1.80*				BD
¹⁵ N	¹⁵ N(p,d) ¹⁴ N	18.6	PR122(1961)595		1.71		4	
¹⁵ N	¹⁵ N(p,d) ¹⁴ N	39.8	PR187(1969)1259		1.38	1.413	2	
¹⁶ N	¹⁵ N(d,p) ¹⁶ N	14.8	PR105(1957)639		0.42	0.42	4	
¹⁶ O	¹⁶ O(p,d) ¹⁵ O	18.5	PR129(1963)272	1.66*			4	BS
¹⁶ O	¹⁶ O(p,d) ¹⁵ O	19	PR129(1963)272	2.53*			5	BS
¹⁶ O	¹⁶ O(p,d) ¹⁵ O	20	PR129(1963)272		2.24		4	
¹⁶ O	¹⁶ O(p,d) ¹⁵ O	21.27	PR187(1969)1246		1.68		6	
¹⁶ O	¹⁶ O(p,d) ¹⁵ O	25.52	PR187(1969)1246		2.68		5	
¹⁶ O	¹⁶ O(p,d) ¹⁵ O	30.3	NPA99(1967)669		2.27		3	
¹⁶ O	¹⁶ O(p,d) ¹⁵ O	31.82	PR187(1969)1246		2.23		4	
¹⁶ O	¹⁶ O(p,d) ¹⁵ O	38.63	PR187(1969)1246		2.11		4	
¹⁶ O	¹⁶ O(p,d) ¹⁵ O	39.8	PR132(1963)813		2.47		2	
¹⁶ O	¹⁶ O(p,d) ¹⁵ O	45.34	PR187(1969)1246		2.59		4	
¹⁶ O	¹⁶ O(p,d) ¹⁵ O	65	NPA255(1975)187		2.36	2.257	3	
¹⁶ O	¹⁶ O(p,d) ¹⁵ O	65	NPA343(1980)234	3.07*			3	NP
¹⁷ O	¹⁶ O(d,p) ¹⁷ O	1.3	NP82(1966)161					
¹⁷ O	¹⁶ O(d,p) ¹⁷ O	2.279	NPA114(1968)330					
¹⁷ O	¹⁶ O(d,p) ¹⁷ O	2.582	NPA114(1968)330	1.45				
¹⁷ O	¹⁶ O(d,p) ¹⁷ O	2.864	NPA114(1968)330	1.50				
¹⁷ O	¹⁶ O(d,p) ¹⁷ O	3.155	NPA114(1968)330	1.54				
¹⁷ O	¹⁶ O(d,p) ¹⁷ O	3.49	PR123(1961)619	2.53				
¹⁷ O	¹⁶ O(d,p) ¹⁷ O	4	NP82(1966)161	2.36				
¹⁷ O	¹⁶ O(d,p) ¹⁷ O	4.11	PR123(1961)619	1.86				
¹⁷ O	¹⁶ O(d,p) ¹⁷ O	6	NPA112(1968)76	1.22				
¹⁷ O	¹⁶ O(d,p) ¹⁷ O	6.26	NPA134(1969)561	1.37				
¹⁷ O	¹⁶ O(d,p) ¹⁷ O	7.5	NPA112(1968)76	1.25				
¹⁷ O	¹⁶ O(d,p) ¹⁷ O	7.85	NPA112(1968)76	1.20				

¹⁷ O	¹⁶ O(d,p) ¹⁷ O	8	NPA172(1971)663	1.31				
¹⁷ O	¹⁶ O(d,p) ¹⁷ O	8.2	NPA112(1968)76	1.09				
¹⁷ O	¹⁶ O(d,p) ¹⁷ O	8.55	NPA112(1968)76	0.96				
¹⁷ O	¹⁶ O(d,p) ¹⁷ O	9	PR123(1961)619	0.95				
¹⁷ O	¹⁶ O(d,p) ¹⁷ O	9.3	NPA188(1972)164	0.83				
¹⁷ O	¹⁶ O(d,p) ¹⁷ O	10	NPA112(1968)76		1.02		3	
¹⁷ O	¹⁶ O(d,p) ¹⁷ O	10.2	PR123(1961)619		0.97		2	
¹⁷ O	¹⁶ O(d,p) ¹⁷ O	11	NPA112(1968)76		0.93		2	
¹⁷ O	¹⁶ O(d,p) ¹⁷ O	11.8	NP53(1964)77	0.60*			3	No
¹⁷ O	¹⁶ O(d,p) ¹⁷ O	12	NPA97(1967)541	0.44*			4	No
¹⁷ O	¹⁶ O(d,p) ¹⁷ O	12.4	PR123(1961)619		0.97		4	
¹⁷ O	¹⁶ O(d,p) ¹⁷ O	13.3	NPA188(1972)164		0.96		5	
¹⁷ O	¹⁶ O(d,p) ¹⁷ O	14.8	PR123(1961)619		1.10		4	
¹⁷ O	¹⁶ O(d,p) ¹⁷ O	15	PR121(1961)820		0.94		10	
¹⁷ O	¹⁶ O(d,p) ¹⁷ O	19	PR123(1961)619	0.79*			1	BS
¹⁷ O	¹⁶ O(d,p) ¹⁷ O	25.4	NPA218(1974)249		0.87		3	
¹⁷ O	¹⁶ O(d,p) ¹⁷ O	26.3	NP50(1964)479	1.48*			6	
¹⁷ O	¹⁶ O(d,p) ¹⁷ O	36	NPA218(1974)249		0.86	0.956	4	
¹⁷ O	¹⁶ O(d,p) ¹⁷ O	63.2	NPA218(1974)249		1.00		3	
¹⁷ O	¹⁷ O(p,d) ¹⁶ O	8.62	NPA244(1975)77	1.08			3	
¹⁷ O	¹⁷ O(p,d) ¹⁶ O	9.56	NPA244(1975)77	1.00			0	BS
¹⁷ O	¹⁷ O(p,d) ¹⁶ O	10.5	NPA244(1975)77		0.74		4	
¹⁷ O	¹⁷ O(p,d) ¹⁶ O	11.16	NPA244(1975)77		0.68		2	
¹⁷ O	¹⁷ O(p,d) ¹⁶ O	11.44	NPA244(1975)77		0.73		4	
¹⁷ O	¹⁷ O(p,d) ¹⁶ O	31	PLB31(1970)126		0.80	0.737	2	
¹⁸ O	¹⁷ O(d,p) ¹⁸ O	18	PRC13(1976)55		1.50	1.500	4	
¹⁸ O	¹⁸ O(p,d) ¹⁷ O	17.6	PR129(1963)272		1.69		4	
¹⁸ O	¹⁸ O(p,d) ¹⁷ O	18.2	NPA101(1967)241		1.56	1.585	3	
¹⁸ O	¹⁸ O(p,d) ¹⁷ O	20	PRC10(1974)445	0.77*			2	BS
¹⁸ O	¹⁸ O(p,d) ¹⁷ O	24.4	PRC10(1974)445	1.68*			1	BS
¹⁸ O	¹⁸ O(p,d) ¹⁷ O	29.8	PRC10(1974)445	1.35*			3	BS
¹⁸ O	¹⁸ O(p,d) ¹⁷ O	37.5	PRC10(1974)445	0.92*			1	BS
¹⁸ O	¹⁸ O(p,d) ¹⁷ O	43.6	PRC10(1974)445	1.04*			2	BD
¹⁹ O	¹⁸ O(d,p) ¹⁹ O	10	NPA331(1979)269	1.00*			1	NP
¹⁹ O	¹⁸ O(d,p) ¹⁹ O	14.8	NPA219(1974)429		0.46		4	
¹⁹ O	¹⁸ O(d,p) ¹⁹ O	15	PR122(1961)150		0.37	0.41	5	
¹⁹ F	¹⁹ F(p,d) ¹⁸ F	18.5	PR122(1961)595		1.58		4	
¹⁹ F	¹⁹ F(p,d) ¹⁸ F	19.3	NPA337(1980)107		1.54	1.563	3	
²⁰ F	¹⁹ F(d,p) ²⁰ F	12	PRC10(1974)1292		0.012	0.012	3	
²⁰ F	¹⁹ F(d,p) ²⁰ F	16	PRC6(1972)21					BD
²¹ Ne	²⁰ Ne(d,p) ²¹ Ne	11	NPA332(1979)125		0.044		2	
²¹ Ne	²⁰ Ne(d,p) ²¹ Ne	16.4	NPA152(1970)317		0.03	0.034	5	
²¹ Ne	²¹ Ne(p,d) ²⁰ Ne	20	NPA150(1970)609		0.03	0.03	8	

²² Ne	²¹ Ne(d,p) ²² Ne	10.2	NPA150(1970)609					BD
²² Ne	²² Ne(p,d) ²¹ Ne	18.2	NPA95(1967)591		0.25		4	
²² Ne	²² Ne(p,d) ²¹ Ne	20	PR184(1969)1094		0.20	0.229	3	
²³ Ne	²² Ne(d,p) ²³ Ne	12.1	NPA152(1970)317		0.24		6	
²³ Ne	²² Ne(d,p) ²³ Ne	12.1	NPA95(1967)591		0.24	0.24	6	
²⁴ Na	²³ Na(d,p) ²⁴ Na	7.83	NP45(1963)273		0.56	0.56	3	
²⁴ Mg	²⁴ Mg(p,d) ²³ Mg	27.3	PR177(1969)1737		0.38		4	
²⁴ Mg	²⁴ Mg(p,d) ²³ Mg	33.6	PR172(1968)1078	0.39*			2	BS
²⁴ Mg	²⁴ Mg(p,d) ²³ Mg	49.2	PRC33(1986)22		0.42	0.40	3	
²⁵ Mg	²⁴ Mg(d,p) ²⁵ Mg	5	NP88(1966)654	0.74			6	
²⁵ Mg	²⁴ Mg(d,p) ²⁵ Mg	6	NP88(1966)654	0.49			3	
²⁵ Mg	²⁴ Mg(d,p) ²⁵ Mg	10	NPA203(1973)177		0.27		3	
²⁵ Mg	²⁴ Mg(d,p) ²⁵ Mg	12	NPA249(1975)205		0.33		3	
²⁵ Mg	²⁴ Mg(d,p) ²⁵ Mg	14	PRC10(1974)556		0.27		3	
²⁵ Mg	²⁴ Mg(d,p) ²⁵ Mg	15	PRC10(1974)556		0.27	0.288	1	
²⁵ Mg	²⁴ Mg(d,p) ²⁵ Mg	56	NPA419(530)530	0.41*			6	NP
²⁶ Mg	²⁵ Mg(d,p) ²⁶ Mg	8	NP88(1966)513		2.99		9	
²⁶ Mg	²⁵ Mg(d,p) ²⁶ Mg	12	PRC29(1984)2013		1.95		8	
²⁶ Mg	²⁵ Mg(d,p) ²⁶ Mg	13	NPA430(1984)234		2.54	2.512	7	
²⁶ Mg	²⁶ Mg(p,d) ²⁵ Mg	20	NPA172(1971)99		1.95		3	
²⁶ Mg	²⁶ Mg(p,d) ²⁵ Mg	23.95	NPA351(1981)77		3.26		6	
²⁶ Mg	²⁶ Mg(p,d) ²⁵ Mg	35	PRC38(1988)2026		4.16	3.066	2	
²⁷ Mg	²⁶ Mg(d,p) ²⁷ Mg	5.07	PR136(1964)B1703	0.83			1	
²⁷ Mg	²⁶ Mg(d,p) ²⁷ Mg	12	NPA230(1974)317		0.44	0.44	2	
²⁷ Al	²⁷ Al(p,d) ²⁶ Al	20	NPA204(1973)609		1.45		3	
²⁷ Al	²⁷ Al(p,d) ²⁶ Al	35	NPA263(1976)293		1.28	1.353	4	
²⁸ Al	²⁷ Al(d,p) ²⁸ Al	6	NPA197(1972)97	0.42			3	
²⁸ Al	²⁷ Al(d,p) ²⁸ Al	12	NPA173(1971)414		0.58		3	
²⁸ Al	²⁷ Al(d,p) ²⁸ Al	23	PRC5(1972)1313		0.83	0.643	1	
²⁸ Si	²⁸ Si(p,d) ²⁷ Si	27.6	NPA107(1968)659	14.9*			6	
²⁸ Si	²⁸ Si(p,d) ²⁷ Si	33.6	PR172(1968)1078		4.23	4.23	4	
²⁹ Si	²⁸ Si(d,p) ²⁹ Si	5	NPA120(1968)94	0.89			1	
²⁹ Si	²⁸ Si(d,p) ²⁹ Si	5.8	NPA149(1970)605	0.40			2	
²⁹ Si	²⁸ Si(d,p) ²⁹ Si	9	NPA172(1971)663		0.27		2	
²⁹ Si	²⁸ Si(d,p) ²⁹ Si	10	NPA189(1972)305		0.55		2	
²⁹ Si	²⁸ Si(d,p) ²⁹ Si	17.85	NPA408(1983)221		0.35		2	
²⁹ Si	²⁸ Si(d,p) ²⁹ Si	18	PRC4(1971)1778		0.23	0.367	1	
²⁹ Si	²⁹ Si(p,d) ²⁸ Si	27.3	PRC2(1970)1440	1.30*		1.30	2	NP
³⁰ Si	²⁹ Si(d,p) ³⁰ Si	10	NPA211(1973)7	1.19*			1	BS
³⁰ Si	²⁹ Si(d,p) ³⁰ Si	12.3	NPA468(1987)357					NP
³⁰ Si	²⁹ Si(d,p) ³⁰ Si	16	NPA202(1973)497		0.62	0.62	1	
³⁰ Si	³⁰ Si(p,d) ²⁹ Si	27	NPA241(1975)285		0.82	0.82	3	
³⁰ Si	³⁰ Si(p,d) ²⁹ Si	27.3	PRC2(1970)1440	0.79*			0	NP

³¹ Si	³⁰ Si(d,p) ³¹ Si	7	NPA108(1968)49	0.57			6	
³¹ Si	³⁰ Si(d,p) ³¹ Si	10	NPA108(1968)49		0.57		8	
³¹ Si	³⁰ Si(d,p) ³¹ Si	12.3	NPA468(1987)357		0.69	0.594	2	
³¹ Si	³⁰ Si(d,p) ³¹ Si	12.3	NPA662(2000)112	0.46*			13	
³² P	³¹ P(d,p) ³² P	10	NPA210(1973)29		0.63		5	
³² P	³¹ P(d,p) ³² P	20	NPA501(1989)413		0.45	0.532	6	
³² S	³² S(p,d) ³¹ S	24.5	NPA177(1971)205	3.00*			1	NP
³² S	³² S(p,d) ³¹ S	33.6	PR172(1968)1078		1.46	1.46		NP
³³ S	³² S(d,p) ³³ S	18	PRC4(1971)1778		0.67	0.67	4	
³⁴ S	³³ S(d,p) ³⁴ S	12	NPA173(1971)456		1.82		4	
³⁴ S	³³ S(d,p) ³⁴ S	12	NPA198(1972)209		1.2	1.554	3	
³⁴ S	³⁴ S(p,d) ³³ S	24.5	NPA177(1971)205		1.05	1.05	3	
³⁴ S	³⁴ S(p,d) ³³ S	35	PRC11(1975)654	3.21*			8	BS
³⁵ S	³⁴ S(d,p) ³⁵ S	10	NPA170(1971)607		0.29	0.29	5	
³⁵ S	³⁴ S(d,p) ³⁵ S	11.8	NPA287(1977)94	0.30*			4	BD
³⁷ S	³⁶ S(d,p) ³⁷ S	12.3	NPA414(1984)219		0.87		4	
³⁷ S	³⁶ S(d,p) ³⁷ S	25	PRC30(1984)1442		0.89	0.88	4	
³⁵ Cl	³⁵ Cl(p,d) ³⁴ Cl	40	NPA189(1972)513		0.33	0.33	4	
³⁶ Cl	³⁵ Cl(d,p) ³⁶ Cl	7	NPA169(1971)513	0.45			4	
³⁶ Cl	³⁵ Cl(d,p) ³⁶ Cl	12.3	NPA481(1988)269		0.69	0.69	3	
³⁷ Cl	³⁷ Cl(p,d) ³⁶ Cl	19	NPA204(1973)609	30*				AU
³⁷ Cl	³⁷ Cl(p,d) ³⁶ Cl	35	NPA239(1975)189		1.54		3	
³⁷ Cl	³⁷ Cl(p,d) ³⁶ Cl	40	NPA189(1972)513		0.65	1.031	4	
³⁸ Cl	³⁷ Cl(d,p) ³⁸ Cl	7.5	NP83(1966)80	1.00			3	
³⁸ Cl	³⁷ Cl(d,p) ³⁸ Cl	12	NPA225(1974)93		1.74	1.74	5	
³⁶ Ar	³⁶ Ar(p,d) ³⁵ Ar	27.5	NPA108(1968)113		4.17		5	
³⁶ Ar	³⁶ Ar(p,d) ³⁵ Ar	33.6	PR172(1968)1078		2.44	3.226	6	
³⁷ Ar	³⁶ Ar(d,p) ³⁷ Ar	9.162	PRC3(1970)2314	0.28			6	
³⁷ Ar	³⁶ Ar(d,p) ³⁷ Ar	10.02	PRC10(1974)1050		0.34		5	
³⁷ Ar	³⁶ Ar(d,p) ³⁷ Ar	18	PRC4(1971)1778		0.36	0.351	6	
³⁸ Ar	³⁸ Ar(p,d) ³⁷ Ar	26	NPA250(1975)309		2.43	2.43	6	
³⁹ Ar	³⁸ Ar(d,p) ³⁹ Ar	10.064	PRC5(1972)1278		0.85		3	
³⁹ Ar	³⁸ Ar(d,p) ³⁹ Ar	11.6	NPA114(1968)392		0.75	0.793	4	
⁴⁰ Ar	⁴⁰ Ar(p,d) ³⁹ Ar	27.5	NPA108(1968)113		1.05	1.05	5	
⁴⁰ Ar	⁴⁰ Ar(p,d) ³⁹ Ar	35	PRC16(1977)1357	2.23*			4	BS
⁴¹ Ar	⁴⁰ Ar(d,p) ⁴¹ Ar	11.6	NPA114(1968)392		0.60		3	
⁴¹ Ar	⁴⁰ Ar(d,p) ⁴¹ Ar	14.83	NPA250(1975)45		0.53	0.551	7	
³⁹ K	³⁹ K(p,d) ³⁸ K	35	PRC10(1974)2184	2.10*			4	BS
⁴⁰ K	³⁹ K(d,p) ⁴⁰ K	12	NPA225(1974)93		1.66	1.66	5	
⁴¹ K	⁴¹ K(p,d) ⁴⁰ K	15	NPA213(1973)317		0.95	0.95	5	
⁴² K	⁴¹ K(d,p) ⁴² K	10	NPA311(1978)61		0.86		1	
⁴² K	⁴¹ K(d,p) ⁴² K	12	NPA127(1969)343		0.67	0.765	1	
⁴⁰ Ca	⁴⁰ Ca(p,d) ³⁹ Ca	27.3	PL14(1965)113		3.39		3	

⁴⁰ Ca	⁴⁰ Ca(p,d) ³⁹ Ca	30	NPA50(1964)49		4.30		1	
⁴⁰ Ca	⁴⁰ Ca(p,d) ³⁹ Ca	33.6	PR172(1968)1078		5.30		3	
⁴⁰ Ca	⁴⁰ Ca(p,d) ³⁹ Ca	40	NPA185(1972)465		4.50		3	
⁴⁰ Ca	⁴⁰ Ca(p,d) ³⁹ Ca	65	PRC48(1993)95		4.15	4.298	6	
⁴⁰ Ca	⁴⁰ Ca(p,d) ³⁹ Ca	65	NPA343(1980)234	4.80*			3	NP
⁴¹ Ca	⁴⁰ Ca(d,p) ⁴¹ Ca	4.13	NP61(1965)209					
⁴¹ Ca	⁴⁰ Ca(d,p) ⁴¹ Ca	4.69	NP61(1965)209	1.18				
⁴¹ Ca	⁴⁰ Ca(d,p) ⁴¹ Ca	5	NPA109(1968)218					
⁴¹ Ca	⁴⁰ Ca(d,p) ⁴¹ Ca	5	NPA172(1971)652	1.37				
⁴¹ Ca	⁴⁰ Ca(d,p) ⁴¹ Ca	6	NPA109(1968)218	1.30				
⁴¹ Ca	⁴⁰ Ca(d,p) ⁴¹ Ca	6	PRC14(1976)2082	1.22				
⁴¹ Ca	⁴⁰ Ca(d,p) ⁴¹ Ca	7	NPA120(1968)401	1.22			3	
⁴¹ Ca	⁴⁰ Ca(d,p) ⁴¹ Ca	7	PR136(1964)B971	1.20				
⁴¹ Ca	⁴⁰ Ca(d,p) ⁴¹ Ca	7.2	NPA120(1968)401	1.24			3	
⁴¹ Ca	⁴⁰ Ca(d,p) ⁴¹ Ca	8	PR136(1964)B971	1.13			3	
⁴¹ Ca	⁴⁰ Ca(d,p) ⁴¹ Ca	9	NPA172(1971)652	1.01			5	
⁴¹ Ca	⁴⁰ Ca(d,p) ⁴¹ Ca	9	PR136(1964)B971	1.17			3	
⁴¹ Ca	⁴⁰ Ca(d,p) ⁴¹ Ca	10	NPA120(1968)421		0.94		3	
⁴¹ Ca	⁴⁰ Ca(d,p) ⁴¹ Ca	10	NPA225(1974)267		0.92		1	
⁴¹ Ca	⁴⁰ Ca(d,p) ⁴¹ Ca	10	PR136(1964)B971	1.13*				BD
⁴¹ Ca	⁴⁰ Ca(d,p) ⁴¹ Ca	11	NP64(1965)241		1.00		3	
⁴¹ Ca	⁴⁰ Ca(d,p) ⁴¹ Ca	11	NPA140(1970)577					NP
⁴¹ Ca	⁴⁰ Ca(d,p) ⁴¹ Ca	11	NPA172(1971)652		0.96		6	
⁴¹ Ca	⁴⁰ Ca(d,p) ⁴¹ Ca	11	NPA302(1978)12		1.06		4	
⁴¹ Ca	⁴⁰ Ca(d,p) ⁴¹ Ca	11	PR136(1964)B971	1.26*			3	BD
⁴¹ Ca	⁴⁰ Ca(d,p) ⁴¹ Ca	11	PR181(1969)1529		0.95		5	
⁴¹ Ca	⁴⁰ Ca(d,p) ⁴¹ Ca	11	PRC14(1976)946		1.00		2	
⁴¹ Ca	⁴⁰ Ca(d,p) ⁴¹ Ca	11.8	NP53(1964)77		0.97		6	
⁴¹ Ca	⁴⁰ Ca(d,p) ⁴¹ Ca	12	NPA140(1970)577		0.96		2	
⁴¹ Ca	⁴⁰ Ca(d,p) ⁴¹ Ca	12	NPA243(1975)100		1.02		6	
⁴¹ Ca	⁴⁰ Ca(d,p) ⁴¹ Ca	12	PR136(1964)B971	1.18*			10	
⁴¹ Ca	⁴⁰ Ca(d,p) ⁴¹ Ca	12.8	PR146(1966)799		1.05		4	
⁴¹ Ca	⁴⁰ Ca(d,p) ⁴¹ Ca	14.3	PR138(1965)B1425		0.98		5	
⁴¹ Ca	⁴⁰ Ca(d,p) ⁴¹ Ca	20	NPA506(1990)159		1.03	0.994	7	
⁴¹ Ca	⁴⁰ Ca(d,p) ⁴¹ Ca	56	NPA419(1984)530	0.74*			4	NP
⁴¹ Ca	⁴⁰ Ca(d,p) ⁴¹ Ca	56	PRC50(1994)263	1.04*			3	BS
⁴² Ca	⁴¹ Ca(d,p) ⁴² Ca	11	NPA302(1978)12		1.87		3	
⁴² Ca	⁴¹ Ca(d,p) ⁴² Ca	12	NPA243(1975)100		1.72		5	
⁴² Ca	⁴¹ Ca(d,p) ⁴² Ca	12	PLB40(1972)641		1.76	1.772	3	
⁴² Ca	⁴² Ca(p,d) ⁴¹ Ca	26.5	NPA113(1968)303		2.11		4	
⁴² Ca	⁴² Ca(p,d) ⁴¹ Ca	40	NPA185(1972)465		2.20	2.14	2	
⁴³ Ca	⁴² Ca(d,p) ⁴³ Ca	7	NPA120(1968)401	0.83			3	
⁴³ Ca	⁴² Ca(d,p) ⁴³ Ca	7.2	NPA120(1968)401	0.91			3	

⁴³ Ca	⁴² Ca(d,p) ⁴³ Ca	7.2	PR146(1966)734	0.74			3	
⁴³ Ca	⁴² Ca(d,p) ⁴³ Ca	10	NPA120(1968)421		0.64		1	
⁴³ Ca	⁴² Ca(d,p) ⁴³ Ca	10	NPA225(1974)267		0.58	0.61	1	
⁴³ Ca	⁴³ Ca(p,d) ⁴² Ca	40	PRC7(1973)637		0.64	0.64	4	
⁴⁴ Ca	⁴³ Ca(d,p) ⁴⁴ Ca	8.5	PR155(1967)1229		5.00		5	
⁴⁴ Ca	⁴⁴ Ca(p,d) ⁴³ Ca	17.5	PR144(1966)941		2.77		2	
⁴⁴ Ca	⁴⁴ Ca(p,d) ⁴³ Ca	26.5	NPA113(1968)303		5.17		4	
⁴⁴ Ca	⁴⁴ Ca(p,d) ⁴³ Ca	40	NPA185(1972)465		3.07	3.779	5	
⁴⁵ Ca	⁴⁴ Ca(d,p) ⁴⁵ Ca	7	NPA120(1968)401	0.54			3	
⁴⁵ Ca	⁴⁴ Ca(d,p) ⁴⁵ Ca	7	PR156(1967)1255	0.60			2	
⁴⁵ Ca	⁴⁴ Ca(d,p) ⁴⁵ Ca	7.2	NPA120(1968)401	0.53			2	
⁴⁵ Ca	⁴⁴ Ca(d,p) ⁴⁵ Ca	10	NPA120(1968)421		0.39		3	
⁴⁵ Ca	⁴⁴ Ca(d,p) ⁴⁵ Ca	10	NPA225(1974)267		0.39	0.39	3	
⁴⁷ Ca	⁴⁶ Ca(d,p) ⁴⁷ Ca	7	NPA120(1968)401	0.34			3	
⁴⁷ Ca	⁴⁶ Ca(d,p) ⁴⁷ Ca	7.2	NPA120(1968)401	0.32			1	
⁴⁷ Ca	⁴⁶ Ca(d,p) ⁴⁷ Ca	10	NPA120(1968)421		0.25		2	
⁴⁷ Ca	⁴⁶ Ca(d,p) ⁴⁷ Ca	10	PR138(1965)B1097		0.25	0.25	4	
⁴⁸ Ca	⁴⁸ Ca(p,d) ⁴⁷ Ca	17.5	PR144(1966)941		8.66		5	
⁴⁸ Ca	⁴⁸ Ca(p,d) ⁴⁷ Ca	18	PR170(1968)1003		5.33		6	
⁴⁸ Ca	⁴⁸ Ca(p,d) ⁴⁷ Ca	40	NPA185(1972)465		7.42	7.047	6	
⁴⁹ Ca	⁴⁸ Ca(d,p) ⁴⁹ Ca	4.5	NPA160(1971)289	1.83			4	
⁴⁹ Ca	⁴⁸ Ca(d,p) ⁴⁹ Ca	5	NPA160(1971)289	1.79			3	
⁴⁹ Ca	⁴⁸ Ca(d,p) ⁴⁹ Ca	5.5	NPA160(1971)289	1.66			3	
⁴⁹ Ca	⁴⁸ Ca(d,p) ⁴⁹ Ca	7	NPA120(1968)401	0.80			3	
⁴⁹ Ca	⁴⁸ Ca(d,p) ⁴⁹ Ca	7	NPA160(1971)289	0.82			4	
⁴⁹ Ca	⁴⁸ Ca(d,p) ⁴⁹ Ca	7	PR135(1964)B865	1.48			4	
⁴⁹ Ca	⁴⁸ Ca(d,p) ⁴⁹ Ca	7.2	NPA120(1968)401	0.86			3	
⁴⁹ Ca	⁴⁸ Ca(d,p) ⁴⁹ Ca	10	NPA120(1968)421	0.77*			1	NP
⁴⁹ Ca	⁴⁸ Ca(d,p) ⁴⁹ Ca	10	NPA225(1974)267		0.62		2	
⁴⁹ Ca	⁴⁸ Ca(d,p) ⁴⁹ Ca	11.9	NPA303(1978)121	0.59*			2	NP
⁴⁹ Ca	⁴⁸ Ca(d,p) ⁴⁹ Ca	13	PRC12(1975)827		0.74		4	
⁴⁹ Ca	⁴⁸ Ca(d,p) ⁴⁹ Ca	16	PRC12(1975)827		0.67		4	
⁴⁹ Ca	⁴⁸ Ca(d,p) ⁴⁹ Ca	19.3	PRC12(1975)827		0.66	0.682	3	
⁴⁹ Ca	⁴⁸ Ca(d,p) ⁴⁹ Ca	56	NPA576(1994)123	0.64*			3	BS
⁴⁵ Sc	⁴⁵ Sc(p,d) ⁴⁴ Sc	17.5	PR134(1964)B378		0.29	0.29	3	
⁴⁶ Sc	⁴⁵ Sc(d,p) ⁴⁶ Sc	7	PR151(1966)939.	0.38			2	
⁴⁶ Sc	⁴⁵ Sc(d,p) ⁴⁶ Sc	12	PRC46(1992)144		0.49	0.49	2	
⁴⁶ Ti	⁴⁶ Ti(p,d) ⁴⁵ Ti	17.5	PR135(1964)B389		2.53		3	
⁴⁶ Ti	⁴⁶ Ti(p,d) ⁴⁵ Ti	26	NPA111(1968)449		2.26	2.376	4	
⁴⁶ Ti	⁴⁶ Ti(p,d) ⁴⁵ Ti	34.78	NPA152(1970)609	1.25*			3	
⁴⁷ Ti	⁴⁶ Ti(d,p) ⁴⁷ Ti	7	NP73(1965)321	0.03				
⁴⁷ Ti	⁴⁶ Ti(d,p) ⁴⁷ Ti	10	NPA196(1972)225	0.01*				BD
⁴⁸ Ti	⁴⁷ Ti(d,p) ⁴⁸ Ti	13.6	J,YF,25,16,77		0.13	0.13		BS

⁴⁸ Ti	⁴⁸ Ti(p,d) ⁴⁷ Ti	24.8	NPA152(1970)609	0.12*			4	BD
⁴⁸ Ti	⁴⁸ Ti(p,d) ⁴⁷ Ti	29.82	NPA152(1970)609	0.12*			3	BD
⁴⁸ Ti	⁴⁸ Ti(p,d) ⁴⁷ Ti	35.15	NPA152(1970)609		0.11		3	
⁴⁸ Ti	⁴⁸ Ti(p,d) ⁴⁷ Ti	39.97	NPA152(1970)609		0.11		3	
⁴⁸ Ti	⁴⁸ Ti(p,d) ⁴⁷ Ti	45.05	NPA152(1970)609		0.097	0.106	3	
⁴⁹ Ti	⁴⁸ Ti(d,p) ⁴⁹ Ti	6	PR159(1967)920	0.29			4	
⁴⁹ Ti	⁴⁸ Ti(d,p) ⁴⁹ Ti	21.4	PR131(1963)811		0.23	0.23	4	
⁴⁹ Ti	⁴⁹ Ti(p,d) ⁴⁸ Ti	17.5	PR135(1964)B389		0.23		4	
⁴⁹ Ti	⁴⁹ Ti(p,d) ⁴⁸ Ti	20.9	NPA177(1971)205		0.26	0.24	4	
⁵⁰ Ti	⁴⁹ Ti(d,p) ⁵⁰ Ti	13.6	J,YF,25,16,77		6.30		4	
⁵⁰ Ti	⁴⁹ Ti(d,p) ⁵⁰ Ti	21.4	PR131(1963)811		7.96	7.356	7	
⁵⁰ Ti	⁵⁰ Ti(p,d) ⁴⁹ Ti	17.5	PR135(1964)B389		5.80		1	
⁵⁰ Ti	⁵⁰ Ti(p,d) ⁴⁹ Ti	45.05	NPA152(1970)609		5.04	5.149	6	
⁵¹ Ti	⁵⁰ Ti(d,p) ⁵¹ Ti	6	PR136(1964)B438	1.33				
⁵¹ Ti	⁵⁰ Ti(d,p) ⁵¹ Ti	21.4	PR131(1963)811		1.21	1.21	5	
⁵¹ V	⁵⁰ V(d,p) ⁵¹ V	7.5	NPA94(1967)673		1.61	1.61	4	
⁵¹ V	⁵¹ V(p,d) ⁵⁰ V	18.5	PR134(1964)B752		1.30		3	
⁵¹ V	⁵¹ V(p,d) ⁵⁰ V	51.9	PLB73(1978)145		0.72	1.309	2	
⁵⁰ Cr	⁵⁰ Cr(p,d) ⁴⁹ Cr	17.5	PR160(1967)997	0.11*			5	BS
⁵⁰ Cr	⁵⁰ Cr(p,d) ⁴⁹ Cr	55	NPA435(1985)7		0.11	0.11	3	BS
⁵¹ Cr	⁵⁰ Cr(d,p) ⁵¹ Cr	6.6	NP51(1964)161	0.61			2	
⁵¹ Cr	⁵⁰ Cr(d,p) ⁵¹ Cr	7.5	PR170(1968)1013	0.65			2	
⁵¹ Cr	⁵⁰ Cr(d,p) ⁵¹ Cr	10	NPA198(1972)237		0.25		2	
⁵¹ Cr	⁵⁰ Cr(d,p) ⁵¹ Cr	12	NPA282(1977)87		0.29	0.27	3	
⁵² Cr	⁵² Cr(p,d) ⁵¹ Cr	17.5	PR160(1967)997		6.30		6	
⁵² Cr	⁵² Cr(p,d) ⁵¹ Cr	18.5	PR134(1964)B752		5.70	6.027	5	
⁵³ Cr	⁵² Cr(d,p) ⁵³ Cr	5.41	NP84(1966)398	0.66			3	
⁵³ Cr	⁵² Cr(d,p) ⁵³ Cr	5.72	NP84(1966)398	0.56			4	
⁵³ Cr	⁵² Cr(d,p) ⁵³ Cr	6	NPA277(1977)374	0.56			4	
⁵³ Cr	⁵² Cr(d,p) ⁵³ Cr	6.02	NP84(1966)398	0.65			2	
⁵³ Cr	⁵² Cr(d,p) ⁵³ Cr	6.33	NP84(1966)398	0.49			3	
⁵³ Cr	⁵² Cr(d,p) ⁵³ Cr	7.5	NPA121(1968)1	0.53			3	
⁵³ Cr	⁵² Cr(d,p) ⁵³ Cr	9.14	NP86(1966)65	0.35			3	
⁵³ Cr	⁵² Cr(d,p) ⁵³ Cr	10	NPA196(1972)225		0.42		3	
⁵³ Cr	⁵² Cr(d,p) ⁵³ Cr	10	NPA206(1973)225		0.42		3	
⁵³ Cr	⁵² Cr(d,p) ⁵³ Cr	10	NPA277(1977)119		0.38		1	
⁵³ Cr	⁵² Cr(d,p) ⁵³ Cr	10	NP72(1965)273		0.35		0	
⁵³ Cr	⁵² Cr(d,p) ⁵³ Cr	10.15	NP86(1966)65		0.36		3	
⁵³ Cr	⁵² Cr(d,p) ⁵³ Cr	11.18	NP86(1966)65		0.36		4	
⁵³ Cr	⁵² Cr(d,p) ⁵³ Cr	12	NPA167(1971)289		0.41		4	
⁵³ Cr	⁵² Cr(d,p) ⁵³ Cr	22	NPA573(1994)1		0.35	0.388	2	
⁵³ Cr	⁵³ Cr(p,d) ⁵² Cr	16.6	NPA177(1971)205		0.37	0.37	2	
⁵⁵ Cr	⁵⁴ Cr(d,p) ⁵⁵ Cr	8	NPA142(1970)469	0.62			2	

^{55}Cr	$^{54}\text{Cr}(\text{d,p})^{55}\text{Cr}$	10	NPA337(1980)389	1.07*			2	NP
^{55}Cr	$^{54}\text{Cr}(\text{d,p})^{55}\text{Cr}$	10	NPA72(1965)273		0.86	0.86	3	

Table II List of nuclei with spectroscopic factors obtained from both (p,d) and (d,p) reactions. N_pd and N_dp denote the number of (p,d) and (d,p) independent measurements included in the analysis.

A	A(p,d)B	N_pd	B(d,p)A	N_dp
¹¹ B	1.25	1	1.44	3
¹¹ Be	0.56	1	0.46	2
¹³ C	0.83	4	0.71	13
¹⁴ C	1.3	4	1.75	2
⁴² Ca	2.14	2	1.77	3
⁴³ Ca	0.64	1	0.62	2
⁴⁴ Ca	4.16	3	5	1
⁵³ Cr	0.37	1	0.39	8
²⁶ Mg	3.07	3	2.51	3
¹⁵ N	1.41	2	1.33	4
²¹ Ne	0.03	1	0.03	2
¹⁷ O	0.765	4	0.952	10
¹⁸ O	1.68	2	1.8	1
³⁰ Si	0.82	1	0.62	1
⁴⁸ Ti	0.11	5	0.13	1
⁴⁹ Ti	0.24	2	0.23	1
⁵⁰ Ti	5.14	2	7.36	2
⁵¹ V	1.61	1	1.31	2

Table III: List of isotopes with the extracted spectroscopic factors and other information such as the mass number (A), charge number (Z) and neutron number (N) for the nuclei. j^π , T and S_n are the spin and parity, isospin and neutron separation energy of the nuclei. For completeness, we also list the root mean square radii obtained from the calculations which yield the spectroscopic factors as explained in the text. Endt's compiled values are also listed when available.

Isotope	A	Z	N	j^π	T	S_n	rms	Endt	SF	LB-SM	Interaction
${}^6\text{Li}$	6	3	3	1^+	0	5.66	2.91		1.08 ± 0.305	0.684	PPN
${}^7\text{Li}$	7	3	4	$3/2^-$	1/2	7.25	2.81		1.82 ± 0.257	0.628	PPN
${}^8\text{Li}$	8	3	5	2^+	1	2.03	3.66		0.61 ± 0.173	1.085	PPN
${}^9\text{Li}$	9	3	6	$3/2^-$	3/2	4.06	3.23		0.98 ± 0.277	0.810	PPN
${}^9\text{Be}$	9	4	5	$3/2^-$	1/2	1.67	3.86		0.44 ± 0.027	0.568	PPN
${}^{10}\text{Be}$	10	4	6	0^+	1	6.81	2.96		1.53 ± 0.153	2.356	PPN
${}^{11}\text{Be}$	11	4	7	$1/2^+$	3/2	0.50	7.11		0.52 ± 0.060	0.743	SPSDPF
${}^{10}\text{B}$	10	5	5	3^+	0	8.44	2.85		0.49 ± 0.069	0.600	PPN
${}^{11}\text{B}$	11	5	6	$3/2^-$	1/2	11.45	2.73		1.34 ± 0.134	1.094	PPN
${}^{12}\text{B}$	12	5	7	1^+	1	3.37	3.46		0.45 ± 0.064	0.826	PPN
${}^{12}\text{C}$	12	6	6	0^+	0	18.72	2.53		2.98 ± 0.344	2.849	PPN
${}^{13}\text{C}$	13	6	7	$1/2^-$	1/2	4.95	3.26		0.79 ± 0.038	0.613	PPN
${}^{14}\text{C}$	14	6	8	0^+	1	8.18	3.00		1.56 ± 0.127	1.734	PPN
${}^{15}\text{C}$	15	6	9	$1/2^+$	3/2	1.22	5.51		1.11 ± 0.314	0.980	SPSDPF
${}^{14}\text{N}$	14	7	7	1^+	0	10.55	2.87		0.73 ± 0.084	0.692	PPN
${}^{15}\text{N}$	15	7	8	$1/2^-$	1/2	10.83	2.89		1.38 ± 0.113	1.459	PPN
${}^{16}\text{N}$	16	7	9	2^-	1	2.49	4.26		0.42 ± 0.119	0.960	SPSDPF
${}^{16}\text{O}$	16	8	8	0^+	0	15.66	2.74		2.23 ± 0.149	2.000	PPN
${}^{17}\text{O}$	17	8	9	$5/2^+$	1/2	4.14	3.48		0.84 ± 0.045	1.000	SDPN
${}^{18}\text{O}$	18	8	10	0^+	1	8.04	3.24		1.75 ± 0.202	1.579	SDPN
${}^{19}\text{O}$	19	8	11	$5/2^+$	3/2	3.95	3.57		0.41 ± 0.058	0.685	SDPN
${}^{19}\text{F}$	19	9	10	$1/2^+$	1/2	10.43	2.66		1.56 ± 0.221	0.558	SDPN
${}^{20}\text{F}$	20	9	11	2^+	1	6.6	3.39		0.01 ± 0.003	0.019	SDPN
${}^{21}\text{Ne}$	21	10	11	$3/2^+$	1/2	6.76	3.41	0.01	0.03 ± 0.003	0.028	SD
${}^{22}\text{Ne}$	22	10	12	0^+	1	10.36	3.27	0.19	0.23 ± 0.033	0.013	SDPN
${}^{23}\text{Ne}$	23	10	13	$5/2^+$	3/2	5.2	3.58	0.24	0.24 ± 0.034	0.034	SDPN
${}^{24}\text{Na}$	24	11	13	4^+	1	8.87	3.49	0.3	0.56 ± 0.158	0.391	SDPN
${}^{24}\text{Mg}$	24	12	12	0^+	0	16.53	3.13		0.40 ± 0.057	0.221	SDPN
${}^{25}\text{Mg}$	25	12	13	$5/2^+$	1/2	7.33	3.50	0.37	0.29 ± 0.029	0.343	SDPN
${}^{26}\text{Mg}$	26	12	14	0^+	1	11.09	3.35	1.8	2.79 ± 0.228	2.510	SDPN
${}^{27}\text{Mg}$	27	12	15	$1/2^+$	3/2	6.44	3.90	0.58	0.44 ± 0.124	0.464	SDPN
${}^{27}\text{Al}$	27	13	14	$5/2^+$	1/2	13.06	3.31	1.1	1.35 ± 0.191	1.101	SDPN
${}^{28}\text{Al}$	28	13	15	3^+	1	7.73	3.78	0.5	0.64 ± 0.091	0.602	SDPN
${}^{28}\text{Si}$	28	14	14	0^+	0	17.18	3.22		4.23 ± 1.196	3.618	SDPN

²⁹ Si	29	14	15	1/2 ⁺	1/2	8.47	3.73	0.55	0.37 ± 0.037	0.451	SDPN
³⁰ Si	30	14	16	0 ⁺	1	10.61	2.87	0.89	0.72 ± 0.102	0.820	SDPN
³¹ Si	31	14	17	3/2 ⁺	3/2	6.59	3.70	0.75	0.59 ± 0.083	0.584	SDPN
³² P	32	15	17	1 ⁺	1	7.94	3.64	0.8	0.53 ± 0.075	0.601	SDPN
³² S	32	16	16	0 ⁺	0	15.04	3.40		1.46 ± 0.413	0.956	SDPN
³³ S	33	16	17	3/2 ⁺	1/2	8.64	3.63	0.7	0.67 ± 0.190	0.609	SDPN
³⁴ S	34	16	18	0 ⁺	1	11.42	3.53	1.9	1.38 ± 0.195	1.834	SDPN
³⁵ S	35	16	19	3/2 ⁺	3/2	6.99	3.77	0.38	0.29 ± 0.082	0.364	SDPN
³⁷ S	37	16	21	7/2 ⁻	5/2	4.3	4.02		0.88 ± 0.124		
³⁵ Cl	35	17	18	3/2 ⁺	1/2	12.64	3.51		0.33 ± 0.093	0.318	SDPN
³⁶ Cl	36	17	19	2 ⁺	1	8.58	3.70	1.2	0.69 ± 0.195	0.766	SDPN
³⁷ Cl	37	17	20	3/2 ⁺	3/2	10.31	3.64	0.95	1.03 ± 0.146	1.152	SDPN
³⁸ Cl	38	17	21	2 ⁻	2	6.11	3.94	0.78	1.74 ± 0.492		
³⁶ Ar	36	18	18	0 ⁺	0	15.26	3.45		3.23 ± 0.457	2.055	SDPN
³⁷ Ar	37	18	19	3/2 ⁺	1/2	8.79	3.71	0.49	0.35 ± 0.049	0.364	SDPN
³⁸ Ar	38	18	20	9 ⁺	1	11.84	3.60	2.5	2.43 ± 0.687	3.043	SDPN
³⁹ Ar	39	18	21	7/2 ⁻	3/2	6.6	3.94	0.64	0.79 ± 0.112		
⁴⁰ Ar	40	18	22	0 ⁺	2	9.87	3.83	1.2	1.05 ± 0.297		
⁴¹ Ar	41	18	23	7/2 ⁻	5/2	6.1	4.01	0.47	0.55 ± 0.078		
³⁹ K	39	19	20	3/2 ⁺	1/2	13.08	3.58	2	2.1 ± 0.594	1.720	SDPN
⁴⁰ K	40	19	21	4 ⁻	1	7.8	3.90	0.94	1.66 ± 0.470		
⁴¹ K	41	19	22	3/2 ⁺	3/2	10.1	3.84	0.56	0.95 ± 0.269		
⁴² K	42	19	23	2 ⁻	2	7.53	3.96	0.34	0.77 ± 0.109		
⁴⁰ Ca	40	20	20	0 ⁺	0	15.64	3.81		4.3 ± 0.385	4.000	SDPN
⁴¹ Ca	41	20	21	7/2 ⁻	1/2	8.36	3.90	0.85	0.99 ± 0.055	1.000	FPPN
⁴² Ca	42	20	22	0 ⁺	1	11.48	3.82	1.6	1.97 ± 0.176	1.810	FPPN
⁴³ Ca	43	20	23	7/2 ⁻	3/2	7.93	3.97	0.58	0.62 ± 0.072	0.750	FPPN
⁴⁴ Ca	44	20	24	0 ⁺	2	11.13	3.87	3.1	4.37 ± 0.437	3.640	FPPN
⁴⁵ Ca	45	20	25	7/2 ⁻	5/2	7.41	4.03		0.39 ± 0.055	0.504	FPPN
⁴⁷ Ca	47	20	27	7/2 ⁻	7/2	7.28	4.08		0.25 ± 0.035	0.256	FPPN
⁴⁸ Ca	48	20	28	0 ⁺	4	9.95	3.99		7.05 ± 0.814	7.383	FPPN
⁴⁹ Ca	49	20	29	3/2 ⁻	9/2	5.15	4.59		0.68 ± 0.068	0.918	FPPN
⁴⁵ Sc	45	21	24	7/2 ⁻	3/2	11.32	3.89	0.34	0.29 ± 0.082	0.352	FPPN
⁴⁶ Sc	46	21	25	4 ⁺	2	8.76	4.00		0.49 ± 0.139	0.370	FPPN
⁴⁶ Ti	46	22	24	0 ⁺	1	13.19	3.85		2.38 ± 0.337	2.580	FPPN
⁴⁷ Ti	47	22	25	5/2 ⁻	3/2	8.88	4.01		0.01 ± 0.003		
⁴⁸ Ti	48	22	26	0 ⁺	2	11.63	3.94		0.12 ± 0.012		
⁴⁹ Ti	49	22	27	7/2 ⁻	5/2	8.14	4.08		0.23 ± 0.027		
⁵⁰ Ti	50	22	28	0 ⁺	3	10.94	4.00		6.25 ± 0.625		
⁵¹ Ti	51	22	29	3/2 ⁻	7/2	6.37	4.46		1.21 ± 0.342		
⁵¹ V	51	23	28	7/2 ⁻	5/2	11.05	4.01		1.49 ± 0.172		
⁵⁰ Cr	50	24	26	0 ⁺	1	13	3.94		0.11 ± 0.031		
⁵¹ Cr	51	24	27	7/2 ⁻	3/2	9.26	4.08		0.27 ± 0.038		

^{52}Cr	52	24	28	0^+	2	12.04	4.00		6.03 ± 0.853		
^{53}Cr	53	24	29	$3/2^-$	$5/2$	7.94	4.34		0.38 ± 0.025		
^{55}Cr	55	24	31	$3/2^-$	$7/2$	6.24	4.03		0.86 ± 0.243		

Figure 1: (Color online) Comparison of digitized data (open points) and tabulated data (closed points) from the same measurement of the angular distributions of the protons obtained in the $^{14}\text{N}(d,p)^{15}\text{N}$ reaction at incident deuteron energy of 12 MeV. The curve is the predicted angular distributions from the code TWOFNR as described in the text, multiplied by 1.1 which is the spectroscopic factor.

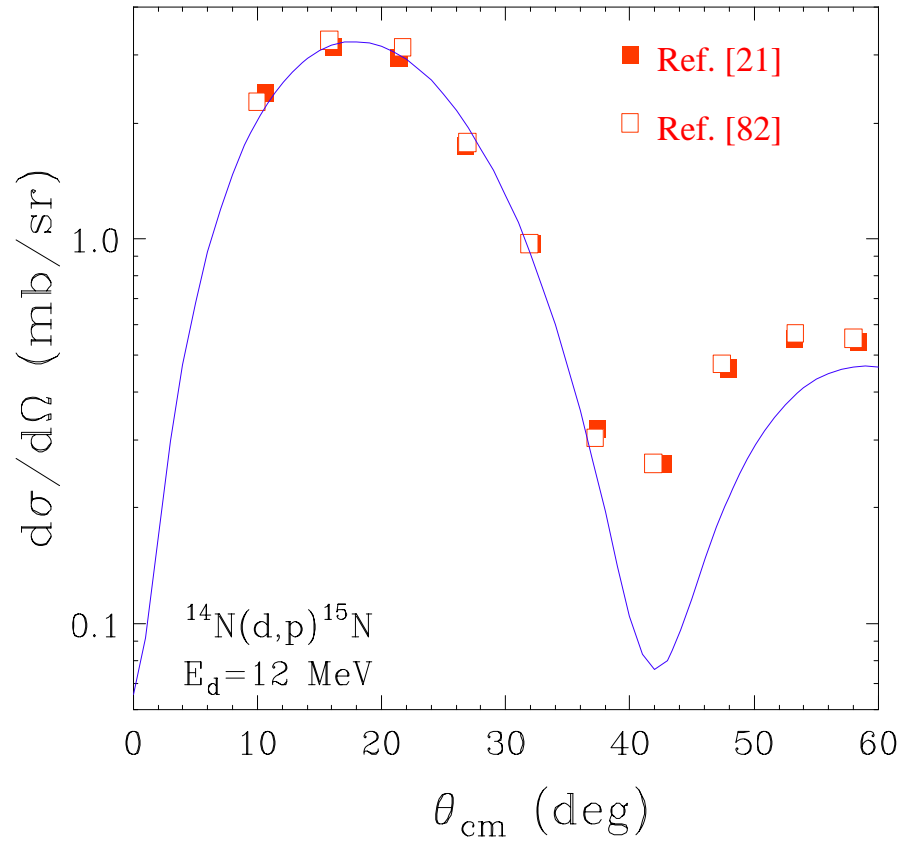


Figure 2: (Color online) The angular distributions of the deuteron obtained in the $^{44}\text{Ca}(p,d)^{43}\text{Ca}$ reaction at incident proton energy of 40 MeV [174]. The curve is the predicted angular distributions from the code TWOFNR as described in the text, multiplied by the spectroscopic factor.

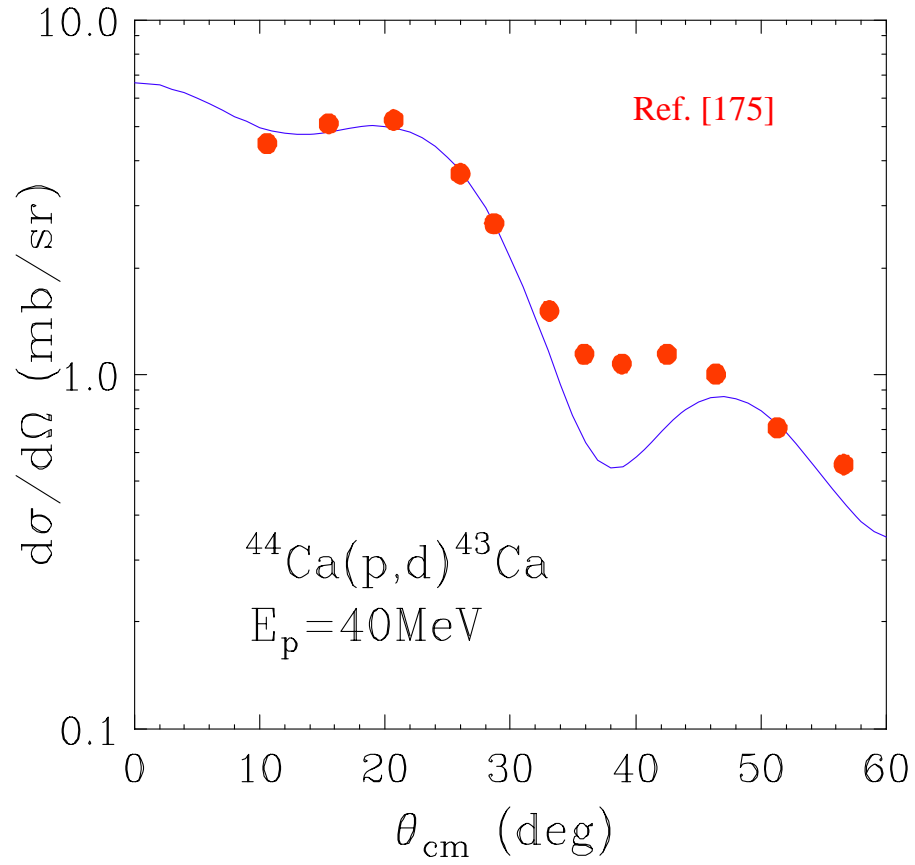


Figure 3: (Color online) Comparisons of the angular distributions of the deuteron measured in the $^{11}\text{B}(d,p)^{12}\text{B}$ reactions in three different experiments.

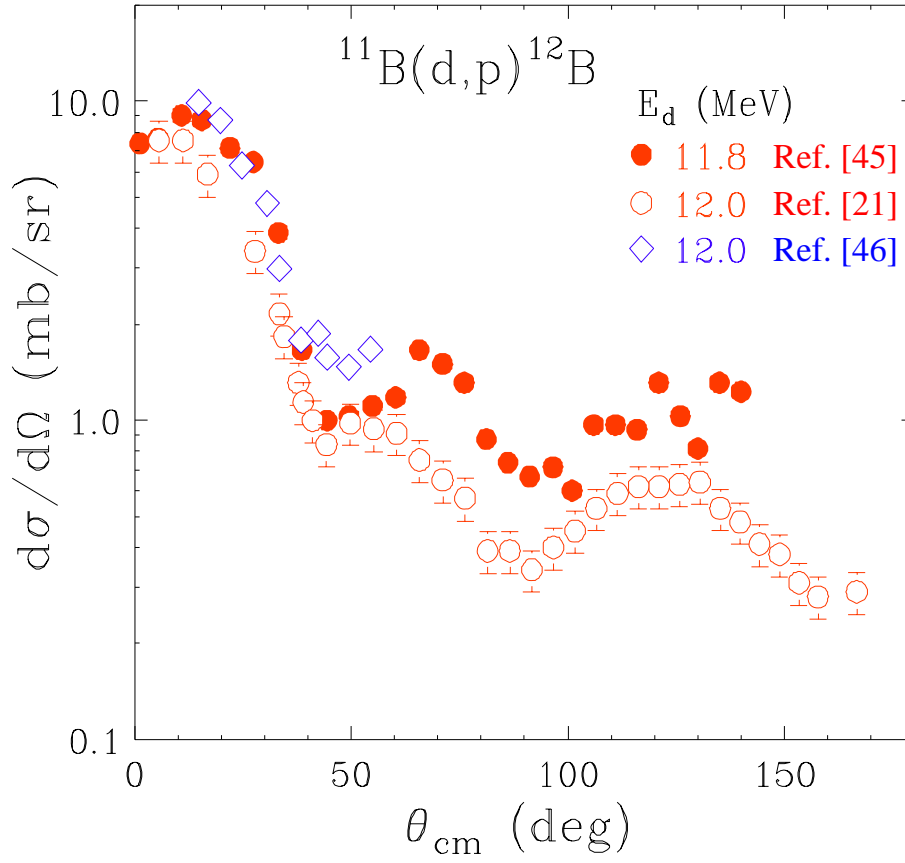


Figure 4: (Color online) Comparisons of the angular distributions of the deuteron measured in the $^{12}\text{C}(d,p)^{13}\text{C}$ reactions in four different experiments.

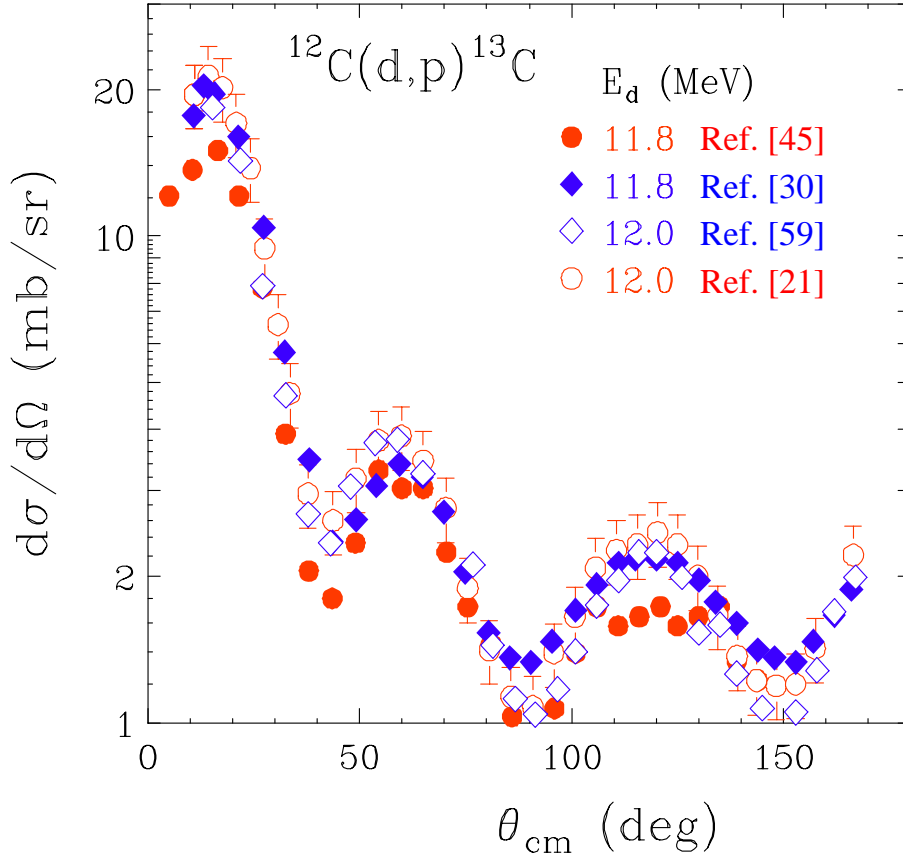


Figure 5: (Color online) Comparison of spectroscopic factors obtained from Ref. [181] (open circles) and from other measurements (closed circles). The increase of spectroscopic factors observed at $E_d < 10$ MeV has been observed before ref. [21] and has been attributed to the resonance structures in the elastic scattering of the deuterons Ref. [244].

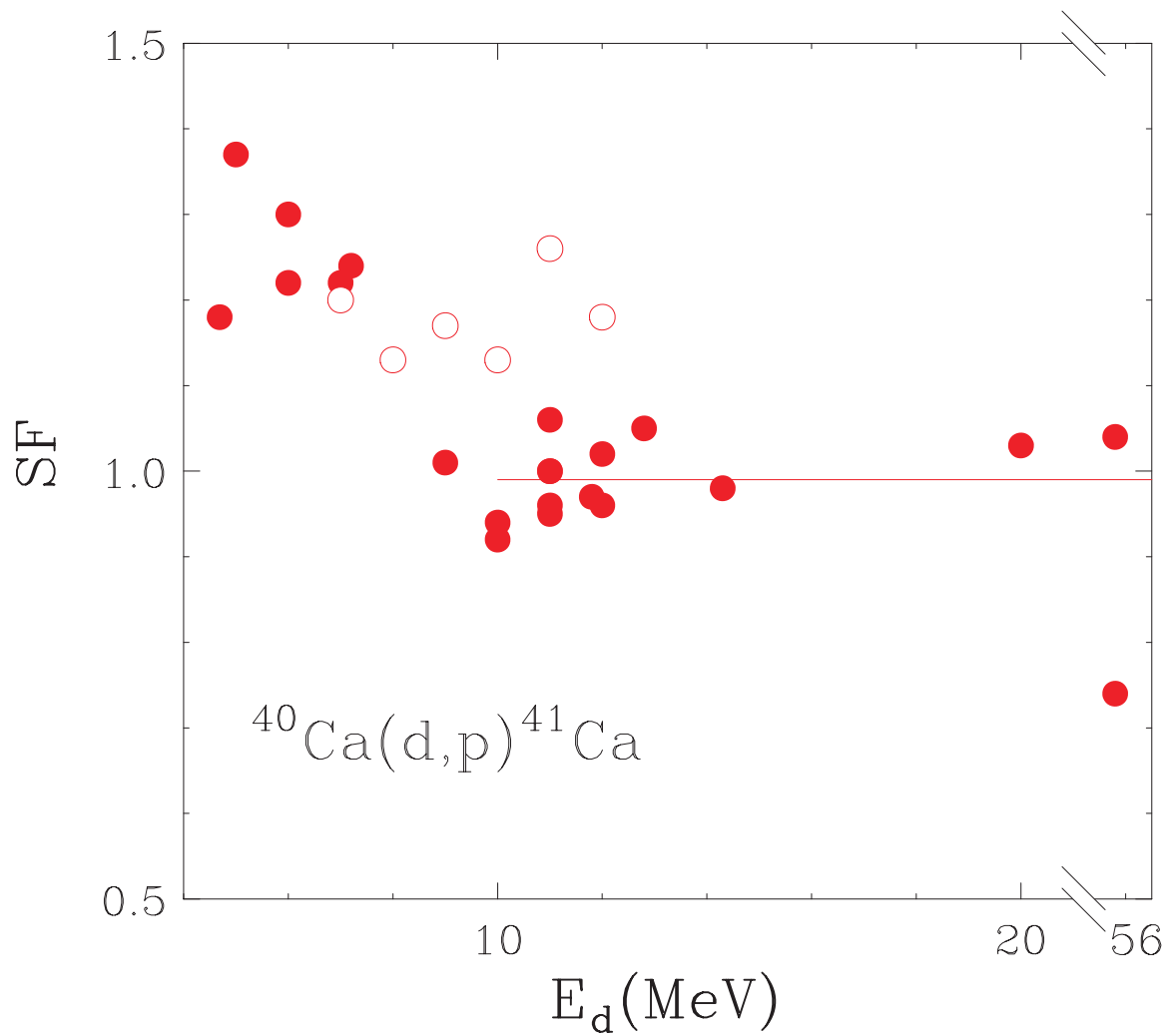


Figure 6: (Color online) Angular distributions for $^{40}\text{Ca}(d,p)^{41}\text{Ca}$ reactions for beam energy from 4.69 to 56 MeV. Each distribution is displaced by factors of 10 from adjacent distributions. The overall normalization factor is 10 for the 7.2 MeV data. References are listed in Table 1.

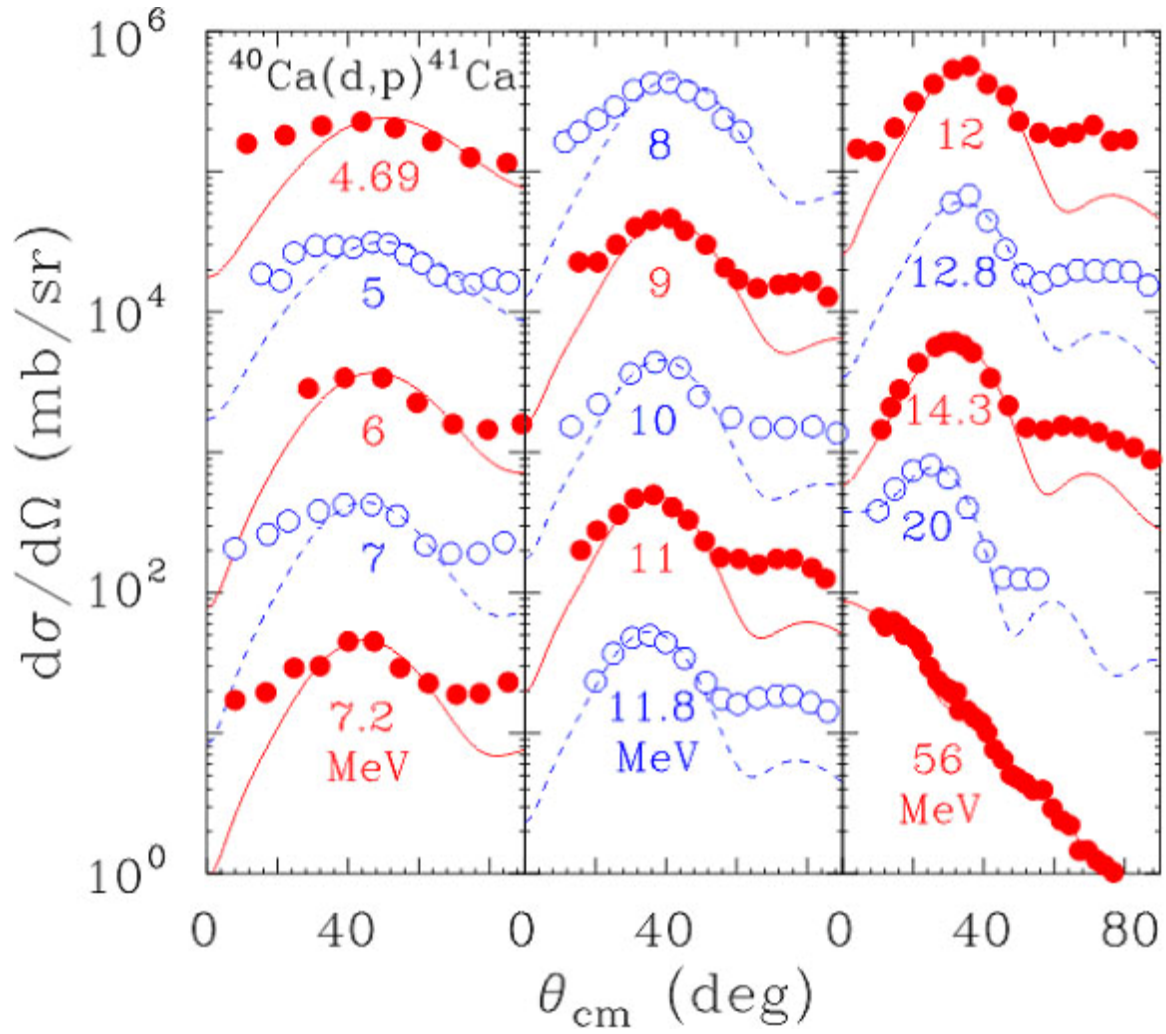


Figure 7: (Color online) Comparisons of the angular distributions of the deuteron measured in the $^{50}\text{Cr}(p,d)^{49}\text{Cr}$ reactions in four different experiments.

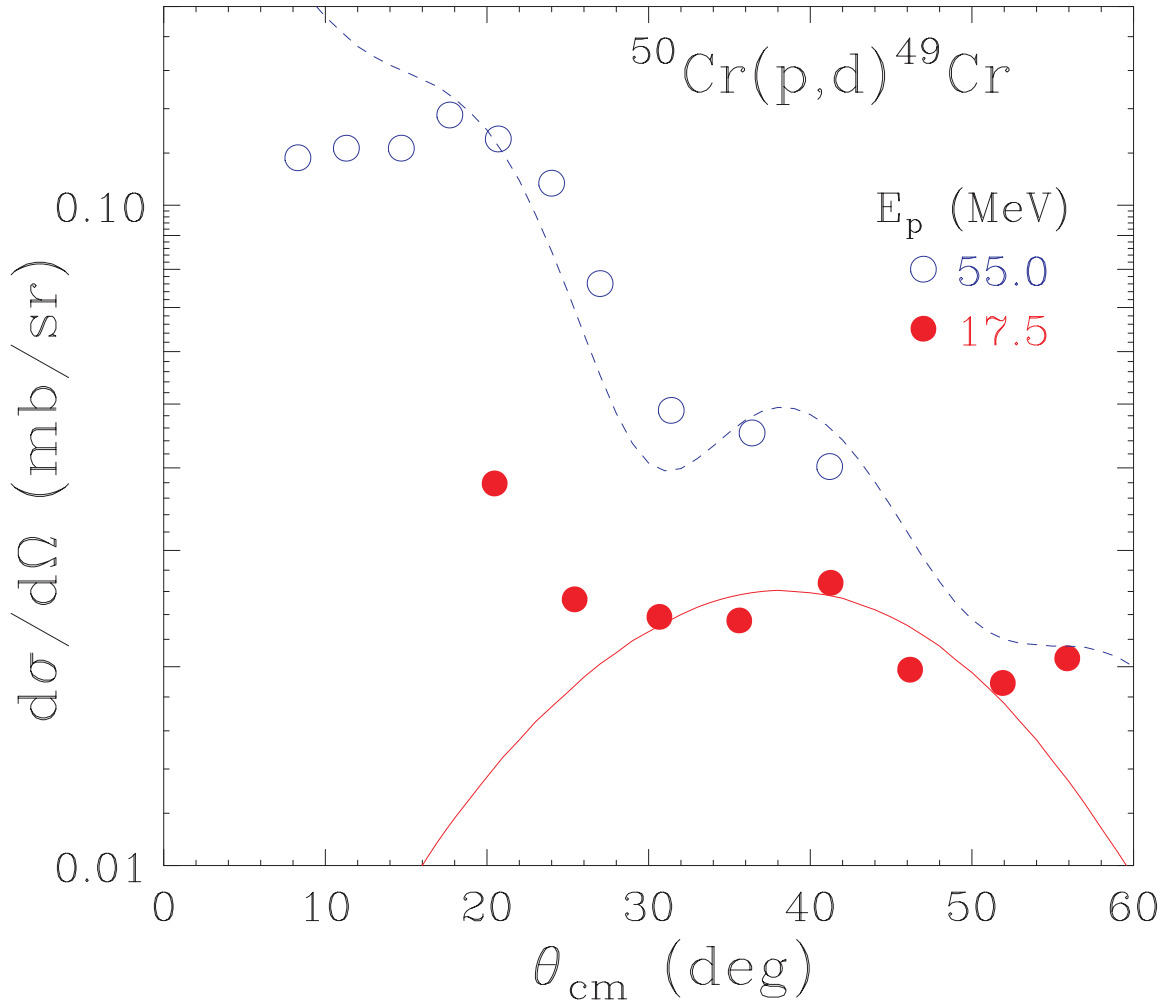


Figure 8: (Color online) Comparisons of three angular distributions of the deuteron measured in the $^{14}\text{C}(d,p)^{15}\text{C}$ reactions in three different experiments. The curve is the predicted angular distributions from the code TWOFNR as described in the text, multiplied by the spectroscopic factor of 1.1 which fits the data of ref. [74], the only set of data with measurements at angles more forward than 15° .

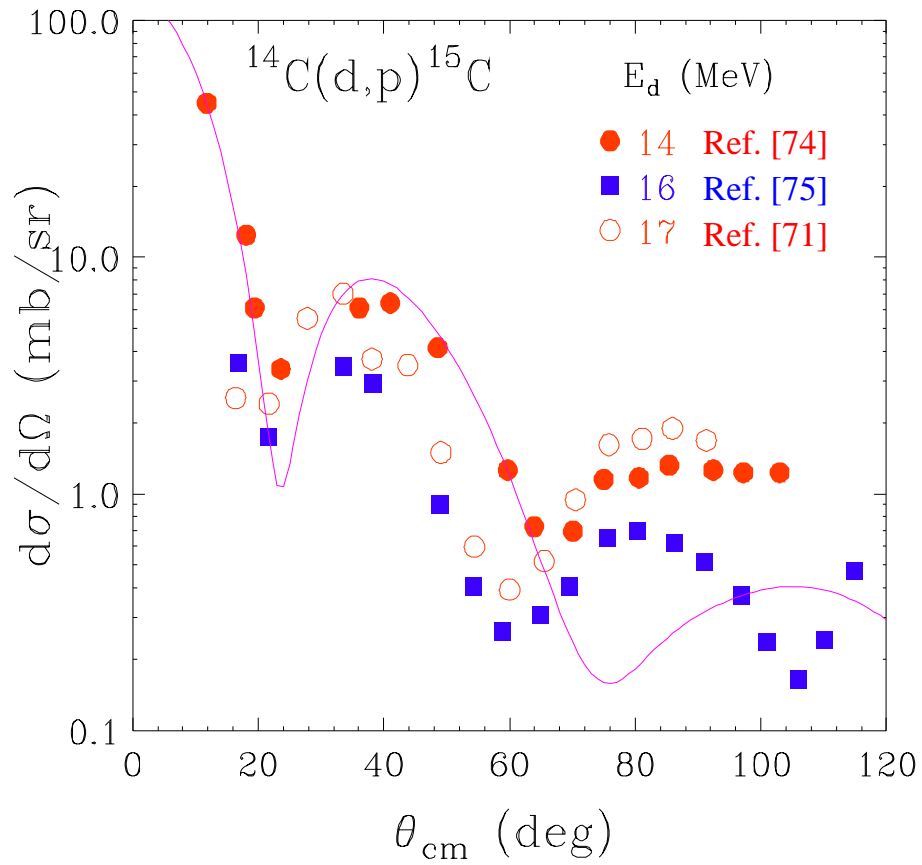


Figure 9: (Color online) Comparisons of spectroscopic factors obtained from (p,d) and (d,p) reactions as listed in Table II. The line indicates perfect agreement between the two values.

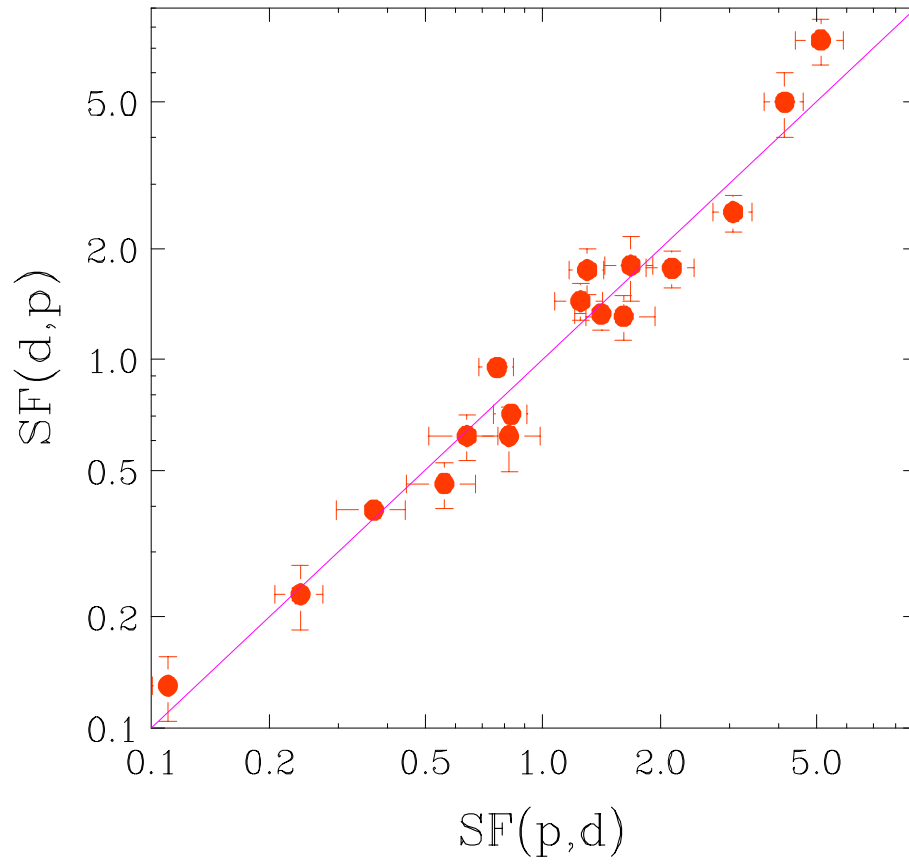


Figure 10: (Color online) Comparisons of spectroscopic factors obtained from this work and the compiled values of Endt [8]. All the values are listed in Table III. The line indicates perfect agreement between our values and Endt's compilation.

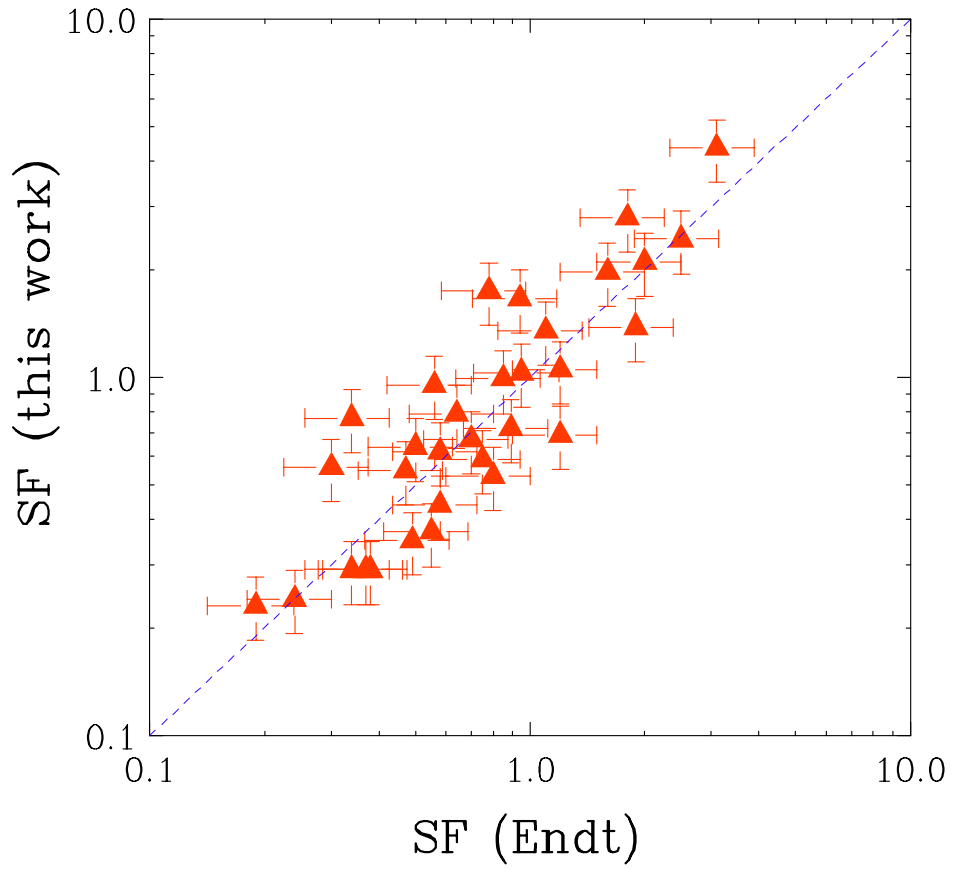


Figure 11: (Color online) Ratios of the SF values from experiment divided by the SF values predicted by the large basis shell model as a function of the neutron separation energy (S_n). Open and closed symbols denote elements with odd and even Z respectively. The three different colors of green, blue and red represent $Z=3-8$, $9-18$ and $19-22$ isotopes respectively.

