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# Systematic study of fusion barriers with energy dependent barrier radius

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## ABSTRACT

Considering energy dependence of the barrier radius in heavy-ion fusion reactions, a modified Siwek-Wilczyński (MSW) fusion cross section formula is proposed. With the MSW formula, the fusion barrier parameters for 367 reaction systems are systematically extracted, based on 443 datasets of measured cross sections. We find that the fusion excitation functions for about 60% reaction systems can be better described by introducing the energy dependence of the barrier radius which is due to the dynamical effects at energies near and below the barrier. Considering both the influence of the geometry radii and that of the reduced de Broglie wavelength of the colliding nuclei, the barrier heights are well reproduced with only one model parameter. The extracted barrier radius parameters linearly decrease with the effective fissility parameter, and the width of the barrier distribution relates to the barrier height, as well as the reduced de Broglie wavelength at energies around the Coulomb barrier.

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## 1. Introduction

The problem of overcoming a potential barrier is of importance not only in nuclear physics, but also in many other fields of the nature sciences. Knowledge of the nucleus–nucleus interaction potential is an essential ingredient in the analysis of elastic and inelastic scattering, as well as of fusion reactions between nuclei. The information concerning the potential barrier is of crucial importance for the synthesis of super-heavy nuclei and heavy-ion fusion at deep sub-barrier energies which has attracted a great deal of attention in recent years [1–10]. Up to now, the fusion cross sections for more than a thousand of reaction systems have been measured in the past several decades. A systematic study of the fusion barriers based on these data is therefore interesting and necessary.

Classically a particle can only overcome a potential barrier when its total energy exceeds the barrier height. In the classical description of fusion excitation functions, the fusion cross section  $\sigma_{\text{fus}}(E)$  at a center-of-mass incident energy *E* is given by

$$\sigma_{\rm fus}(E) = \pi R_B^2 (1 - V_B/E),\tag{1}$$

where  $R_B$  is the barrier radius and  $V_B$  is the barrier height. The barrier parameters are obtained from the data by fitting a straight line through a plot of  $\sigma_{fus}$  vs 1/E. The slope and intercept of this line with the 1/E axis lead to the barrier radius and height, respectively. At energies below the barrier, the particle may tunnel through the potential barrier, as a consequence of quantum mechanics. This tunneling effect was first recognized in the 1920's and the  $\alpha$ -decay of nuclei was explained as a tunneling effect [11]. In the 1970's, the fusion cross sections are analytically described by the well known Wong formula [12], based on the assumption of a parabolic barrier together with the barrier penetration concept,

$$\sigma_{\rm fus}(E) = \frac{\hbar\omega}{2E} R_B^2 \ln\{1 + \exp[2\pi(E - V_B)/\hbar\omega]\},\tag{2}$$

where,  $\hbar\omega$  is the s-wave barrier curvature. The energy dependence of the barrier curvature is introduced in Ref. [13] for a better description of the fusion cross sections at deeply subbarrier energies. For relatively large values of *E*, the result of Wong formula reduces to the classical formula Eq. (1).

For the sub-barrier fusion reactions leading to heavy compound nuclei, an important observation is that the measured fusion cross sections exhibit strong enhancements compared to estimations using a simple one-dimensional barrier penetration model [8]. These enhancements have been accounted for in terms of strong couplings between the relative motion of colliding nuclei and the intrinsic degrees of freedom, such as the collective vibrations of nuclei and nucleon transfer in the neck region. To consider the coupling effects, Stelson introduced a distribution of barrier heights D(B) in the calculation of the fusion excitation function around 1990 [14,15],

$$\sigma_{\rm fus}(E) = \int D(B)\sigma_{\rm fus}^{(1)}(E,B)dB,\tag{3}$$

with  $\int D(B)dB = 1$ . Here,  $\sigma_{\text{fus}}^{(1)}(E, B)$  is the fusion cross section based on a single barrier with a height *B*.

To describe D(B), a single-Gaussian distribution of barrier heights predicted from different orientations of colliding nuclei undergoing slow deviations from sphericity is used by Siwek-Wilczyńska and Wilczyński (SW). Together with Eq. (1) for describing  $\sigma_{\text{fus}}^{(1)}(E, B)$ , the SW formula was proposed [16]. With the SW formula, the heavy-ion fusion cross sections for 29 systems, from  ${}^{16}O+{}^{18}O$  to  ${}^{64}Ni+{}^{124}Sn$ , at extreme sub-barrier energies have been analyzed [17]. Very recently, Wen et al. applied the SW formula to systematically extract the barrier information from the experimental fusion excitation functions, and found that the SW formula behaves much better for the barrier fitting than the Wong formula [18]. In addition to the single-Gaussian function for describing *D*(*B*), two-Gaussian function [19,20], asymmetric Gaussian function [21,22] and as well as multi-Gaussian function [23,24] are also frequently used. The experimental barrier height distribution D(E) can be extracted from a precise experiment of the fusion excitation function via the second derivative [25,26]:

$$D(E) = \frac{1}{\pi R_B^2} \frac{d^2 (E\sigma_{\rm fus})}{dE^2}.$$
 (4)

The validity of all these analyses mentioned above requires that all *l* waves contributing to the fusion cross section have the same barrier radius  $R_B$ , a condition which is probably not fulfilled for most reactions [27]. The energy dependence of the nucleus-nucleus potential was clearly observed from some microscopic dynamics calculations, such as the simulations based on the time-dependent Hartree–Fock (TDHF) theory [28,29] and the improved quantum molecular dynamic (ImQMD) model [30,31], due to the strong dynamical effects in fusion process. For fusion reactions with deformed nuclei, the orientation of the colliding nuclei significantly influences not only the barrier height but also the barrier radius. For tip-tip configuration in fusion reaction induced by prolate nuclei, one obtains a larger barrier radius, comparing with that for side-side configuration [29,32]. It is therefore necessary to investigate the influence of energy and orientation dependence of the barrier radius on the fusion cross sections.

The purpose of the present work is to systematically extract the fusion barriers based on the SW formula together with the energy dependence of the barrier radius being considered. The structure of this paper is as follows: In Section 2, energy dependence of the barrier radius for  $^{16}O+^{208}Pb$  and  $^{34}S+^{168}Er$  will be investigated. In Section 3, a modified SW formula will be proposed and the model accuracy for describing some fusion



**Fig. 1.** Barrier radius as a function of  $E/V_B$  for  ${}^{16}\text{O}+{}^{208}\text{Pb}$  (a) and  ${}^{34}\text{S}+{}^{168}\text{Er}$  (b) from the TDHF calculations.  $A_1$  and  $A_2$  denote the mass number of projectile and target nuclei, respectively.  $V_B$  in horizontal axis are taken from a linear fit of the measured  $\sigma_{\text{fus}}$  [33,34] vs 1/*E* in the region larger than 100 mb.

excitation functions will be tested. In Section 4, the information concerning fusion barriers extracted from 443 datasets of experimental data for 367 different projectile–target combinations, will be presented and the systematics of the fusion barrier will also be analyzed. Finally, a summary will be given in Section 5.

### 2. Energy dependence of barrier radius

To investigate the energy dependence of barrier radius, we firstly use the time dependent Hartree–Fock (TDHF) theory for simulating the fusion reactions <sup>16</sup>O+<sup>208</sup>Pb and <sup>34</sup>S+<sup>168</sup>Er. The nucleus–nucleus interaction potential is extracted by using the density-constrained TDHF approach [32,35]. In <sup>34</sup>S+<sup>168</sup>Er, the tip–tip and tip–side orientations for the deformed reaction partners are taken into account. The Skyrme SLy4d interactions [26] are used by static HF and TDHF dynamic evolution, in which the numerical boxes are chosen as  $30 \times 30 \times 30$  fm<sup>3</sup> and  $30 \times 30 \times 50$  fm<sup>3</sup>, respectively. The time propagation is carried out using a Taylor-series expansion up to the sixth order of the unitary mean-field propagator with a time step of 0.2 fm/c, and the initial distance of two nuclei is set to 20 fm.

In Fig. 1, we show the calculated barrier radii at different incident energies for <sup>16</sup>O+<sup>208</sup>Pb and <sup>34</sup>S+<sup>168</sup>Er, which are scaled by  $A_1^{1/3} + A_2^{1/3}$  to see the radius parameter. One can see that for both reactions at energies around the barrier height  $V_B$ , the barrier radius decrease evidently with incident energy. Especially for <sup>34</sup>S+<sup>168</sup>Er at tip-side orientation, the radius parameter falls sharply with energy, from 1.4 fm at  $E \approx V_B$  down to 1.1 fm at  $E \approx 1.3V_B$ . At energies much higher than the barrier height, the barrier radius does not change too much. The energy dependence of the barrier radius is due to the dynamical effects in fusion process. At energies around the barrier height, the fusion process is relatively slow and the reaction partners have enough time to readjust nuclear density distributions of the reaction system. The dynamical deformation of the densities and neutron transfer in the neck region can result in the enlargement of the barrier radius and the reduction of barrier height correspondingly.

In addition to the TDHF calculations, the barrier radius is also analyzed based on the measured fusion excitation function. According to Eq. (1), the barrier radius can be expressed as,

$$R_B(E) = \left[\frac{\sigma_{\rm fus}}{\pi (1 - V_B/E)}\right]^{1/2}.$$
(5)

In Fig. 2, we show the extracted barrier radius for  ${}^{16}\text{O}+{}^{208}\text{Pb}$  and  ${}^{34}\text{S}+{}^{168}\text{Er}$ , based on the measured fusion excitation function  $\sigma_{\text{fus}}$  [33,34]. At energies above the fusion barrier, the barrier radius does not change significantly with incident energy. At

sub-barrier energies, the enhancement of the barrier radius can be clearly observed. In Ref. [36], a generalized Wong formula is proposed by Rowley and Hagino through considering energy dependence of the barrier parameters. The trend of the energy dependence for barrier radius observed in Fig. 2 is generally in agreement with those from the TDHF calculations and the generalized Wong formula.

Both the TDHF calculations and the data analysis imply that the assumption used in the traditional formula, i.e., all l waves contributing to the fusion cross section having the same barrier radius  $R_B$ , is generally valid at energies above the barrier height. However, at energies around the barrier, the enhancement of barrier radius due to dynamical effects should be considered for a better description of the fusion excitation functions. To consider the influence of the dynamical effects on barrier radius, we empirically introduce a correction term to the traditional barrier radius  $R_0$ ,

$$R_B(X) = R_0 + \Delta R \exp(-X) \operatorname{erfc}(X).$$
(6)

The definition of *X* and the determination of the correction factor  $\Delta R$  will be discussed later. The solid curves in Fig. 2 denote the results according to Eq. (6). Comparing with the results of SW formula, the trend of energy dependence for the barrier radius can be much better described by using Eq. (6), especially at sub-barrier energies.

### 3. Modified Siwek-Wilczyński formula and some tests

Considering the energy dependence of the barrier radius given by Eq. (6), we propose a modified Siwek-Wilczyński (MSW) formula for describing the fusion excitation function

$$\sigma_{\rm fus}(E) = \pi R_B^2(X) \frac{W}{\sqrt{2E}} [X \operatorname{erfc}(-X) + \frac{1}{\sqrt{\pi}} \exp(-X^2)],$$
(7)

where  $X = \frac{E-V_B}{\sqrt{2W}}$ .  $V_B$  and W denote the centroid and the standard deviation of the Gaussian function, respectively. Together with the traditional barrier radius  $R_0$  and the correction factor  $\Delta R$  in Eq. (6), there are a total of four barrier parameters in the MSW formula. If  $\Delta R = 0$ , the result of Eq. (7) reduces to the standard SW formula [16]. For a certain fusion reaction, the four parameters in the MSW formula can be determined by fitting the measured fusion excitation function. The popular Minuit minimization program [39] is usually applied to determine the fitting parameters by searching the global minimum in the hypersurface of the  $\chi^2$  function. The  $\chi^2$  per energy point is expressed as

$$\chi_{pt}^{2} = \frac{1}{N} \sum_{i=1}^{N} \left[ \frac{\sigma_{\text{th}} \left( E_{i} \right) - \sigma_{\exp} \left( E_{i} \right)}{\delta \sigma_{\exp} \left( E_{i} \right)} \right]^{2}, \tag{8}$$



Fig. 2. Barrier radius for  ${}^{16}O+{}^{208}Pb$  (a) and  ${}^{34}S+{}^{168}Er$  (b) from the measured fusion excitation functions. The circles denote the extracted results from the data by using Eq. (5). The dashed lines denote the results of SW formula. The solid curves denote the results of Eq. (6).



**Fig. 3.** (Color online) Fusion excitation functions and fusion barrier distributions for  ${}^{32}S+{}^{96}Zr$  and  ${}^{36}S+{}^{110}Pd$ . The squares in (a1) and (b1) denote the experimental data taken from [37,38] for  ${}^{32}S+{}^{96}Zr$  and  ${}^{36}S+{}^{110}Er$ , respectively. The squares in (a2) and (b2) denote the extracted barrier distribution according to Eq. (4). The dash-dotted curve and the solid curve denote the results of SW formula and those of MSW formula, respectively.

in which the uncertainty of fusion cross section is involved in the fitting process. In addition to  $\chi^2_{pt}$ , the mean-square deviation between the measured fusion cross sections and model predictions is also frequently used to determine the best-fit model parameters [22,23]. Here, the mean-square deviation in logarithmic scale is defined as,

$$\chi_{\log}^{2} = \frac{1}{N} \sum_{i=1}^{N} \left[ \log \left( \sigma_{\text{th}} \left( E_{i} \right) \right) - \log \left( \sigma_{\exp} \left( E_{i} \right) \right) \right]^{2}.$$
(9)

 $\chi^2_{log}$  is more effective to check the trend of fusion cross sections at sub-barrier energies. In this work, we combine these two

quantities and use  $\bar{\chi} = (\chi_{pt}^2 + \chi_{\log}^2)^{1/2}$  to search for the best-fit parameters.

Figs. 3 and 4 show the fusion excitation functions and barrier distributions for <sup>32</sup>S+<sup>96</sup>Zr, <sup>36</sup>S+<sup>110</sup>Pd, <sup>58</sup>Ni+<sup>54</sup>Fe and <sup>58</sup>Ni+<sup>60</sup>Ni reactions. We note that introducing the energy dependence of barrier radius, the experimental data can be much better reproduced, especially for the fusion cross sections at deep sub-barrier energies. With the MSW formula, both  $\chi^2_{pt}$  and  $\chi^2_{log}$  are significantly smaller than those with the SW formula. In addition, the barrier distributions are also studied to check the details in reproducing the fusion excitation functions. The distributions are extracted from the experimental excitation functions using the point-difference



Fig. 4. (Color online) The same as Fig. 3, but for  ${}^{58}Ni+{}^{54}Fe$  and  ${}^{58}Ni+{}^{60}Ni$ . *Source:* The experimental data are taken from [40,41].

approximation [26] according to Eq. (4),

$$\frac{d^2 (E\sigma_{\rm fus})}{dE^2} \approx \frac{2E\sigma_{\rm fus}(E) - E\sigma_{\rm fus}(E + \Delta E) - E\sigma_{\rm fus}(E - \Delta E)}{(\Delta E)^2}, \quad (10)$$

with an energy step  $\Delta E = 2.5$  MeV. From (a2) and (b2) in Figs. 3 and 4, one can see that with energy dependence of  $R_B$ , the left shoulders in the barrier distributions for these four systems can be evidently observed in the MSW calculations, although the single-Gaussian function is adopted in Eq. (3).

#### 4. Extracted barrier parameters

Up to now, a large number of fusion excitation functions have been measured in the past several decades. Most of data for the fusion cross sections including fusion-fission and evaporation residue obtained from the tables or the graphs of the corresponding publications, are collected in the NRV website [42]. In this work, we use a similar procedure as adopted in Ref. [18] to select the experimental fusion data. In addition to the data in the NRV website, some fusion excitation functions measured in very recent vears are also collected in this work. One usually defines the fusion cross section  $\sigma_{\rm fus}$  as a sum of evaporation residue cross section  $\sigma_{\text{EvR}}$  and fission cross section  $\sigma_{\text{FF}}$ . For light and intermediate mass systems, it is thought that  $\sigma_{\rm fus} \simeq \sigma_{\rm EvR}$ , since the fission barrier of the compound nuclei is high enough and the fission cross sections could be negligible. For heavy systems, e.g. the reactions leading to lanthanides or heavier nuclei, the contribution of fission cannot be ignored, the fission cross sections need to be included in  $\sigma_{fus}$ . For fusion reactions leading to actinides, the evaporation residue cross sections are relatively small and the fission cross sections play a dominant role in the extraction of the fusion barrier. For fusion reactions leading to super-heavy

nuclei, the evaporation residues become negligible and the quasifission cross sections are dominant in the total capture cross sections with which the Coulomb barrier can be extracted. For some systems with the same projectile-target combination, the data from different experimental groups are slightly different and the fusion barrier is separately analyzed and presented in this work.

Firstly, we analyze the 29 fusion reaction systems mentioned in Ref. [17], where Jiang et al. systematically analyzed the fusion cross sections for the 29 systems by using the SW formula. In Fig. 5, we compare the results from the SW formula and those from the MSW formula proposed in this work. From Fig. 5(a), one notes that for most of reactions, the  $\chi^2_{pt}$  values with the MSW formula are much smaller than those with SW formula, since one more parameter  $\Delta R$  is involved. For the lightest system <sup>16</sup>O+<sup>18</sup>O, the obtained barrier parameters from the two formulas are very close to each other, although the obtained  $\chi^2_{pt}$  in this work is larger than that in Ref. [17]. The obtained barrier heights from the two formulas are in good agreement with each other. The discrepancies in *W* and  $R_0$  are within 25%, which indicates that the introduction of the correction factor  $\Delta R$  in the MSW formula influences *W* and  $R_0$  relatively larger than  $V_B$ .

Then, we systematically analyze a total of 443 datasets of measured fusion (and/or fission) cross sections for 367 different projectile-target combinations by using the MSW formula. The values of  $\bar{\chi}$  corresponding to the best-fit parameters for all considered systems are simultaneously obtained. In Fig. 6, we show the distribution for the relative deviation of  $\bar{\chi}$  between the results of MSW and those of SW, i.e.,  $(\bar{\chi}^{SW} - \bar{\chi}^{MSW})/\bar{\chi}^{SW}$ . We find that for 173 datasets, the relative deviation  $\Delta \bar{\chi}/\bar{\chi}$  is smaller than 0.1%. For 122 datasets, the improvement is larger than 10% and for 148 datasets the values of  $\Delta \bar{\chi}/\bar{\chi}$  are located in the region of 0.1%–10%. It indicates that the measured fusion excitation



**Fig. 5.** (Color online) Ratios between the extracted barrier parameters in this work and those in Ref. [17].  $\chi_g^2$ ,  $V_g$ ,  $W_g$  and  $R_g$  denote the obtained  $\chi_{pt}^2$ , the barrier height, the standard deviation and the barrier radius in Ref. [17], respectively.



**Fig. 6.** (Color online) Distribution of the relative improvement in  $\bar{\chi}$  by using MSW comparing with SW.

functions for about 60% reactions can be better reproduced by introducing the energy dependence of barrier radius into the SW formula. The extracted barrier parameters and the references for these systems are listed in Table A.

For studying the fusion of heavy nuclei, one usually introduces a parameter to describe the fissility of the reaction system. The effective fissility parameter is defined as,

$$x_{\rm eff} = \frac{(Z^2/A)_{\rm eff}}{(Z^2/A)_{\rm thr}},$$
(11)

with the effective fissility

$$(Z^2/A)_{\rm eff} = \frac{4Z_1Z_2}{A_1^{1/3}A_2^{1/3}(A_1^{1/3} + A_2^{1/3})}$$
(12)

and the threshold [43] for the effective fissility  $(Z^2/A)_{\text{thr}} \approx 33$ , beyond which an extra push is needed to achieve fusion.  $Z_1$  and  $Z_2$  in Eq. (12) denote the charge numbers of the projectile and target nuclei, respectively.

Based on the extracted barrier height  $V_B$ , the radius of the corresponding Coulomb potential  $R_{\text{Coul}} = Z_1 Z_2 e^2 / V_B$  is systematically analyzed. In Fig. 7(a), we show the extracted radius parameter  $R_{\text{Coul}}$ . The decreasing trend of the radius parameter  $R_{\text{Coul}}/(A_1^{1/3} + A_2^{1/3})$  with the effective fissility parameter  $x_{\text{eff}}$  can be evidently observed. To understand the physics behind, we also show in Fig. 7(b) the reduced de Broglie wavelength  $\lambda_B = \hbar/\sqrt{2\mu V_B}$  of the colliding nuclei at an incident energy of  $E = V_B$ .  $\mu$  is the reduced mass of the reaction system. One can see that  $\lambda_B$  approaches to zero with the increase of  $x_{\text{eff}}$ , which indicates that the influence of



**Fig. 7.** (Color online) (a) Extracted radius parameter for the Coulomb potential as a function of the effective fissility parameter  $x_{\text{eff}}$ . The open circles and the crosses denote the data based on the extracted barrier heights and the calculated results by using Eq. (13), respectively. (b) Reduced de Broglie wavelength  $\lambda_B$  of the colliding nuclei at an incident energy of  $E = V_B$ .

de Broglie wavelength is negligible for heavy fusion systems. It is known that the capture cross section  $\sigma_{cap} \propto \pi (R+\lambda)^2$  considering the wave properties of incident particles. For heavy fusion system  $\lambda$  is very small and consequently one obtains the traditional geometry cross section  $\propto \pi R^2$ . For very light fusion systems (with smaller values of  $x_{eff}$ ) and thermal neutron induced capture cross sections, the contribution of  $\lambda$  needs to be considered.

To describe the radius of the Coulomb potential  $R_{Coul}$ , we consider both the influence of the geometry radii of nuclei and that of the wave properties of particles. We write  $R_{Coul}$  as a sum of the charge radii of projectile and target nuclei, a parameter d = 1.75 fm which is related to the interaction range, and as well as the reduced de Broglie wavelength,

$$R_{\text{Coul}} = R_1^{\mathsf{C}} + R_2^{\mathsf{C}} + 1.75 + \lambda_B. \tag{13}$$

The charge radius  $R^C \simeq \sqrt{\frac{5}{3}}r_{ch}$  of a nucleus neglecting its deformations is taken from the root-mean-square (rms) charge radius  $r_{ch}$  which can be measured with high precision [44–46]. In the calculations, the reduced de Broglie wavelength  $\lambda_B = \hbar/\sqrt{2\mu V_B}$  can be obtained by using an iterative procedure with an initial value of  $V_B \approx Z_1 Z_2 e^2/(R_1^C + R_2^C + 1.75)$ . The calculated results of  $R_{Coul}$  are also shown in Fig. 7(a) for comparison. One sees that the extracted radius parameter can be well reproduced. It indicates that the decreasing trend of the barrier radius parameter could have a relationship with the de Broglie wavelength of the colliding nuclei. With only one parameter in Eq. (13), the extracted barrier heights can be well reproduced by using

$$V_B = Z_1 Z_2 e^2 / R_{\text{Coul}},\tag{14}$$

with an rms deviation of only 1.52 MeV for all considered reactions. The relative deviation  $\Delta V_B = (V_B^{exp} - V_B^{th})/V_B^{exp}$  between data and model predictions is also calculated, the corresponding rms error is 2.83% with Eq. (14) for calculating  $V_B^{th}$ , which is much smaller than the corresponding value of 4.29% from the threeparameter WKJ formula in Ref. [47] and slightly smaller than that of 2.84% from the two-parameter MCW formula in Ref. [18]. The systematics of the extracted barrier radius  $R_0$  and that of the standard deviation of the Gaussian function W are investigated simultaneously. In Fig. 8, we show the extracted barrier radius parameters  $R_0/(A_1^{1/3} + A_2^{1/3})$  and the value  $W/V_B$  as functions of the effective fissility parameter  $x_{\text{eff}}$ . We note that the extracted barrier radius parameter linearly decreases with the effective fissility parameter, and the decreasing trend of  $W/V_B$  is very similar to that of  $\lambda_B$  in Fig. 7(b). We therefore propose two formulas,

$$R_0 = (1.62 - 0.57x_{\rm eff})(A_1^{1/3} + A_2^{1/3})$$
(15)

and

$$W = (0.014 + 0.135\lambda_B)V_B, \tag{16}$$

for describing  $R_0$  and W, respectively. The similar trends for the barrier radius and the distribution width are also observed in Ref. [17]. In addition to the influence of wave properties of reaction partners, the systematic decreasing trend of the barrier radius  $R_0$  could also be due to the influence of quasi-fission of reaction systems, since the quasi-fission cross sections are not involved in the present analysis. The contribution of quasi-fission to the total capture cross sections may increase with  $x_{\text{eff}}$ . It is thought that the influence of quasi-fission becomes evident and an extra push is needed to achieve fusion for the systems with  $x_{\text{eff}} > 1$  [43,48]. The systematics of the correction factor  $\Delta R$  is unclear at the moment. The shell effects of reaction systems and the change of Q value due to nucleon transfer should be further investigated to explore the systematics of  $\Delta R$ .

For fusion reactions with  $\Delta R = 0$  listed in Table A, we systematically analyze the experimental data. Simultaneously, the fusion cross sections for these systems are also calculated for comparison by using the SW formula with Eqs. (14)–(16) for calculating  $V_B$ ,  $R_0$  and W. In Fig. 9, the measured cross sections scaled by  $\pi R_0^2$  are shown as a function of X. We note that the cross sections for different reactions have a quite similar trend at sub-barrier and over-barrier energies. The experimental data can be reasonably well reproduced by the SW formula together with the proposed barrier parameter formulas.



**Fig. 8.** (Color online) (a) Extracted barrier radius parameters as a function of the effective fissility parameter  $x_{eff}$ . The line denotes a linear fit to the extracted results. (b) Standard deviation of the Gaussian function *W* divided by the corresponding barrier height  $V_B$  as a function of  $x_{eff}$ . The circles denote the extracted results and the squares denote the predictions with Eq. (16).



**Fig. 9.** (Color online) Measured cross sections for reactions with  $\Delta R = 0$  as a function of  $X = \frac{E - V_B}{\sqrt{2W}}$ . Here, the cross sections are scaled by  $\pi R_0^2$ . Eqs. (14)-(16) are used in the calculations of  $V_B$ ,  $R_0$  and W, respectively. Squares denote the model predictions from the SW formula.

#### 5. Summary

A total of 443 datasets of measured fusion (and/or fission) excitation functions for 367 different projectile–target combinations, are systematically analyzed by using a new fusion cross section formula, in which the energy-dependent barrier radius  $R_B$  is introduced into the Siwek–Wilczyński formula. We find that the fusion excitation functions for about 60% reaction systems can be better described by considering the energy dependence of  $R_B$ . The energy dependence of barrier radius can also be clearly observed from the time-dependent Hartree–Fock (TDHF) calculations, which is due to the dynamical effects at energies around

the Coulomb barrier. With the energy dependence of  $R_B$ , the barrier distributions based on the double-differentiation process can be better reproduced for some systems, especially the left shoulder in the distribution. Considering both the influence of the geometry radii and that of the wave properties of the colliding nuclei, the barrier height  $V_B$  can be well reproduced with only one model parameter. We also note that the extracted barrier radius parameters linearly decrease with the effective fissility parameter, from about 1.6 fm for very light reaction systems to about 1.0 fm for heavy systems in which quasi-fission could occur. It seems that the width of the barrier distribution relates to the barrier height, as well as the reduced de Broglie wavelength of the colliding nuclei at energies around the Coulomb barrier.

#### Table A

Extracted barrier parameters based on 443 datasets of measured cross sections together with the MSW formula.  $V_B$  and W denote the centroid and the standard deviation of the Gaussian function for barrier distribution, respectively.  $R_0$  denotes the traditional barrier radius.  $\Delta R$  denotes the correction factor for the barrier radius.  $\chi^2_{pt}$  denotes the  $\chi^2$  per energy point, and  $\chi^2_{log}$  denotes the mean-square deviation between data and predictions in logarithmic scale. EvR and FF are cross sections for fusion–evaporation residues and fusion–fission, respectively.

Reaction	$V_B$ (MeV)	W (MeV)	$R_0$ (fm)	$\Delta R$ (fm)	$\chi^2_{pt}$	$\chi^2_{log}(\times 100)$	Туре	Ref.
<sup>4</sup> He+ <sup>93</sup> Nb	11.74	1.00	9.38	0.350	0.609	0.666	EvR	[49]
<sup>4</sup> He+ <sup>154</sup> Sm	15.29	0.39	9.77	3.744	0.393	0.398	EvR	[50]
<sup>4</sup> He+ <sup>233</sup> U	22.63	1.67	11.83	0.244	5.418	14.639	FF	[51]
<sup>4</sup> He+ <sup>235</sup> U	23.28	2.06	10.49	0.003	0.041	0.042	FF	[52]
<sup>4</sup> He+ <sup>236</sup> U	22.25	1.59	10.55	0	0.169	0.124	FF	[53]
<sup>4</sup> He+ <sup>238</sup> U	22.90	1.67	12.57	0.242	4.341	9.856	FF	[51]
<sup>4</sup> He+ <sup>238</sup> U	23.00	2.02	10.04	0.001	0.024	0.024	FF	[54]
<sup>4</sup> He+ <sup>237</sup> Np	21.12	0.64	9.39	2.391	0.810	0.877	EvR+FF	[55]
<sup>6</sup> He+ <sup>64</sup> Zn	9.86	2.06	8.14	0	0.015	0.083	EvR	56
<sup>6</sup> He+ <sup>209</sup> Bi	19.57	2.23	9.67	0	0.496	0.457	EvR	[57]
<sup>8</sup> He+ <sup>197</sup> Au	19.61	1.95	11.41	0	0.196	0.331	EvR	58
<sup>6</sup> Li+ <sup>64</sup> Ni	11.82	1.24	8.57	0	0.089	0.165	EvR	[59]
<sup>6</sup> Li+ <sup>64</sup> Zn	12.68	1.63	8.75	0.161	0.392	1.802	EvR	[60]
<sup>6</sup> Li+ <sup>90</sup> Zr	17.45	1.05	8.17	2.478	1.351	1.180	EvR	[61]
<sup>6</sup> Li+ <sup>144</sup> Sm	25.02	1.66	7.70	0.145	0.931	4.811	EvR	[62]
<sup>6</sup> Li+ <sup>152</sup> Sm	24.47	1.95	8.26	0	0.890	0.301	EvR	[63]
<sup>6</sup> Li+ <sup>159</sup> Tb	24.27	2.01	8.08	0.189	0.433	0.353	EvR	[64]
<sup>6</sup> Li+ <sup>198</sup> Pt	28.69	1.82	8.45	0.192	0.426	2.926	EvR	[65]
<sup>6</sup> Li+ <sup>197</sup> Au	27.79	1.54	7.51	0	0.557	1.470	EvR	66
<sup>6</sup> Li+ <sup>209</sup> Bi	29.87	1.84	8.71	0.104	0.168	0.451	EvR+FF	[67]
<sup>6</sup> Li+ <sup>232</sup> Th	31.61	2.76	11.28	0.156	0.206	0.532	FF	[68]
<sup>6</sup> Li+ <sup>238</sup> U	30.93	2.62	10.33	0.081	0.685	1.760	FF	[68]
<sup>7</sup> Li+ <sup>16</sup> O	4.31	0.89	8.99	0.029	0.677	0.669	EvR	[69]
<sup>7</sup> Li+ <sup>28</sup> Si	6.98	0.78	7.79	0	0.596	0.646	EvR	70
<sup>7</sup> Li+ <sup>59</sup> Co	11.77	1.40	7.86	0	0.271	0.268	EvR	[71]
<sup>7</sup> Li+ <sup>64</sup> Zn	12.60	1.26	9.09	0.181	0.644	4.213	EvR	[60]
<sup>7</sup> Li+ <sup>144</sup> Sm	24.66	1.33	8.55	1.123	0.308	0.115	EvR	[72]
<sup>7</sup> Li+ <sup>152</sup> Sm	24.23	1.96	8.61	0	1.176	0.555	EvR	[72]
<sup>7</sup> Li+ <sup>159</sup> Tb	23.06	1.51	10.31	0.280	1.044	4.231	EvR	[73]
<sup>7</sup> Li+ <sup>198</sup> Pt	28.06	1.66	9.52	0	0.108	0.363	EvR	[74]
<sup>7</sup> Li+ <sup>197</sup> Au	28.79	1.80	10.32	0	0.019	0.044	EvR	[66]
<sup>7</sup> Li+ <sup>209</sup> Bi	29.69	1.69	9.86	0.149	0.302	1.279	EvR+FF	[75]
<sup>7</sup> Li+ <sup>209</sup> Bi	29.53	1.67	9.58	0.188	0.056	0.072	EvR+FF	[67]
<sup>7</sup> Li+ <sup>232</sup> Th	31.12	2.12	11.00	0.120	0.366	6.620	FF	[68]
<sup>7</sup> Li+ <sup>235</sup> U	31.59	2.13	12.23	0.337	0.354	0.136	FF	[76]
<sup>7</sup> Li+ <sup>238</sup> U	31.20	2.12	11.02	0.138	2.202	6.573	FF	[68]
<sup>7</sup> Be+ <sup>58</sup> Ni	16.27	2.07	9.33	0	0.005	0.040	EvR	[77]
<sup>7</sup> Be+ <sup>238</sup> U	43.15	1.72	9.51	0.409	0.305	28.512	FF	[78]
<sup>9</sup> Be+ <sup>89</sup> Y	21.00	1.25	8.34	0.111	3.127	1.782	EvR	[49]
<sup>9</sup> Be+ <sup>124</sup> Sn	26.05	2.10	8.88	0	1.148	0.152	EvR	[79]
<sup>9</sup> Be+ <sup>144</sup> Sm	31.45	1.56	10.03	0	0.145	0.711	EvR	[ <mark>80</mark> ]
<sup>9</sup> Be+ <sup>169</sup> Tm	34.71	1.18	9.87	2.380	0.777	0.490	EvR	[81]
<sup>9</sup> Be+ <sup>181</sup> Ta	35.95	2.01	9.09	0.466	0.471	0.193	EvR	[82]
<sup>9</sup> Be+ <sup>187</sup> Re	37.01	2.08	9.92	0	0.346	0.439	EvR	[81]
<sup>9</sup> Be+ <sup>208</sup> Pb	38.32	1.77	9.31	0	1.146	0.803	EvR+FF	[83]
<sup>9</sup> Be+ <sup>209</sup> Bi	38.14	1.58	9.82	0.050	0.179	0.175	EvR	[84]
<sup>9</sup> Be+ <sup>209</sup> Bi	38.15	1.56	10.01	0.107	0.199	0.466	EvR	[85]
<sup>9</sup> Be+ <sup>209</sup> Bi	37.66	0.91	9.02	2.011	0.045	0.037	EvR	[86]
<sup>10</sup> B+ <sup>159</sup> Tb	39.23	1.15	9.46	3.048	0.071	0.172	EvR	[87]
<sup>11</sup> B+ <sup>13</sup> C	4.94	0.52	7.98	0.895	0.182	0.460	EvR	[88]
<sup>11</sup> B+ <sup>159</sup> Tb	39.41	2.20	10.31	0	0.039	0.171	EvR	[87]
<sup>11</sup> B+ <sup>238</sup> U	49.66	1.64	11.34	0.333	0.181	0.719	FF	[89]
<sup>11</sup> B+ <sup>237</sup> Np	54.84	2.79	11.80	0	0.312	1.132	FF	[89]
<sup>12</sup> C+ <sup>9</sup> Be	3.86	0.63	7.12	0	0.237	1.023	EvR	[90]
<sup>12</sup> C+ <sup>11</sup> B	4.79	0.50	5.45	0.657	0.303	0.752	EvR	[91]
<sup>12</sup> C+ <sup>11</sup> B	4.88	0.50	6.30	0.880	1.386	0.920	EvR	[92]
<sup>12</sup> C+ <sup>13</sup> C	5.63	0.52	6.82	0.558	0.495	0.688	EvR	[92]
$^{12}C+^{14}C$	5.49	0.39	6.24	0	0.002	0.006	EvR	93
<sup>12</sup> C+ <sup>14</sup> N	6.90	0.64	7.64	0.646	0.424	0.424	EvR	[92]
<sup>12</sup> C+ <sup>20</sup> Ne	9.80	0.88	7.66	0.170	1.405	1.692	EVR	[94]
<sup>12</sup> C+ <sup>40</sup> Ti <sup>12</sup> a <sup>48</sup> Ti	21.31	1.58	9.82	0.118	0.222	0.911	EVR	[95]
<sup>12</sup> C+ <sup>40</sup> Ti	20.40	1.53	8.29	0	0.486	0.728	EVR	[95]
<sup>12</sup> C+ <sup>30</sup> Ti	19.72	1.20	8.12	0.296	0.167	0.409	EVR	[95]
<sup>12</sup> C+ <sup>09</sup> Y	32.17	1.50	10.50	0.202	0.256	0.830	EVR	[49]
<sup>12</sup> C+ <sup>32</sup> Zr	31.82	1.25	9.13	U 0.107	3.264	13.703	EVK	[96]
<sup>12</sup> C+ <sup>13</sup> Sm	46.83	1.54	11.63	0.127	0.501	1.100	EVK	[97]
12 c+ 154 c	4/.22	2.09	11.20	2.101	0.043	0.024	EVK	[73]
<sup>12</sup> C+ <sup>13</sup> Sm	44.54	0.84	9.40	1.831	U.144	0.302	EVK	[50]
"C+"" la	52.43	2.07	10.66	U	0.211	0.216	EVK	[98]

# Table A (continued).

Table A (continued	1).							
<sup>12</sup> C+ <sup>194</sup> Pt	54 91	1 5 2	10 34	0 127	1 1 1 5	0 363	FvR+FF	[99]
12 C + 198 D+	55.37	1.52	10.54	0.127	2.152	0.000	EVIC II	[00]
12 PC	55.27	1.55	10.62	0.101	2.152	0.222	EVK+FF	[99]
<sup>12</sup> C+ <sup>204</sup> Pb	55.99	1.04	11.23	0.190	0.482	2.494	EvR+FF	[100]
$^{12}C + ^{208}Ph$	56 34	126	10 59	0	1 329	0.091	FvR+FF	[101]
12 C + 237 Nm	62.00	2.50	10.55	0	0.220	1.050	EVIC	[00]
C+Np	62.96	2.52	10.51	0	0.326	1.852	FF	[89]
<sup>13</sup> C+ <sup>10</sup> B	4.94	0.63	7.67	0	0.124	0.190	EvR	[88]
$^{13}C + ^{11}B$	5.02	0 54	8 44	0.864	0 200	0.212	FvR	1881
13 C + 13 C	5.02	0.51	0.00	0.001	24.250	0.212	Evit.	[102]
······································	5.98	0.64	8.08	0.335	34.259	0.956	EVK	[102]
<sup>13</sup> C+ <sup>48</sup> Ti	20.50	2.45	8.64	0	0.074	0.190	EvR	[103]
$^{13}C + ^{232}Th$	61.68	2 20	12 75	2 002	0 198	0.036	FF	104
14 10 0	5 70	2.20	12.75	2.002	0.150	0.050		[104]
14N+10B	5.72	0.65	7.79	0.153	0.180	1.105	EVR	[105]
<sup>14</sup> N+ <sup>12</sup> C	6.90	0.64	7.64	0.648	0.430	0.430	EvR	[106]
$^{14}N + ^{14}N$	7 5 5	0.74	6 10	0	0.024	0.042	EvR	[107]
14 14	7.55	0.74	0.10	0	0.024	0.042		[107]
<sup>14</sup> N+ <sup>14</sup> N	8.25	0.81	8.12	0.181	2.372	1.327	EvR	[108]
<sup>14</sup> N+ <sup>14</sup> N	8.23	0.80	8.11	0.196	1.537	1.370	EvR	[92]
14N+16O	0.22	0.02	0 70	0.100	0.221	0.220	Evp	[02]
14 50 J	9.25	0.85	8.70	0.199	0.221	0.228	EVK	[92]
<sup>14</sup> N+ <sup>59</sup> Co	26.81	1.41	9.46	0.367	0.282	0.509	EvR	[109]
<sup>14</sup> N+ <sup>232</sup> Th	70.99	2.03	12.13	1.933	0 185	0.163	FF	[110]
15 1.54 5-	26.10	1.01	10.04	0	0.554	0.053	ГD	[110]
<sup>15</sup> N+ <sup>5</sup> Fe	26.19	1.81	10.04	0	0.554	0.952	EVR	
<sup>15</sup> N+ <sup>209</sup> Bi	66.53	1.58	10.90	0	0.159	1.595	FF	[112]
$^{16}O + ^{12}C$	7 7 2	0.67	7.81	0 543	4 989	1 782	EVR	1113
160.130	7.72	0.07	7.01	0.545	4.505	1.702	EVR	[115]
100+13C	7.80	0.80	7.29	0	0.344	0.590	EVR	[114]
<sup>16</sup> O+ <sup>14</sup> N	9.16	0.82	8.25	0.176	0.259	0.268	EvR	[106]
$^{16}O + ^{16}O$	10 34	0 02	8 50	0.146	0.253	0.250	EvP	1115
160,160	10.04	0.52	0.00	0.140	0.235	0.200	EVIN	
100+100	10.32	0.95	9.09	0	0.229	0.638	EVR	[116]
<sup>16</sup> O+ <sup>27</sup> Al	15.76	1.19	7.41	0	0.015	0.077	EvR	[117]
16 Ou 46 T:	20.70	1 40	0.00	0 450	0.071	0.076	Evn	[110]
10+11	26.21	1.40	8.92	0.459	0.071	0.076	EVK	[118]
<sup>16</sup> O+ <sup>50</sup> Ti	26.06	1.65	8.28	0.050	0.222	1.031	EvR	[109]
<sup>16</sup> O+ <sup>50</sup> Ti	25.98	1 5 5	9.12	0 125	0.075	0.445	EvR	[118]
160.545	20.00	1.55	5.12	0.125	0.075	0.445	EVR	
<sup>10</sup> O+ <sup>34</sup> Fe	30.29	1.46	8.76	0.404	0.340	0.693	EVR	
<sup>16</sup> O+ <sup>56</sup> Fe	30.24	1.05	9.13	3.085	0.445	0.330	EvR	[111]
16 O+ 58 NG	21.22	1.07	0.22	0 129	1 260	1 5 5 6	Evp	[110]
16 a. 62 a.u	51.52	1.07	5.55	0.120	1.200	1.550	LVK	[119]
<sup>10</sup> O+ <sup>62</sup> Ni	30.54	1.04	8.93	0.179	1.265	0.472	EvR	[119]
<sup>16</sup> O+ <sup>63</sup> Cu	34.88	2.77	9.20	0	0 391	0.390	EvR	[120]
160+630	25.22	2.00	0.44	ů 0	0.624	0 5 1 9	Evp	[120]
0+°Cu	55.52	2.69	9.44	0	0.034	0.518	EVK	
<sup>16</sup> O+ <sup>63</sup> Cu	33.07	1.03	8.95	1.402	0.115	0.003	EvR	[122]
$^{16}O+^{65}Cu$	33.68	2.86	8 97	0	0 302	0 358	FvR	[120]
160,647	22.00	2.00	10.22	0	0.302	0.550	Evit	[120]
100+01Zh	33.00	2.54	10.32	0	0.230	0.265	EVK	[123]
<sup>16</sup> O+ <sup>70</sup> Ge	34.76	1.45	9.75	0	0.955	0.189	EvR	[124]
<sup>16</sup> O+ <sup>72</sup> Ce	35.62	1 79	10.03	0	1 700	0 370	EvR	124
160.736	55.02	1.75	10.05	0	1.700	0.570	EVR	
100+73Ge	33.98	1.01	8.31	1.880	0.064	0.034	EVR	[124]
<sup>16</sup> O+ <sup>74</sup> Ge	34.89	1.16	9.66	2.095	1.729	0.631	EvR	[124]
160+76Ca	34.05	1 1 2	0.42	1 066	0.775	0.612	Evp	[125]
16 a 76 a	54.95	1.12	9.45	1.900	5.775	0.012	LVK	[12]
<sup>10</sup> O+ <sup>70</sup> Ge	34.50	1.13	9.55	1.624	1.188	0.279	EvR	[124]
$^{16}O + ^{92}Zr$	41 47	1.58	9.56	0	3 6 3 3	1.394	EvR	[96]
160+112Cd	10 10	1.66	11.02	ů 0	0.414	1 001	Evp	[106]
0+ Cu	40.20	1.00	11.02	0	0.414	1.891	EVK	[120]
<sup>16</sup> O+ <sup>112</sup> Sn	50.61	1.38	9.81	0.127	0.811	19.177	EvR	[127]
<sup>16</sup> O+ <sup>116</sup> Sn	50.20	1.39	9 96	0.155	0 793	3,315	EvR	[127]
16 O + 144 N d	57.21	1.50	11 10	0	0.042	0.145	Evp	[100]
16 150	57.51	1.55	11.12	U	0.042	0.145	LVK	[128]
100+150Nd	57.04	1.67	9.25	0	0.555	0.120	EvR	[73]
<sup>16</sup> O+ <sup>144</sup> Sm	60.51	1.59	10.34	0	21,851	4.572	EvR	[129]
160+1475-	FOOA	1 4 4	0.01	0	0 707	1 = = 4	Evn	[120]
0T 5111	30.04	1.44	9.01	U	0.797	1.554	EVK	[130]
10O+148Sm	59.73	1.75	10.51	1.158	9.033	1.269	EvR	[129]
<sup>16</sup> O+ <sup>148</sup> Sm	59.74	2.07	11.26	0	0.215	0.384	EvR	[130]
160+1480-	E0.1E	1 00	0.70	0	0.154	0.154	Evn	[101]
07 SIII	59.15	1.00	9.13	U	0.134	0.154	EVK	[131]
10O+149Sm	58.95	1.88	9.97	0	0.523	1.714	EvR	[130]
<sup>16</sup> O+ <sup>150</sup> Sm	59.20	1.67	10.64	1.481	0.099	0.098	EvR	[131]
16 O+ 152 cm	50.20	1.07	10.95	2 107	0.216	0.204	EvP	[121]
16 - 15 4 C	79.67	1.80	10.80	2.197	0.210	0.204	EVK	[131]
100+154Sm	58.90	2.53	10.13	0	0.039	0.037	EvR	[131]
<sup>16</sup> O+ <sup>154</sup> Sm	59.03	2.80	10.30	0	0.095	0.024	EvR	[132]
16 O+ 154 cm	E0 20	1.00	10 16	1 = 1 2	2 200	1 700	EvD	[100]
UT 154	39.20	1.99	10.40	1.545	3.208	1./85	LVK	[129]
<sup>10</sup> O+ <sup>154</sup> Sm	59.21	1.84	10.20	1.992	3.395	2.101	EvR	[133]
<sup>16</sup> O+ <sup>166</sup> Fr	63 66	1 48	10.29	2,643	0.673	1,126	EvR	[134]
160+174vb	CC E2	2.10	10.23	0.110	0.070	1.120	Evn	[105]
10+***YD	00.52	2.59	10.93	0.119	0.039	1.529	EVK	[135]
<sup>16</sup> O+ <sup>176</sup> Yb	66.79	2.94	9.75	0.100	1.420	4.830	EvR	[135]
<sup>16</sup> O+ <sup>186</sup> W	68.31	2.29	10 44	0	6 333	1.323	EvR+FF	136
160, 186147	CO 10	2.23	10.11	0 100	0.000	1.525	EvDIPE	[107]
**U+***W	68.18	2.13	10.38	0.106	0.383	1.8/4	EVK+FF	[137]
<sup>16</sup> O+ <sup>194</sup> Pt	72.60	2.18	11.73	0.003	0.028	0.047	EvR+FF	[138,139]
16 O+208 ph	73 70	1 20	10.62	1 877	20 220	0.080	FvP+FF	[32]
16 o. 209 pr	13.13	1.20	10.02	1.0//	23.330	0.005		
100+200 Pb	74.13	1.23	10.59	2.135	0.097	0.151	EVR+FF	[112]
<sup>16</sup> O+ <sup>209</sup> Bi	75.03	1.21	10.75	2.245	0.088	0.138	FF	[112]
16 O+209 D;	77 17	2 / 2	10.11	0.210	1 072	2 207	FC	[140]
UT DI	//.1/	2.45	10.11	0.219	1.925	2.397	rr	[140]
1/ 0+12C	7.66	0.70	7.27	0.208	0.111	0.065	EvR	[141]
<sup>17</sup> O+ <sup>12</sup> C	9.50	0.83	11.51	3.671	1.253	2.932	EvR	[142]
170+130	7 00	0.00	C 0 1	0.000	0.275	0.422	EvP	[1/2]
	7.00	0.05	0.01	0.000	0.275	0.452	EVIX	[142]

Table A (continued).

Table A (continued).								
<sup>17</sup> 0+ <sup>16</sup> 0	10.08	0.93	9.11	0.143	0.628	11.320	EvR	[116]
<sup>17</sup> O+ <sup>144</sup> Sm	60.25	1.86	10.42	0	5.928	4.610	EvR	[129]
<sup>18</sup> O+ <sup>9</sup> Be	4 96	0 49	6.57	0.858	0.090	1,765	EvR	143
<sup>18</sup> O+ <sup>12</sup> C	7.42	0.15	7.24	2 401	0.050	0.028	EVR	[1/1]
180,120	7.45	0.33	7.34	2.401	0.032	0.028	EVR	[141]
18 2 16 2	7.71	0.87	7.42	0	0.008	0.729	EVK	[144]
180+100	9.90	0.85	8.07	0.153	0.419	0.769	EVR	[116]
<sup>18</sup> O+ <sup>44</sup> Ca	22.44	1.37	8.35	0.027	0.230	0.643	EvR	[95]
<sup>18</sup> O+ <sup>58</sup> Ni	31.68	2.85	8.02	0	2.540	0.995	EvR	[145]
<sup>18</sup> O+ <sup>60</sup> Ni	33.77	2.72	10.70	0	1 474	1 493	EvR	[146]
<sup>18</sup> O+ <sup>64</sup> Ni	33.70	2.36	9.77	0	0.456	0.488	EVR	[1/6]
180.630	24.22	2.00	10.00	0 5 1 2	0.220	0.400	EVR E-D	[120]
18 - 74 -	34.32	2.30	10.09	0.513	0.229	0.186	EVK	[120]
<sup>18</sup> 0+/4Ge	34.31	1.09	9.23	2.076	32.807	0.795	EVR	[125]
<sup>18</sup> O+ <sup>148</sup> Nd	58.21	2.95	9.13	0	0.088	0.101	EvR	[73]
<sup>18</sup> O+ <sup>208</sup> Pb	74.14	1.33	10.79	2.562	0.175	0.290	FF	[112]
<sup>19</sup> F+ <sup>54</sup> Fe	33.87	3.14	9.50	0	0.334	0.564	EvR	i111i
19 E+56 Ee	33.00	273	9.10	0	0.611	0.852	EVP	[111]
19 E 193 NIL	JJ.00	2.75	0.00	0	0.011	0.032	EVR	[11]
10 - 181 -	47.00	2.51	9.98	0	0.905	0.217	EVK	[147]
<sup>19</sup> F+ <sup>181</sup> Ta	76.22	2.90	10.96	0.954	0.149	0.031	EVR+FF	[148]
<sup>19</sup> F+ <sup>188</sup> Os	78.21	2.96	10.34	0	0.208	0.259	EvR+FF	[149]
<sup>19</sup> F+ <sup>192</sup> Os	78.80	2.11	10.31	3.142	0.028	0.028	EvR+FF	[149]
<sup>19</sup> F+ <sup>208</sup> Pb	82.48	2.28	10.97	0.516	12.345	0.161	EvR+FF	[150]
<sup>19</sup> F+ <sup>208</sup> Ph	83.47	271	11.22	0.275	0.211	0 294	FF	[151]
19 E + 208 Dh	03.47	2.71	12.07	0.275	0.211	2 277	FF	[151]
19 - 209	05.04	2.37	12.07	0.000	0.772	5.277	rr FF	[132]
<sup>15</sup> F+205B1	83.96	2.60	10.84	0	0.722	0.337	FF	[153]
<sup>19</sup> F+ <sup>232</sup> Th	87.85	3.90	9.91	0	0.698	0.732	FF	[154]
<sup>19</sup> F+ <sup>232</sup> Th	89.94	4.23	12.01	0	0.034	0.071	FF	[155]
<sup>19</sup> F+ <sup>232</sup> Th	90.28	4.61	13.51	0.373	1.815	6.393	FF	[156]
<sup>20</sup> Ne+ <sup>208</sup> Pb	94 52	2.16	11.22	2 121	0.600	1 025	FF	[157]
20 No 23811	102.02	5.00	11.22	0	0.000	0.022	FF	[157]
23 N 48 T	102.82	5.08	12.52	0	0.703	0.933	rr F D	[158]
<sup>23</sup> Na+ <sup>40</sup> I1	33.45	0.86	9.30	3.361	0.199	0.365	EVK	[159]
<sup>23</sup> Na+ <sup>206</sup> Pb	99.46	2.74	11.59	0.002	0.002	0.006	FF	[159]
<sup>24</sup> Mg+ <sup>24</sup> Mg	22.07	1.09	8.57	1.437	1.341	0.194	EvR	[160]
<sup>24</sup> Mg+ <sup>26</sup> Mg	20.89	1.24	8.35	0	0.376	0.047	EvR	160
<sup>24</sup> Mg+ <sup>30</sup> Si	24.10	1.06	8.07	0 107	0.260	1 108	FvR	[161]
$^{26}Mg^{+248}Cm$	129.60	5.16	14.00	0.107	0.200	1.100	EVIC	[162]
<sup>27</sup> A1: 45 C	120.00	J.10	14.05	0.015	0.045	1.212	FF D	[102]
<sup>27</sup> AI+ <sup>45</sup> SC	37.86	1.33	7.70	0.237	0.102	1.927	EVK	[163]
<sup>27</sup> Al+ <sup>70</sup> Ge	54.15	1.76	9.08	0	1.856	0.719	EvR	[164]
<sup>27</sup> Al+ <sup>72</sup> Ge	54.00	1.61	9.02	0.238	1.700	0.750	EvR	[164]
<sup>27</sup> Al+ <sup>73</sup> Ge	54.12	1.60	8.79	1.254	0.485	0.363	EvR	[164]
<sup>27</sup> Al+ <sup>74</sup> Ge	53.15	1.20	8.14	1 475	0.846	0.689	EvR	[164]
<sup>27</sup> A1+ <sup>76</sup> Co	52.17	1.20	0.11	1.175	1 0 2 9	0.005	EVR	[164]
29 41 197 4	111.00	1.55	0.07	1.220	0.000	0.428	EVK	[104]
AI+ AU	111.09	2.96	11.00	0	0.090	0.528		[165]
<sup>20</sup> S1+ <sup>24</sup> Mg	24.51	1.09	8.13	0.082	1.035	15.515	EVR	[166]
<sup>28</sup> Si+ <sup>24</sup> Mg	24.64	0.91	8.10	1.318	1.536	0.160	EvR	[160]
<sup>28</sup> Si+ <sup>26</sup> Mg	24.91	1.10	8.47	0.110	1.834	1.834	EvR	[166]
<sup>28</sup> Si+ <sup>28</sup> Si	29.03	1.63	8.26	0	2.384	0.919	EvR	1601
<sup>28</sup> Si+ <sup>28</sup> Si	20.53	1 / 1	0.12	- 0.207	0.805	25 466	EVP	[167]
286:1296:	20.00	1.41	0.12	0.207	0.005	1 100	EVR	[160]
28 ct - 30 ct	20.33	1.42	0.24	0	2.245	1.100	EVK	
20 51+50 51	28.22	1.41	8.41	0	1.645	0.270	EVK	[160]
<sup>28</sup> Si+ <sup>30</sup> Si	28.73	1.75	8.18	0	0.158	0.441	EvR	[95]
<sup>28</sup> Si+ <sup>30</sup> Si	28.19	1.13	8.02	0.120	1.054	1.217	EvR	[168]
<sup>28</sup> Si+ <sup>58</sup> Ni	53.92	1.52	9.01	0.188	3.051	8.115	EvR	[169]
<sup>28</sup> Si+ <sup>62</sup> Ni	51.33	1.22	7.86	0	0.254	2.776	EvR	[170]
<sup>28</sup> Si+ <sup>64</sup> Ni	51.33	0 99	8.51	2,686	0 167	0.910	EvR	1701
<sup>28</sup> Si+ <sup>64</sup> Ni	50.37	1 30	7 23	0.131	0.328	1643	EVP	[171]
28 c: 164 NI	50.57	1.30	7.10	0.101	0.320	0.594	EVIN	[172]
SI+* 'INI	50.72	1.23	/.18	U	0.100	0.584	EVK	[1/2]
<sup>28</sup> Si+ <sup>68</sup> Zn	53.43	1.40	7.47	0	4.352	3.577	EvR	[173]
<sup>28</sup> Si+ <sup>68</sup> Zn	53.42	1.44	7.67	0	0.350	2.250	EvR	[174]
<sup>28</sup> Si+ <sup>90</sup> Zr	72.36	2.17	10.24	0.110	0.795	1.751	EvR	[175]
<sup>28</sup> Si+ <sup>92</sup> Zr	70.23	2.47	9.63	0	5 7 3 6	0 540	EvR	[96]
$^{28}Si+^{94}7r$	69.70	1 0/	8 25	0.208	1 5 3 2	5 135	EVR	[175]
28 c: 96 7.	70.00	1.04	0.25	0.200	0.501	1 1 0	EVR E-D	[175]
28 c1 - 93 NI	70.00	1.01	J./J	2.990	0.301	1.100		[1/0]
51+ ND	/ 3.52	1.03	10.45	2.972	0.1/6	0./33	EVK	[1/7]
<sup>20</sup> Si+ <sup>94</sup> Mo	/4.20	1.26	8.03	2.142	2.164	213.559	EVR	[178]
<sup>28</sup> Si+ <sup>94</sup> Mo	75.35	1.75	8.89	1.487	0.239	1.190	EvR	[179]
<sup>28</sup> Si+ <sup>144</sup> Nd	101.95	2.64	11.94	2.348	0.421	0.244	EvR	[172]
<sup>28</sup> Si+ <sup>154</sup> Sm	101.11	485	10.58	0	1 434	2 274	EvR	1801
28 Ci+164 Er	107.01	2.50	11.66	2 5 1 6	0.028	0.051	EVDTEE	[101]
28 ci 170 c.	107.01	2.00	11.00	2.310	0.000	0.001	EVINTIT'	[101]
31+*** EI	104.15	2.09	11.31	2.909	0.032			[101]
<sup>20</sup> Si+ <sup>1/0</sup> Ht	114.59	2.98	10.75	2.453	7.061	0.197	EVR+FF	[182]
<sup>28</sup> Si+ <sup>198</sup> Pt	121.64	2.54	10.28	2.171	0.276	0.618	FF	[183]
<sup>28</sup> Si+ <sup>208</sup> Pb	126.74	2.15	10.88	3.212	0.147	0.150	FF	[184]
<sup>29</sup> Si+ <sup>178</sup> Hf	114.73	4.36	11.15	0	11.560	2.254	EvR+FF	1821
<sup>30</sup> Si+ <sup>24</sup> Mo	23.98	101	8.07	0	0 326	0.293	FvR	[166]
30 51 26 Ma	23.30	1 1 4	0.51	0 140	2 2 10	4 204	EvD	[160]
JIT IVIS	24.0/	1.14	5.51	0.140	2.310	4.394	LVK	ניטו

# Table A (continued).

Table A (continued).								
<sup>30</sup> Si+ <sup>30</sup> Si	28.10	0.91	8.60	0	0.763	1.862	EvR	[95]
<sup>30</sup> Si+ <sup>58</sup> Ni	52.74	1.44	8.70	0.277	0.220	1.676	EvR	[170]
<sup>30</sup> Si+ <sup>62</sup> Ni	51.94	1.42	9.57	0.180	0.552	7.554	EvR	[170]
30 SI+0 NI	51.29	1.31	9.45	0.190	0.404	0.902	EVK EVD+EE	[1/0]
<sup>30</sup> Si+ <sup>238</sup> U	109.34	5.40	13.12	2.020	0.087	5 5 2 3	EVNTIF FF	[140]
<sup>30</sup> Si+ <sup>238</sup> U	137.69	4.68	11.07	0	0.225	6.054	FF	[185]
<sup>31</sup> P+ <sup>175</sup> Lu	120.53	4.75	10.98	0	2.505	0.171	EvR+FF	[182]
<sup>32</sup> S+ <sup>12</sup> C	15.14	1.07	8.30	0	0.291	1.010	EvR	[187]
<sup>32</sup> S+ <sup>13</sup> C	15.78	1.29	9.55	0.077	0.276	0.743	EvR	[187]
<sup>32</sup> S+ <sup>24</sup> Mg	27.84	1.12	8.71	0.489	0.118	0.178	EvR	[188]
<sup>32</sup> S+ <sup>25</sup> Mg	27.09	1.11	8.31	0	0.256	0.378	EvR	[188]
<sup>32</sup> S+ <sup>20</sup> Mg	27.05	1.19	8.47	0	0.305	0.820	EvR	[188]
<sup>32</sup> S+ <sup>27</sup> AI	29.70	1.17 1.40	8.78	0 192	0.612	1.004	EVK	[188]
<sup>32</sup> S+ <sup>58</sup> Ni	42.J7 58.47	0.89	8.10	1 724	1 002	2 401	EVR	[100]
<sup>32</sup> S+ <sup>58</sup> Ni	59.64	1.32	8.49	0.114	0.264	1.688	EVR	[170]
<sup>32</sup> S+ <sup>58</sup> Ni	59.60	1.29	8.38	0.156	0.672	2.871	EvR	[191]
<sup>32</sup> S+ <sup>64</sup> Ni	56.74	1.03	8.38	2.005	0.314	0.154	EvR	[190]
<sup>32</sup> S+ <sup>64</sup> Ni	58.94	1.73	10.21	2.964	1.238	0.704	EvR	[173]
<sup>32</sup> S+ <sup>64</sup> Ni	59.40	2.99	11.03	0	0.239	1.661	EvR	[174]
<sup>32</sup> S+ <sup>64</sup> Ni	57.44	1.51	8.32	0.154	0.361	2.129	EvR	[191]
<sup>32</sup> S+ <sup>64</sup> Ni	57.41	1.51	8.33	0.156	0.321	2.559	EvR	[170]
<sup>32</sup> S+ <sup>69</sup> Y	76.94	1.22	9.63	2.132	9.856	2.061	EvR	[192]
<sup>32</sup> S+ <sup>30</sup> Zr <sup>32</sup> S+ <sup>94</sup> Zr	/9.3/	1.68	10.40	2.180	44.555	4.001	EVK	[37]
<sup>32</sup> S + <sup>96</sup> 7 r	78.97	2.55	10.80	1.092	41.002	2.852	EVK	[195]
<sup>32</sup> S+ <sup>94</sup> Mo	78.20 83.16	2.31	10.11	1.949	42.939	1.009	EVR	[37]
<sup>32</sup> S+ <sup>98</sup> Mo	82.16	1.89	9.20	2,777	5 571	13 037	EVR	[194]
<sup>32</sup> S+ <sup>100</sup> Mo	83.29	2.57	10.18	1.925	2.959	2.484	EvR	[194]
<sup>32</sup> S+ <sup>100</sup> Ru	84.05	1.88	8.32	0.182	0.218	8.962	EvR	[194]
<sup>32</sup> S+ <sup>101</sup> Ru	84.77	2.61	8.51	0	0.279	0.902	EvR	[194]
<sup>32</sup> S+ <sup>102</sup> Ru	84.04	2.31	8.59	0	0.615	2.061	EvR	[194]
<sup>32</sup> S+ <sup>104</sup> Ru	83.31	2.58	8.38	0	0.075	0.449	EvR	[194]
<sup>32</sup> S+ <sup>103</sup> Rh	85.24	1.71	7.33	1.083	1.754	6.753	EvR	[194]
<sup>32</sup> S+ <sup>105</sup> Pd	86.80	2.13	7.35	0	0.046	0.230	EvR	[194]
<sup>32</sup> S+ <sup>108</sup> Pd	86.00	1.80	7.28	0	0.304	2.938	EVK	[194]
32 S+110 Pd	87.01	2.03	7.09 8.61	1 395	0.199	0.300	EVR	[194]
<sup>32</sup> S+ <sup>110</sup> Pd	87.82	2.13	8.59	1.863	0 275	0.550	EVR	[194]
<sup>32</sup> S+ <sup>112</sup> Sn	94.98	1.73	8.93	0.965	0.117	0.598	EvR	[127]
<sup>32</sup> S+ <sup>120</sup> Sn	94.13	1.89	9.65	1.738	0.255	0.331	EvR	[127]
<sup>32</sup> S+ <sup>138</sup> Ba	107.55	3.14	10.36	1.241	4.382	3.078	EvR+FF	[195]
<sup>32</sup> S+ <sup>154</sup> Sm	112.78	3.64	8.91	1.133	0.220	0.403	EvR+FF	[196]
<sup>32</sup> S+ <sup>182</sup> W	131.10	2.39	9.89	2.575	0.526	2.395	FF	[197]
<sup>32</sup> S+ <sup>184</sup> W	127.12	2.91	9.24	0.193	0.153	0.224	EvR+FF	[198,199]
<sup>33</sup> S+ <sup>31</sup> Zf <sup>33</sup> S+ <sup>92</sup> 7r	78.03	1.75	9.52	0	0.201	0.976	EVK	[200]
<sup>34</sup> S+ <sup>24</sup> Mσ	27 50	1.55	9 31	0.129	0.209	7 702	EVR	[200]
<sup>34</sup> S+ <sup>26</sup> Mg	26.93	1.12	9.00	0.125	0.675	1 5 3 9	EVR	[188]
<sup>34</sup> S+ <sup>58</sup> Ni	58.60	1.27	7.78	0	0.058	0.385	EvR	[170]
<sup>34</sup> S+ <sup>64</sup> Ni	56.42	1.37	8.52	0	0.412	0.250	EvR	[190]
<sup>34</sup> S+ <sup>64</sup> Ni	56.99	1.29	8.81	0	0.090	0.490	EvR	[170]
<sup>34</sup> S+ <sup>89</sup> Y	76.10	1.42	9.67	0	11.382	2.220	EvR	[192]
<sup>34</sup> S+ <sup>168</sup> Er	121.60	2.96	10.46	2.055	2.564	0.123	EvR+FF	[34]
<sup>34</sup> S+ <sup>108</sup> Er	121.44	2.88	10.36	2.109	0.065	0.045	EVR+FF	[201]
34 S+100 EF	123.61	3.29	10.64	1.883	2.333	0.346	FF	[34]
34 S+206 Pb	142.41	2.03	9.45	0	0.078	13 544	FF	[202]
<sup>34</sup> S+ <sup>208</sup> Ph	141.30	1.57	9.50	2 378	0.205	10.072	FF	[202]
<sup>34</sup> S+ <sup>238</sup> U	153.29	4.77	8.95	0	0.074	1.046	FF	[203]
<sup>36</sup> S+ <sup>48</sup> Ca	42.44	1.22	10.39	0.232	0.603	2.775	EvR	[204]
<sup>36</sup> S+ <sup>48</sup> Ca	42.15	1.09	11.13	0.238	1.091	21.585	EvR	[205]
<sup>36</sup> S+ <sup>58</sup> Ni	58.30	1.42	7.58	0.171	0.105	0.644	EvR	[170]
<sup>36</sup> S+ <sup>58</sup> Ni	58.34	1.42	7.91	0.184	0.162	0.834	EvR	[191]
<sup>30</sup> S+ <sup>64</sup> Ni	57.04	1.17	8.88	0.153	0.415	1.875	EvR	[191]
<sup>30</sup> S+ <sup>64</sup> Ni	56.87	1.14	8.83	0.137	0.157	1.386	EvR	[170]
<sup>36</sup> S+ <sup>90</sup> N1	56.25	1.19	9.79	0.121	5.629	2.783	EVR	[206]
36 S+96 7r	75.35	1.30	11.14	U 3 6 4 9	3.920	1.072	EVK	[207]
<sup>36</sup> S+ <sup>92</sup> Mo	84.87	2.04	13.87	3 978	0.499	9 453	EVR	[207]
<sup>36</sup> S+ <sup>94</sup> Mo	80.82	1.91	10.25	0	0.665	7.829	EvR	[194]
<sup>36</sup> S+ <sup>96</sup> Mo	79.83	1.14	8.41	2.051	2.374	8.993	EvR	[194]
<sup>36</sup> S+ <sup>98</sup> Mo	78.61	0.83	8.68	2.667	0.810	1.136	EvR	[194]
<sup>36</sup> S+ <sup>100</sup> Mo	78.92	1.08	10.02	2.689	0.492	1.379	EvR	[194]

# Table A (continued).

Table A (continued).								
<sup>36</sup> S+ <sup>100</sup> Ru	82.93	1.24	8.45	1.542	0.731	14.787	EvR	[194]
<sup>36</sup> S+ <sup>101</sup> Ru	82.79	1.64	9.75	0	0.122	0.346	EvR	[194]
<sup>36</sup> S+ <sup>102</sup> R11	81 97	1 41	8 42	0.021	7 317	3 355	FvR	[194]
$^{36}$ S+ $^{104}$ B11	83.18	150	10.54	2 2 1 6	2 3 1 2	6 163	EvR	[10/]
36 c + 106 p.d	05.10 07.76	1.50	11.02	2.210	0.055	4 9 9 2	EVR	[104]
36 c 108 p J	87.70 87.40	1.40	11.02	3.730	0.933	4.005		[194]
<sup>36</sup> 2 110 Pd	87.49	1.55	10.41	3.395	0.071	2.187	EVR	[194]
<sup>50</sup> S+ <sup>110</sup> Pd	86.08	1.52	8.57	1.819	7.026	0.932	EvR	[38]
<sup>36</sup> S+ <sup>110</sup> Pd	84.74	1.53	7.96	0.161	1.484	19.173	EvR	[194]
<sup>36</sup> S+ <sup>204</sup> Pb	141.08	1.01	9.60	3.362	0.203	3.384	FF	[202]
<sup>36</sup> S+ <sup>206</sup> Pb	139.98	1.38	8.97	0	0.463	9.838	FF	202
<sup>36</sup> S+ <sup>208</sup> Ph	139.90	1 36	9 92	0	0.282	6 264	FF	[202]
36 C+238 I	154.91	1.50	12.26	0 004	0.424	2.015	EE	[162]
35 C1 + 24 M	20.22	1.15	12.20	0.304	1.507	2.015	II E-D	[200]
25 -1 25	30.22	1.05	9.84	0.192	1.597	1.928	EVK	[208]
<sup>55</sup> CI+ <sup>25</sup> Mg	30.08	1.85	9.31	0	0.980	1.047	EVR	[208]
<sup>35</sup> Cl+ <sup>26</sup> Mg	29.47	1.93	8.29	0	0.378	0.370	EvR	[208]
<sup>35</sup> Cl+ <sup>27</sup> Al	30.55	0.76	8.26	0	0.234	0.110	EvR	[209]
<sup>35</sup> Cl+ <sup>51</sup> V	51.66	1.59	10.38	0.012	0.153	0.190	EvR	[210]
<sup>35</sup> Cl+ <sup>58</sup> Ni	61.32	1 40	9.00	0	0 907	1.373	EvR	209
<sup>35</sup> Cl+ <sup>60</sup> Ni	61.03	2 12	0.00	0	0.511	1583	EvR	[200]
35 C1 (62 N)	01.05	1.52	0.49	1 C 1 E	0.311	0.107		[203]
35 CL 62 N	00.39	1.55	9.40	1.015	0.214	0.107		[209]
<sup>35</sup> CI+ <sup>62</sup> Ni	60.73	1.57	9.65	1.850	0.190	0.143	EVR	[211]
<sup>35</sup> Cl+ <sup>62</sup> Ni	60.71	1.69	9.59	1.318	0.089	0.067	EvR	[209]
<sup>35</sup> Cl+ <sup>64</sup> Ni	60.30	2.26	9.67	0	0.373	0.388	EvR	[209]
<sup>35</sup> Cl+ <sup>92</sup> Zr	82.50	2.33	9.74	0	2.757	1.044	EvR	[96]
<sup>35</sup> Cl+ <sup>130</sup> Te	102.37	2.71	11.67	0	0.191	0.281	EvR+FF	[212]
$^{37}Cl+^{24}Mg$	20.30	1 98	8 54	0	0.467	0.493	FvR	[208]
$^{37}C1+^{25}Mg$	20.00	0.01	0.34	1 775	0.407	4 220	EVR	[200]
37 CL 26 M	20.00	0.91	0.54	1.773	2.455	4.520	EVK	[200]
57 CI+25 Mg	28.61	0.87	7.59	1.779	0.452	0.441	EVK	[208]
<sup>37</sup> Cl+ <sup>39</sup> Co	58.36	1.48	8.74	0	1.252	0.701	EvR	[173]
<sup>37</sup> Cl+ <sup>70</sup> Ge	66.97	1.68	8.31	0	0.741	0.600	EvR	[213]
<sup>37</sup> Cl+ <sup>72</sup> Ge	67.01	1.60	8.90	0	1.121	0.300	EvR	[213]
<sup>37</sup> Cl+ <sup>73</sup> Ge	67.45	2.41	8.37	0	0.877	0.327	EvR	[213]
<sup>37</sup> Cl+ <sup>74</sup> Ge	68.04	2.52	9.75	0	0.361	0.175	EvR	[213]
<sup>37</sup> Cl+ <sup>76</sup> Ce	68.13	1.62	10.11	2 461	0.405	0 122	FvR	[213]
<sup>37</sup> CI+ <sup>98</sup> Mo	84.08	1.02	0.20	0	0.127	0.122	EVR	[213]
40 A = 110 D 4	04.90	1.55	0.00	0	0.127	1.300	EVK	[214]
<sup>10</sup> AF+ <sup>110</sup> P0	97.26	4.08	11.04	0	0.457	1.256	EVK	[132]
<sup>40</sup> Ar+ <sup>112</sup> Sn	104.77	1.86	9.43	1.910	0.776	1.075	EVR+FF	[215]
<sup>40</sup> Ar+ <sup>116</sup> Sn	104.89	1.99	9.65	2.267	0.371	0.194	EvR+FF	[215]
<sup>40</sup> Ar+ <sup>122</sup> Sn	104.55	2.13	10.38	2.020	1.832	2.154	EvR+FF	[215]
<sup>40</sup> Ar+ <sup>144</sup> Sm	125.75	2.01	9.24	1.674	2.289	2.525	EvR+FF	[215]
<sup>40</sup> Ar+ <sup>144</sup> Sm	126.73	2.20	9.61	1.539	0.602	2.438	EvR	[216]
<sup>40</sup> Ar+ <sup>148</sup> Sm	127 50	3.07	10.42	1 902	2 628	6 590	FvR+FF	[215]
40  Ar + 148  Sm	127.36	3.01	10.12	2 778	0.766	3 7 7 7	EVR	[216]
40 A m + 154 C m	127.30	2.01	0.71	2.770	0.700	10.005		[210]
40 4 154 6	125.41	5.00	9.71	1.901	0.920	10.065		
40 c 176 c 2	126.04	5.14	12.49	0	0.496	1.687	EVR	[216]
<sup>40</sup> Ar+ <sup>176</sup> Hf	146.00	7.23	10.89	0	0.887	0.244	FF	[217]
<sup>40</sup> Ar+ <sup>179</sup> Hf	144.96	7.24	10.86	0	0.595	0.146	FF	[217]
<sup>40</sup> Ar+ <sup>208</sup> Pb	158.75	3.86	10.56	0	4.271	1.273	FF	[217]
<sup>40</sup> Ca+ <sup>40</sup> Ca	53.32	1.37	9.93	0.137	1.689	8.400	EvR	[218]
<sup>40</sup> Ca+ <sup>40</sup> Ca	53.51	1.31	10.15	0.165	0.636	7.953	EvR	219
$^{40}C_{2}+^{44}C_{2}$	52.08	1 16	8 75	1658	0.281	4 082	EvR	[218]
<sup>40</sup> C2+ <sup>48</sup> C2	51.00	1.10	7.96	0	0.201	2 2 2 7	EVR	[210]
40 Ca + 48 Ca	51.20	1.47	7.00	0 0 0 1 2	4.252	2.527	EVR	[220]
40 c 48 c	J1.0/	1.57	0.24	0.010	4.233	2.302		[220]
~ La+™ La	51.68	1.67	11.29	0.043	8.322	1.094	EVK	[221]
<sup>40</sup> Ca+ <sup>46</sup> Ti	57.21	1.41	9.37	0	0.128	0.459	EvR	[222]
<sup>40</sup> Ca+ <sup>48</sup> Ti	56.97	1.45	9.20	0	0.052	0.250	EvR	[222]
<sup>40</sup> Ca+ <sup>50</sup> Ti	57.00	1.62	9.03	0	0.024	0.093	EvR	[222]
<sup>40</sup> Ca+ <sup>58</sup> Ni	71.71	1.90	8.87	0	0.458	1.120	EvR	223
<sup>40</sup> Ca+ <sup>58</sup> Ni	71.15	1 30	8 60	0	0 342	0.890	FvR	[224]
40 Ca+60 Ni	70.02	1.00	0.00	0	0.068	0.259	EVR	[22]
40 Ca + 62 Ni	70.95	1.33	9.40	0	0.008	0.338	EVIX EviDi EE	[223]
40 Ca + 62 M	70.00	2.32	J.JJ	0	0.237	0.472		[223]
** Ca+*** IN1	/0.80	2.39	9.52	U	0.341	0.668	EVK	[223]
<sup>*</sup> Ca+ <sup>°</sup> Ni	69.44	1.39	8.68	1.412	0.808	6.110	EvR	[224]
40Ca+90Zr	96.18	1.58	10.00	0	5.326	0.226	EvR	[26]
<sup>40</sup> Ca+ <sup>90</sup> Zr	96.40	1.54	9.97	0	0.304	0.218	EvR	[225]
<sup>40</sup> Ca+ <sup>94</sup> Zr	94.95	2.60	9.96	0.394	0.601	0.197	EvR	[226]
<sup>40</sup> Ca+ <sup>96</sup> Zr	94.09	2.16	9.62	1.443	3.419	0.115	EvR	[26]
$^{40}C_{2}+^{96}7r$	94 32	2 17	9.60	1 411	0.079	0.063	FVR	[225]
$40_{C_{2}}$	05.05	2.17	10.20	2 204	0.075	0.600	EVIL	[223]
40 Ca + 124 Ca	112.00	2.20	0.23	2.307	0.100	0.021	EVIN	[220]
Ca+ 'Sn 40 c 124 c	113.22	2.19	9.62	0.809	2.543	0.248	EVK	[228]
™Ca+12ªSn	113.34	2.26	9.56	0.792	1.399	0.119	EVK	[229]
<sup>40</sup> Ca+ <sup>192</sup> Os	166.75	4.69	10.24	0.185	0.368	2.358	FF	[230]
<sup>40</sup> Ca+ <sup>194</sup> Pt	171.46	3.31	9.71	1.473	0.386	0.889	FF	[230]
<sup>40</sup> Ca+ <sup>197</sup> Au	174.59	6.84	10.61	0.179	3.159	1.645	FF	[231]
<sup>40</sup> Ca+ <sup>208</sup> Pb	176.68	3.91	9.96	2.503	5.646	0.098	FF	231
								r 1

# Table A (continued).

"""""         """         ""         ""         '         '         '         '         "         "         "         '        '         '         '<	Table A (continued).								
"G-m <sup>2</sup> Co         51.51         1.10         1.0.41         0.202         2.655         36.45         FAR         1.231           "G-m <sup>2</sup> Co         31.60         0.314         30.50         0         31.80         2.071         Bar         2.211           "G-m <sup>2</sup> Co         31.60         0.318         0.368         0         31.80         2.071         Bar         2.211           "G-m <sup>4</sup> So         134.00         3.44         10.05         131.10         15.80         2.071         Bar         2.231           "G-m <sup>4</sup> So         134.00         3.44         10.05         12.31         0.202         13.38         0.337         PK PF         12.31           "G-m <sup>4</sup> No         10.23         4.20         11.33         0.202         5.38         0.374         1.402         PK PF         12.31           "G-m <sup>4</sup> No         77.50         2.03         0.53         1.454         1.447         0.442         PK PF         12.31           "G-m <sup>4</sup> No         77.39         1.30         0.45         0.304         0.331         DVA         1.31           "G-m <sup>4</sup> No         77.39         1.30         0.45         0.304         0.31         DVA         1.32	<sup>40</sup> Ca+ <sup>238</sup> U	192.86	5.60	8.57	0	0.182	0.464	FF	[232]
""C"C-         51.4         0.68         0.68         0.51.4         1.075         0.786         Perk         1.231           "C"C-T-         0.131         1.31         10.06         3.311         7.065         0.737         Perk         1.231           "C"T-T-         0.134         1.31         10.06         3.311         7.065         0.737         Perk         1.231           "C"T-T-         1.34.4         2.432         1.232         0.244         0.114         0.835         Perk         1.231           "C"T-T-         1.32.7         1.422         1.233         0.244         0.130         0.372         Perk         1.231           "CT-T-         1.232         1.42         1.432         1.432         1.441         0.431         0.332         Perk         1.231           "CT-T-         1.233         0.331         0.376         0.431         0.332         Perk         1.231           "CT-T-         1.333         0.445         1.437         0.343         0.337         Perk         1.231           "CT-T-         1.339         0.453         1.437         0.343         0.337         Perk         1.331           "CT-T-	<sup>48</sup> Ca+ <sup>48</sup> Ca	51.51	1.10	10.43	0.202	2.655	36.945	EvR	233
"Control         3.128         2.074         PDR         PDR           "Control         3.128         2.074         PDR         [234]           "Control         134         10.66         3.57         7.00         0.77         For Res         [234]           "Control         134.40         3.48         10.81         1.81         1388         3.485         Devictive         [234]           "Control         134.40         3.47         1502         0.134         0.865         FF         1231           "Serve"         61.82         1.40         8.74         1.00         0.37         EV         1241           "Serve"         61.82         1.02         1.03         0.374         EV         1241           "Serve"         1.63         8.58         1.425         0.226         2.311         EV         1241           "Serve"         1.53         8.58         1.425         0.262         2.311         EV         1241           "Serve"         1.53         8.58         1.425         0.262         2.331         EV         1241           "Serve"         7.15         1.63         1.63         0.664         1.633         0.664	<sup>48</sup> Ca+ <sup>48</sup> Ca	51.04	0.88	10.68	0.814	3.075	0 798	FvR	[221]
"Got"Sn         93.4         1.31         1006         5.271         7.000         0.737         128         1231           "Got"Sn         138.4         3.44         10.65         2.228         2.308         3.587         FWHTP         1231           "Got"Sn         117.48         2.480         11.53         0         2.211         135.22         FF         1231           "Got"Sn         10.57         10.74         2.201         10.38         0.035.2         FF         1231           "Got"Sn         0.55         10.74         2.201         10.38         0.035.7         FF         1231           "Got"Sn         0.55         10.74         2.201         10.38         0.035.7         FF         1231           "How         10.52         2.37         0.56         1.632         0.442         0.432         0.442         0.442         FF         1241           "How         10.52         1.52         1.55         1.55         1.57         0.632         0.66         1.633         0.616         57         1.47           "How         10.56         1.57         1.57         1.57         1.57         1.57         1.57         1.57         <	$^{48}C_{2+}^{90}7r$	0470	1 79	0.86	0	5 126	2.074	EVR	[224]
abs         b	$48 C_{2} + 967\pi$	02.42	1.70	5.00	2 071	7.000	2.074	EVK	[234]
""b-""         Hall         <	48 c 154 c	93.43	1.31	10.06	3.8/1	7.090	0.737	EVK	[234]
************************************	<sup>40</sup> Ca <sup>+154</sup> Sm	140.22	4.16	10.63	1.811	1.856	3.485	EVR+FF	[235]
#c.h.*#h         17.54         2.89         12.53         0         2.821         18.52         F         1337           #c.h.*#h         133.27         4.52         1.55         1.242         0.114         0.855         14.57         12.337           #r1-#%n         0.30         1.55         1.242         1.007         0.345         0.037         164         1.77           #r1-#%n         0.633         2.37         10.45         1.007         0.345         0.237         Evk         153           #r1-#%n         7.715         1.34         8.58         1.462         0.244         0.237         Evk         123           #r1-#%n         7.799         1.62         1.678         0.668         0.350         Evk         124           #r1-#%n         7.799         1.62         1.658         0.357         0.582         1247         144           #r1+#%n         7.727         1.99         9.70         1.81         1.466         2.475         1.237         Evk         147           #r1+#%n         7.727         1.99         9.70         1.23         0.128         2.775         1.237         2.84         1.417           #r1+#%n	<sup>48</sup> Ca+ <sup>154</sup> Sm	138.49	3.44	10.65	2.228	2.308	3.587	EvR+FF	[236]
"ac.+""         193.27         4.62         11.55         0.204         0.114         0.865         FF         1232           "Ti-Tin"         61.30         1.35         10.74         2.081         5.638         0.037         Evel         1231           "Ti-Tin"         61.30         1.35         10.74         2.081         5.638         0.037         Evel         1231           "Ti-Tin"         61.30         3.61         10.78         0         0.444         0.132         Evel         151           "Ti-Tin"         71.50         1.43         8.58         1.425         0.226         2.381         Evel         1240           "Ti-Tin"         77.39         1.80         9.88         0.165         1.867         0.522         Evel         1240           "Ti-Tin"         77.39         1.80         9.88         0.165         1.867         0.308         Evel         1241           "Ti-Tin"         77.37         1.84         1.18         1.738         0.464         0.130         Evel         1141           "Ti-Tin"         1.33         9.47         1.238         0.444         2.441         2.557         1.573         1.573         1.573	<sup>48</sup> Ca+ <sup>208</sup> Pb	175.48	2.89	12.53	0	2.821	18.852	FF	[237]
*****         ·****         ·***         ·****         ·****         ·****         ·****	<sup>48</sup> Ca+ <sup>238</sup> U	193.27	4.62	11.55	0.204	0.114	0.865	FF	[232]
***1.***         62.00         1.55         10.74         2.031         52.88         0.037         Ev8         [12]           ***1.***         106.31         2.37         10.45         1.007         0.343         0.237         Ev8         [15]           ***1.***         108.70         3.31         10.73         0         0.444         0.137         Ev8         [15]           ***1.***         7.268         2.33         8.33         1.425         0.226         2.331         Ev8         2.231           ***1.***         7.289         3.29         9.83         0.188         2.375         0.320         Ev8         [14]           ***1.***         7.27         1.99         9.87         0.128         2.475         0.320         Ev8         [15]           ***1.***         10.65         1.31         0.165         1.753         0.444         0.580         Ev8<         [15]           ***1.***         1.13         0.128         2.371         0.418         0.428         0.428         0.428           ***1.***         1.13         0.141         0.241         2.341         Ev8         [14]           ****1.*********         0.143         0.357	<sup>45</sup> Sc+ <sup>51</sup> V	61.82	1.40	874	1 902	0.130	0.374	EvR	173
************************************	46Ti+46Ti	63.09	1.55	10.74	2 001	5,638	0.037	EVR	[238]
matrix         for         for<	46T; 164N;	77.05	1.55	0.59	1 464	1 1 47	0.337	EVD	[230]
************************************	46m: 90m	11.03	2.05	9.38	1.404	1.14/	0.442	EVK	[147]
"II-"Nb         108.70         3.61         10.78         0         0.444         0.132         Dr.R         [23]           "II-"Nb         71.30         1.44         8.88         0.167         1.028         0.331         Dr.R         [24]           "II-"Nb         77.39         2.40         9.89         0.167         1.028         0.230         Dr.R         [24]           "II-"Nb         77.39         1.62         1.165         3.759         6.520         2.880         Dr.R         [14]           "II-"Nb         1.62.64         2.40         9.43         1.866         2.875         0.632         Dr.R         [14]           "II-"Nb         106.76         1.81         10.16         1.738         0.444         0.130         Dr.R         [15]           "II-"Nb         106.76         1.81         10.16         1.738         0.448         0.360         Dr.R         [16]           "II-"Nb         9.10         1.37         9.41         2.241         0.3170         2.352         DR.R         [17]           "Nb-"Nb         9.13         1.38         8.34         2.356         D.977         D.82         D.878         D.878           "N	40 11+30 Zr	106.23	2.37	10.45	1.007	0.343	0.237	EVK	[15]
********         7.150         1.43         8.58         1.425         0.226         2.31         EvR         2.401           ********         7.38         2.24         0.85         0.176         1.667         0.632         EvR         2.401           ********         7.739         1.80         0.89         0.166         1.683         0.616         EvR         2.401           *******         7.739         1.80         0.89         0.166         1.683         0.616         EvR         1.401           ********         0.420         1.37         0.464         0.300         EvR         1.51           **************         91.67         1.25         9.02         2.571         0.413         2.541         EvR         2.431           *****************         91.0         1.33         9.41         2.414         5.177         2.856         EvR         2.431           ***********************         91.0         1.47         8.04         2.330         0.330         2.227         EvR         2.331           **************************         91.78         8.34         2.356         6.497         1.012         8.441           ************************************	<sup>40</sup> Ti+ <sup>93</sup> Nb	108.70	3.61	10.78	0	0.404	0.132	EvR	[15]
#iii-#iii         78.8         2.24         8.85         0.176         1.667         0.652         EvR         [240]           #Tire Min         77.39         1.62         11.65         1.753         0.520         2.80         EvR         [240]           #Tire Min         1.28.45         2.40         8.83         0.166         1.683         0.0163         EvR         [241]           #Tire Min         1.28.45         2.40         8.84         0.180         2.280         EvR         [15]           #Tire Min         10.67         1.78         0.448         0.320         EvR         [15]           #Nin Min         9.167         1.25         9.02         2.515         0.448         0.320         EvR         [241]           #Nin Min         9.19         1.30         8.44         2.300         0.33         2.227         EvR         [242]           #Nin Min         9.677         1.57         8.45         2.435         0.404         1.402         EvR         [243]           #Nin Min         9.677         1.57         8.45         2.467         0.531         0.77         EvR         [244]           #Nin Min         9.552         8.33	<sup>48</sup> Ti+ <sup>58</sup> Fe	71.50	1.43	8.58	1.425	0.226	2.531	EvR	[239]
"#int-"Mini         77.39         1.80         9.80         0.166         1.683         0.616         EvR         240           "#int-"Sin         1.26.45         2.40         9.43         1.866         2.375         0.652         EvR-FF         1.95           "#int-"Sin         1.72.3         1.04         0.128         2.075         1.237         EvR         1.17           "#int-"Sin         1.04         1.33         0.41         2.173         0.441         0.138         EvR         1.17           "#int-"Fine         1.100         1.33         0.401         2.330         0.303         EvR         1.201           "#int-"Fine         0.130         1.30         8.44         2.356         6.947         1.402         EvR         1.231           "#int-"Fine         0.133         9.44         2.356         6.947         1.402         EvR         1.243           "#int-"Fini         9.739         1.68         8.44         0.330         2.104         EvR         2.431           "Wint-"Fini         9.730         1.68         8.44         0.330         0.100         EvR         2.431           Wint-"Fini         9.733         0.6530         2.01	<sup>48</sup> Ti+ <sup>58</sup> Ni	78.88	2.24	9.85	0.176	1.667	0.582	EvR	[240]
#int=Min         77.99         10.2         11.85         7.99         65.20         2.380         Evk = [149]           #int=Min         126.66         2.40         8.43         1.866         2.875         0.295         Evk = [149]           #int=Min         10.05         1.31         10.05         1.733         0.043         0.50         Evk = [15]           #int=Min         91.67         1.33         9.41         2.414         0.177         2.380         Evk = [16]           #int=Min         91.07         1.25         3.02         2.531         0.413         2.641         Evk = [241]           #int=Min         91.07         1.25         3.02         2.531         0.547         1.722         Evk = [241]           #int=Min         91.09         1.68         8.34         2.356         0.547         1.702         Evk = [241]           #int=Min         96.057         1.97         8.45         2.467         0.352         Evk = [241]         Evk = [241]           #int=Min         96.057         1.97         8.45         0.367         0.392         Evk = [241]         Evk = [241]           #int=Min         96.057         1.97         8.35         0.613         0.1	<sup>48</sup> Ti+ <sup>60</sup> Ni	77.39	1.80	9.89	0.166	1.683	0.616	EvR	240
and transform         isoland	<sup>48</sup> Ti+ <sup>64</sup> Ni	77 99	1.62	11.65	3 7 5 9	6 5 2 0	2 380	FvR	[240]
••n-•••         ·•n         ··n	48 Ti + 122 C p	176 45	2.40	0.42	1 966	2.975	2.500	EVIC	[105]
The The Direct Constraint of the Constraint	50 T: 60 NI	120.45	2.40	9.45	1.000	2.075	0.932		[195]
"In-"AC         104.29         1.37         10.05         1.73         0.448         0.150         Ev8         151           "NI-"Re         91.07         1.25         30.2         2.571         0.413         2.481         Ev8         [241]           "NI-"Re         91.00         1.43         8.44         2.430         1.313         2.481         Ev8         [241]           "NI-"Re         91.00         1.47         8.00         2.555         6.047         1.402         Ev8         [241]           "NI-"Re         90.10         1.47         8.00         2.555         6.047         1.402         Ev8         [243]           "NI-"Re         0.03.0         2.62         7.94         1.336         0.658         2.104         Ev8         [244]           "NI-"Re         0.03.0         2.62         7.94         1.336         0.058         2.107         Ev8         [246]           "NI-"Re         0.03.0         2.62         7.94         1.336         0.057         0.128         Ev8+FF         [246]           "NI-"Sin         135.0         1.000         2.406         0.035         0.108         Ev8+FF         [246]           "NI-"Sin	50 11+00 N1	11.21	1.99	9.87	0.128	2.075	1.297	EVK	[147]
************************************	<sup>50</sup> Ti+ <sup>90</sup> Zr	104.29	1.37	10.05	1.753	0.464	0.130	EvR	[15]
an k-a <sup>b</sup> re         91.07         1.25         9.02         2.571         0.413         2.641         EWR         [41]           an k-a <sup>b</sup> re         91.78         1.30         8.94         2.330         0.330         2.227         EWR         [24]           an k-a <sup>b</sup> wi         99.99         1.68         8.34         2.355         6.947         1.402         EWR         [41]           an k-a <sup>b</sup> wi         95.667         1.97         8.45         2.447         0.750         2.661         EWR         [24]           an k-a <sup>b</sup> wi         96.67         1.97         8.45         2.447         0.750         2.661         EWR         [24]           an k-a <sup>b</sup> wi         1.33,24         2.18         7.76         1.765         0.011         0.177         EWR         [24]           an k-a <sup>b</sup> wi         1.33,23         3.50         0.667         0.066         0.067         0.128         EWR FT         [246]           an k-a <sup>b</sup> wi         1.633         0.461         0.330         0.934         EWR FT         [246]           an k-a <sup>b</sup> wi         1.632         1.613         7.33         0.666         0.067         0.334         EWR FT         [248]           an k-	<sup>50</sup> Ti+ <sup>93</sup> Nb	106.76	1.81	10.16	1.788	0.438	0.580	EvR	[15]
Sh N=1*Pc         9190         1.33         9.41         2.414         5.177         2.836         Furk         [10]           Sh N=1*N         919.1         1.47         8.09         2.535         1.094         3.762         Furk         [24]           Sh N=1*N         95.43         1.88         8.49         0.397         0.392         1.773         EVR         [24]           Sh N=1*N         95.43         1.88         8.49         0.397         0.392         1.773         EVR         [24]           Sh N=1*N         95.43         2.62         7.94         1.336         0.658         1.144         EVR         2.461           Sh N=1*N         135.2         4.67         7.53         0.613         0.007         0.128         EVR+F         2.461           Sh N=1*Sn         105.50         7.01         7.83         0.613         0.030         EVR+FF         2.481           Sh N=1*Sn         165.79         5.35         9.12         2.300         0.133         C030         EVR+FF         2.481           Sh N=1*Sn         163.22         3.19         8.15         2.385         0.038         0.334         EVR+FF         2.481           Sh N=1	<sup>58</sup> Ni+ <sup>54</sup> Fe	91.67	1.25	9.02	2.571	0.413	2.641	EvR	[241]
************************************	<sup>58</sup> Ni+ <sup>54</sup> Fe	91.90	1.33	941	2.414	5.177	2,836	EvR	[40]
**N:**N:         90.19         1.47         8.09         2.535         1.094         *.702         DeR         [41]           **N:**N:         97.35         1.88         8.49         0.357         0.352         1.773         DeR         [173]           **N:**N:         96.37         1.92         8.45         0.367         0.352         1.773         DeR         [24]           **N:***C         108.30         2.62         7.94         1.336         0.658         2.104         Eve         2.42           *N:****C         133.59         2.55         8.33         0         0.109         0.300         Eve         2.46           *N:****         135.52         4.67         7.53         0.613         0.067         0.128         Ever+FF         2.48           *N:***         165.50         7.01         7.82         0.466         0.033         0.703         Ever+FF         2.48           *N:***         165.71         3.91         8.71         2.83         0.033         0.733         Ever+FF         2.48           *N:***         165.71         3.91         8.71         2.83         0.033         0.734         Ever+FF         2.48           <	<sup>58</sup> Ni+ <sup>54</sup> Fe	91.78	1 30	8 94	2 330	0 3 3 0	2,000	EvR	[230]
num         97.05         1.42         8.05         2.135         1.054         1.042         DA         DA <thda< th="">         DA         DA         <thda< th=""></thda<></thda<>	58 NI; 158 NI;	00.10	1.50	0.54	2.550	1.004	2,227	EVR	[233]
Thi Ni         9/.99         1.88         8.44         2.356         6.547         1.412         UNK         [11]           Mine Air         96.67         1.97         8.45         2.457         0.750         2.661         UNK         [24]           Mine Air         0.667         1.97         8.45         2.487         0.750         2.661         UNK         243           Mine Air         1.33.74         2.18         7.76         1.765         0.013         0.177         UNK         245           Mine Air         1.33.53         3.50         10.09         2.490         0.084         0.235         UNK         246           Mine Air         1.55.52         4.77         7.33         0.613         0.017         U.128         UNK+FF         248           Mine Air         1.65.50         7.01         7.82         0.466         0.033         0.138         UNK+FF         248           Mine Air         16.521         6.13         7.17         2.083         0.014         UZ1         UNK+FF         248           Mine Air         16.522         3.91         8.71         2.033         0.133         0.703         UNK+FF         248	58 NI - 60 NI	99.19	1.47	0.09	2.333	1.094	5.702	EVK	[242]
***N+**Ni         95.43         1.98         8.49         0.397         0.392         1.773         EvR         [178]           ***N+**a         108.30         2.62         7.94         1.336         0.658         2.104         EvR         2.43]           **N+**a         133.74         2.18         7.76         1.755         0.613         0.109         0.300         EvR         2.461           **N+**a         133.59         3.50         10.09         2.490         0.084         0.235         EvR         2.461           **N+***a         165.50         7.01         7.52         0.613         0.067         0.128         EvR+FF         2.481           **N+***5         165.21         7.17         7.82         0.466         0.033         0.703         EvR+FF         2.481           **N+***5         165.71         3.91         8.71         2.833         0.013         0.703         EvR+FF         2.481           **N+***5         165.71         3.91         8.71         2.833         0.033         0.344         0.221         EvR+FF         2.481           **N+***5         165.71         3.91         8.71         2.037         0.332         1.341	50 N1+00 N1	97.99	1.68	8.34	2.356	6.947	1.402	EVK	[41]
***********************************	<sup>38</sup> Ni+ <sup>64</sup> Ni	95.43	1.98	8.49	0.397	0.392	1.773	EvR	[178]
*******Ge         (108.30)         2.62         7.94         1.336         0.658         2.104         EVR         (244)           ********         133.89         2.55         8.33         0         0.109         0.300         EVR         (245)           ********         138.99         2.55         8.33         0         0.109         0.300         EVR         (246)           ********         155.52         4.67         7.33         0.613         0.067         0.128         EVR+FF         (247)           ********         165.21         6.13         7.33         0         0.866         0.334         EVR+FF         (248)           ********         163.22         3.19         8.17         2.330         0.133         0.734         EVR+FF         (248)           ********         163.22         3.19         8.17         2.333         0.0301         0.014         EVR+FF         (248)           ********         157.66         3.99         9.44         0         0.00101         EVR+FF         (247)           ********         157.66         3.93         1.627         0.529         4.531         EVR         (249)           ************ <td< td=""><td><sup>58</sup>Ni+<sup>64</sup>Ni</td><td>96.67</td><td>1.97</td><td>8.45</td><td>2.487</td><td>0.750</td><td>2.661</td><td>EvR</td><td>[243]</td></td<>	<sup>58</sup> Ni+ <sup>64</sup> Ni	96.67	1.97	8.45	2.487	0.750	2.661	EvR	[243]
BN-B* 	<sup>58</sup> Ni+ <sup>74</sup> Ge	108.30	2.62	7.94	1.336	0.658	2.104	EvR	[244]
************************************	<sup>58</sup> Ni+ <sup>90</sup> Zr	133.74	2.18	7.76	1.765	0.031	0.177	EvR	[245]
*N.1***0%         195.50         15.0         10.09         2.490         0.084         0.235         FVR         2.65           *N.1***0%         165.50         7.01         7.32         0.613         0.067         0.128         EVR+FF         2.47           *N.1***5%         165.50         7.01         7.32         0.466         0.035         0.138         EVR+FF         2.481           *N.1***5%         163.21         3.13         8.15         2.330         0.134         EVR+FF         2.481           *N.1***5%         163.22         3.13         8.15         2.835         0.038         0.134         EVR+FF         2.481           *N.1**5%         163.22         5.63         8.93         0         0.225         1.596         EVR+FF         2.481           *N.1**5%         158.28         3.09         9.68         1.257         0.498         4.938         EVR *FF         2.491           *N.1**5%         136.03         2.97         8.33         1.627         0.522         1.381         EVR *FF         2.441           *N.1**5%         9.44         0         0.037         0.371         0.371         0.344         2.421           *N.1**5%	<sup>58</sup> Ni+ <sup>92</sup> Mo	138.89	2 55	8 33	0	0 109	0 300	FvR	[246]
International         Los         Los <thlos< th=""> <t< td=""><td>58 Ni+100 Mo</td><td>130.55</td><td>3 50</td><td>10.00</td><td>2 /00</td><td>0.084</td><td>0.235</td><td>EVR</td><td>[246]</td></t<></thlos<>	58 Ni+100 Mo	130.55	3 50	10.00	2 /00	0.084	0.235	EVR	[246]
	58 Ni + 112 Cm	150.55	3.50	7.50	2.450	0.004	0.233		[240]
	58 NI - 112 C	159.52	4.67	7.55	0.013	0.067	0.128	EVK+FF	[247]
********         162.31         6.13         7.33         0         0.86         3.934         EVR+FF         [248]           *******         163.22         3.19         8.15         2.330         0.133         0.703         EVR+FF         [248]           *******         163.22         3.19         8.17         2.083         0.044         0.221         EVR+FF         [248]           *******         155.6         EVR+FF         [248]         3******         158.28         3.09         9.64         0         0.001         EVR+FF         [248]           ******************         158.28         3.09         9.68         1.235         0.488         4.938         EvR         [249]           ************************************	<sup>58</sup> Ni+ <sup>112</sup> Sn	165.50	7.01	7.82	0.466	0.035	0.138	EVR+FF	[248]
<sup>38</sup> Ni <sup>+118</sup> Sn         165.79         5.35         9.12         2.330         0.133         0.703         EVR+FF         [248] <sup>38</sup> Ni <sup>+118</sup> Sn         163.21         3.19         8.15         2.835         0.038         0.134         EVR+FF         [248] <sup>38</sup> Ni <sup>+143</sup> Sn         163.71         3.91         8.71         2.833         0.014         0.221         EVR+FF         [248] <sup>38</sup> Ni <sup>+143</sup> Sn         157.46         3.99         9.44         0         0.011         0.001         EVR+FF         [247] <sup>38</sup> Ni <sup>+143</sup> Sn         158.28         3.09         9.68         1.235         0.498         4.938         EVR         [250] <sup>49</sup> Ni <sup>44</sup> Sn         158.28         3.09         9.68         1.235         0.232         1.381         EVR         [244] <sup>69 Ni<sup>44</sup>Ni         9.499         1.47         1.0.16         1.699         0.515         2.542         EVR         [272]           <sup>61 Ni<sup>44</sup>Ni         9.445         1.23         9.69         1.908         1.919         7.259         EVR         [272]           <sup>61 Ni<sup>44</sup>Ni         9.445         1.23         9.60         0.167         0.461         EVR       </sup></sup></sup>	<sup>58</sup> Ni+ <sup>114</sup> Sn	162.31	6.13	7.33	0	0.866	3.934	EvR+FF	[248]
************************************	<sup>58</sup> Ni+ <sup>116</sup> Sn	166.79	5.35	9.12	2.330	0.133	0.703	EvR+FF	[248]
Sin Hards         163.71         3.91         8.71         2.083         0.044         0.221         EvR+FF         [248]           Sin Hards         150.20         563         8.93         0         0.225         1.596         EvR+FF         [247]           Sin Hards         157.46         3.99         9.44         0         0.001         0.001         EvR +FF         [247]           Sin Hards         158.28         3.09         9.68         1.257         0.529         4.631         EvR          [250]           Sin Hards         136.03         2.97         8.33         1.627         0.532         1.381         EvR          [244]           Sin Hards         94.99         1.47         1.016         1.699         0.515         2.542         EvR          [274]           Sin Hards         9.374         1.30         8.57         2.605         0.419         1.10         EvR          [253]           Sin Hards         9.374         1.32         9.69         1.908         1.919         7.259         EvR          [253]           Sin Hards         9.374         0.303         1.269         8.01         1.533         0.855         2.461         EvR	<sup>58</sup> Ni+ <sup>118</sup> Sn	163.22	3.19	8.15	2.835	0.038	0.134	EvR+FF	[248]
SN H <sup>+14</sup> Sn         162.02         5.63         8.93         0         0.325         1.596         EVR+FF         [248]           SN H <sup>+14</sup> Sn         152.02         5.63         8.93         0         0.325         1.596         EVR+FF         [247]           SN H <sup>+14</sup> Sn         152.28         3.09         9.44         0         0.01         0.001         EVR+FF         [248]           SN H <sup>+14</sup> Sn         152.28         1.38         7.45         1.597         0.529         4.631         EVR         [251]           6 <sup>N</sup> N <sup>+100</sup> M0         16.03         2.97         8.33         1.627         0.532         1.381         EVR         [251]           6 <sup>N</sup> N <sup>+100</sup> M1         94.99         1.47         10.16         1.699         0.515         2.542         EVR         [178]           6 <sup>N</sup> N <sup>+100</sup> M1         94.45         1.23         9.69         1.908         1.919         7.259         EVR         [252]           6 <sup>N</sup> N <sup>+100</sup> M1         94.45         1.23         9.69         1.673         0.464         EVR         [253]           6 <sup>N</sup> N <sup>+100</sup> M2         131.55         3.04         9.41         0         0.400         1.219         EVR         [253] <tr< td=""><td><sup>58</sup>Ni+<sup>120</sup>Sn</td><td>163.71</td><td>3.91</td><td>8.71</td><td>2.083</td><td>0.044</td><td>0.221</td><td>EvR+FF</td><td>[248]</td></tr<>	<sup>58</sup> Ni+ <sup>120</sup> Sn	163.71	3.91	8.71	2.083	0.044	0.221	EvR+FF	[248]
S <sup>1</sup> N1+ <sup>12</sup> Sn         157.46         3.99         9.44         0         0.001         0.001         EVR+FF         [247]           S <sup>1</sup> N1+ <sup>12</sup> Sn         158.28         3.09         9.68         1.235         0.498         4.938         EVR         [249]           S <sup>1</sup> N1+ <sup>12</sup> Sn         158.28         3.09         9.68         1.235         0.498         4.938         EVR         [249]           S <sup>1</sup> N1+ <sup>10</sup> Sn         166.03         2.97         8.33         1.627         0.532         1.381         EVR         [241]           S <sup>1</sup> N1+ <sup>10</sup> N1         94.49         1.47         10.16         1.699         0.515         2.542         EVR         [178]           S <sup>1</sup> N1+ <sup>40</sup> N1         94.45         1.23         9.69         1.908         1.919         7.259         EVR         [241]           S <sup>1</sup> N1+ <sup>40</sup> N1         94.45         1.23         8.40         0.217         0.333         1.269         EVR         [253]           S <sup>1</sup> N1+ <sup>40</sup> N1         92.43         1.32         8.40         0.167         0.169         0.605         EVR         [253]           S <sup>1</sup> N1+ <sup>40</sup> N1         92.43         0.32         0.733         0.400         1.219         EVR         [246]	<sup>58</sup> Ni+ <sup>124</sup> Sn	162.02	5.63	8.93	0	0 325	1 596	FvR+FF	[248]
n1,1         10,1         3.93         3.74         0         0.001         0.001         0.001         0.011         0.011         0.011         0.011         0.011         0.011         0.011         0.011         0.011         0.011         0.011         0.011         0.011         0.011         0.011         0.0137         0.037<	58 Ni+124 Sp	157.46	3.00	0.44	ů 0	0.001	0.001	EVICTI	[247]
TNP         18.2.8         3.09         9.08         1.233         0.498         4.938         EVR         [249]           60N14 <sup>4</sup> 07         136.03         2.97         8.33         1.627         0.532         1.381         EvR         [251]           60N14 <sup>40</sup> Ni         94.98         3.03         7.91         0         0.037         EvR         [244]           6 <sup>4</sup> N14 <sup>45</sup> Ni         94.99         1.47         10.16         1.699         0.515         2.542         EvR         [178]           6 <sup>4</sup> N14 <sup>45</sup> Ni         94.45         1.23         9.69         1.908         1.919         7.259         EvR         [274]           6 <sup>4</sup> N14 <sup>46</sup> Ni         94.45         1.23         9.69         1.908         1.919         7.259         EvR         [274]           6 <sup>4</sup> N14 <sup>46</sup> Ni         94.45         1.23         9.69         1.553         0.856         2.461         EvR         [223]           6 <sup>4</sup> N14 <sup>40</sup> Xi         13.86         3.04         9.41         0         0.000         1.065         EvR         [224]           6 <sup>6</sup> N14 <sup>40</sup> No         13.456         3.04         9.41         0         0.000         0.000         EvR+FF         [248]	58 NI + 124 C-	157.40	3.99	9.44	1 225	0.001	0.001	EVRTIT E-D	[247]
Only 1-00         129_25         1.58         7.45         1.59/         0.529         4.631         EVR         [250]           6 <sup>6</sup> N1+ <sup>100</sup> Mo         136.03         2.97         8.33         1.677         0.532         1.381         EVR         [241]           6 <sup>6</sup> N1+ <sup>40</sup> Mi         94.99         1.47         10.16         1.699         0.515         2.542         EVR         [178]           6 <sup>6</sup> N1+ <sup>40</sup> Mi         93.74         1.30         8.57         2.605         0.419         1.110         EVR         [241]           6 <sup>6</sup> N1+ <sup>40</sup> Mi         93.74         1.32         9.69         1.908         1.919         7.259         EVR         [272]           6 <sup>6</sup> N1+ <sup>40</sup> Mi         92.43         1.32         8.60         0.217         0.333         1.269         EVR         [253]           6 <sup>6</sup> N1+ <sup>40</sup> Ce         10.61         1.79         7.50         1.553         0.856         2.461         EVR         [253]           6 <sup>6</sup> N1+ <sup>40</sup> Dr         135.86         3.04         9.41         0         0.400         1.219         EVR         [246]           6 <sup>6</sup> N1+ <sup>40</sup> Dr         135.86         3.04         9.41         0         0.400         0.913         EVR+FF <t< td=""><td>50 NI+ 5Π</td><td>158.28</td><td>3.09</td><td>9.68</td><td>1.235</td><td>0.498</td><td>4.938</td><td>EVK</td><td>[249]</td></t<>	50 NI+ 5Π	158.28	3.09	9.68	1.235	0.498	4.938	EVK	[249]
<sup>60</sup> Ni+ <sup>80</sup> Ni         96.48         3.03         7.97         8.33         1.627         0.532         1.381         EvR         [251] <sup>60</sup> Ni+ <sup>85</sup> Ni         96.48         3.03         7.91         0         0.037         0.037         EvR         [244] <sup>61</sup> Ni+ <sup>45</sup> Ni         94.99         1.47         10.16         1.699         0.515         2.542         EvR         [178] <sup>64</sup> Ni+ <sup>46</sup> Ni         94.53         1.32         8.60         0.217         0.333         1.269         EvR         [252] <sup>64</sup> Ni+ <sup>46</sup> C         104.61         1.79         7.50         1.53         0.856         2.461         EvR         [253] <sup>64</sup> Ni+ <sup>46</sup> C         104.53         0.453         0.456         2.441         EvR         [253] <sup>64</sup> Ni+ <sup>40</sup> Dr         135.86         3.04         9.41         0         0.400         1.219         EvR         [246] <sup>64</sup> Ni+ <sup>40</sup> Dr         135.86         3.04         9.41         0         0.400         0.246         0.979         EvR         [248] <sup>64</sup> Ni+ <sup>115</sup> Sn         158.47         3.92         10.02         0         0.800         0.843         EvR+FF         [2	<sup>60</sup> N1+ <sup>85</sup> Y	129.25	1.58	7.45	1.597	0.529	4.631	EVR	[250]
6 <sup>4</sup> Ni+ <sup>48</sup> Ni         96.48         3.03         7.91         0         0.037         0.037         EvR         244           6 <sup>4</sup> Ni+ <sup>46</sup> Ni         94.09         1.47         1.06         1.699         0.515         2.542         EvR         [178]           6 <sup>4</sup> Ni+ <sup>46</sup> Ni         93.74         1.30         8.57         2.605         0.419         1.110         EvR         [24]           6 <sup>6</sup> Ni+ <sup>46</sup> Ni         92.43         1.32         8.60         0.217         0.33         1.269         EvR         [252]           6 <sup>6</sup> Ni+ <sup>46</sup> Ni-         1.461         1.79         7.50         1.553         0.856         2.461         EvR         [24]           6 <sup>6</sup> Ni+ <sup>40</sup> 2r         131.72         3.09         7.39         0.167         0.169         0.605         EvR         [253]           6 <sup>6</sup> Ni+ <sup>40</sup> 2r         135.86         3.04         9.41         0         0.400         1.219         EvR         [246]           6 <sup>6</sup> Ni+ <sup>40</sup> 2n         135.85         3.04         9.41         0.62         0.979         EvR+FF         [248]           6 <sup>6</sup> Ni+ <sup>114</sup> 2s         157.61         2.69         8.64         3.62         0.913         EvR+FF         [248]           6 <sup></sup>	<sup>60</sup> Ni+ <sup>100</sup> Mo	136.03	2.97	8.33	1.627	0.532	1.381	EvR	[251]
6 <sup>4</sup> Ni+6 <sup>4</sup> Ni         94.99         1.47         10.16         1.699         0.515         2.542         EVR         [178]           6 <sup>4</sup> Ni+6 <sup>4</sup> Ni         93.74         1.30         8.57         2.605         0.419         1.110         EVR         [244]           6 <sup>4</sup> Ni+6 <sup>4</sup> Ni         94.45         1.23         9.69         1.908         1.919         7.259         EVR         [252]           6 <sup>4</sup> Ni+6 <sup>4</sup> Ni         92.43         1.32         8.40         0.217         0.333         1.269         EVR         [253]           6 <sup>4</sup> Ni+6 <sup>4</sup> Ni         92.43         1.32         8.40         0.217         0.333         1.269         EVR         [253]           6 <sup>4</sup> Ni+6 <sup>4</sup> Di         131.72         3.09         7.39         0.167         0.169         0.605         EVR         [246]           6 <sup>4</sup> Ni+6 <sup>4</sup> Di         135.86         3.04         9.71         0.793         0.246         0.979         EVR         [246]           6 <sup>4</sup> Ni+ <sup>112</sup> Sn         157.61         2.69         8.64         3.062         0.195         0.913         EVR+FF         [248]           6 <sup>4</sup> Ni+ <sup>112</sup> Sn         158.47         3.92         1.002         0         0.800         0.843         EVR+FF <td><sup>64</sup>Ni+<sup>58</sup>Ni</td> <td>96.48</td> <td>3.03</td> <td>7.91</td> <td>0</td> <td>0.037</td> <td>0.037</td> <td>EvR</td> <td>[244]</td>	<sup>64</sup> Ni+ <sup>58</sup> Ni	96.48	3.03	7.91	0	0.037	0.037	EvR	[244]
6 <sup>4</sup> Ni+ <sup>34</sup> Ni         93.74         1.30         8.57         2.605         0.419         1.110         EvR         124           6 <sup>4</sup> Ni+ <sup>34</sup> Ni         94.45         1.23         9.69         1.908         1.919         7.259         EvR         [725]           6 <sup>4</sup> Ni+ <sup>34</sup> Ni         92.43         1.32         8.40         0.217         0.333         1.269         EvR         [252]           6 <sup>6</sup> Ni+ <sup>34</sup> Ni         92.43         1.32         8.40         0.217         0.333         1.269         EvR         [253]           6 <sup>6</sup> Ni+ <sup>34</sup> Gr         13.62         0.461         1.79         7.50         1.53         0.856         2.461         EvR         [253]           6 <sup>6</sup> Ni+ <sup>34</sup> Dr         135.86         3.04         9.41         0         0.400         1.219         EvR         [246]           6 <sup>6</sup> Ni+ <sup>110</sup> Sr         157.61         2.69         8.64         3.062         0.195         0.913         EvR+FF         [248]           6 <sup>6</sup> Ni+ <sup>114</sup> Sr         158.55         4.08         9.37         0         0.000         0.000         EvR+FF         [248]           6 <sup>6</sup> Ni+ <sup>114</sup> Sr         158.57         3.54         9.33         0         0.336         0.172	<sup>64</sup> Ni+ <sup>64</sup> Ni	94.99	1.47	10.16	1.699	0.515	2.542	EvR	[178]
6 <sup>4</sup> Ni+ <sup>46</sup> Ni         94.45         1.23         9.69         1.908         1.919         7.259         EvR         1.79           6 <sup>4</sup> Ni+ <sup>46</sup> Ni         92.43         1.32         8.40         0.217         0.333         1.269         EvR         [252]           6 <sup>4</sup> Ni+ <sup>46</sup> C         104.61         1.79         7.50         1.553         0.856         2.461         EvR         [244]           6 <sup>4</sup> Ni+ <sup>46</sup> Zr         131.72         3.09         7.39         0.167         0.169         0.605         EvR         [253]           6 <sup>4</sup> Ni+ <sup>46</sup> Zr         128.96         2.39         8.09         1.763         0.173         0.444         EvR         [253]           6 <sup>4</sup> Ni+ <sup>40</sup> Mo         134.56         3.34         7.78         0.793         0.246         0.979         EvR         [246]           6 <sup>4</sup> Ni+ <sup>112</sup> Sn         157.61         2.69         8.64         3.062         0.195         0.913         EvR+FF         [248]           6 <sup>4</sup> Ni+ <sup>115</sup> Sn         158.47         3.92         10.02         0         0.180         0.843         EvR+FF         [248]           6 <sup>4</sup> Ni+ <sup>112</sup> Sn         156.44         3.54         9.33         0         0.036         0.172         EvR+FF <td><sup>64</sup>Ni+<sup>64</sup>Ni</td> <td>93.74</td> <td>1.30</td> <td>8 57</td> <td>2,605</td> <td>0 4 1 9</td> <td>1.110</td> <td>EvR</td> <td>244</td>	<sup>64</sup> Ni+ <sup>64</sup> Ni	93.74	1.30	8 57	2,605	0 4 1 9	1.110	EvR	244
	64 Ni+64 Ni	94.45	1.33	9.69	1 008	1 0 1 0	7 250	EVP	[170]
	64NI: 64NI:	02.42	1.20	9.40	0.017	0.222	1,255	EvD	[175]
Orn Mark Ge         104.61         1.79         7.50         1.53         0.856         2.461         EVR         [243]           6 <sup>4</sup> Ni + <sup>32</sup> Zr         131.72         3.09         7.39         0.167         0.169         0.605         EVR         [253]           6 <sup>4</sup> Ni + <sup>32</sup> Zr         131.72         3.09         7.39         0.167         0.400         1.219         EVR         [263]           6 <sup>6</sup> Ni + <sup>32</sup> Zr         135.86         3.04         9.41         0         0.400         1.219         EVR         [246]           6 <sup>6</sup> Ni + <sup>100</sup> Mo         134.56         3.44         7.78         0.793         0.246         0.979         EVR         [248]           6 <sup>6</sup> Ni + <sup>114</sup> Sn         158.87         0.69         8.64         3.062         0.195         0.913         EVR+FF         [248]           6 <sup>4</sup> Ni + <sup>116</sup> Sn         158.47         3.92         10.02         0         0.180         0.843         EVR+FF         [248]           6 <sup>4</sup> Ni + <sup>120</sup> Sn         156.44         3.54         9.33         0         0.036         0.172         EVR+FF         [248]           6 <sup>4</sup> Ni + <sup>122</sup> Sn         154.87         2.85         9.60         0         0.034         0.172         EVR	64	92.43	1.32	8.40	0.217	0.333	1.209	EVK	[252]
On Ni = 22 r         131.72         3.09         7.39         0.167         0.169         0.605         EVR         [253]           64 Ni = 56 r         128.96         2.39         8.09         1.763         0.173         0.444         EVR         [253]           64 Ni = 56 r         135.86         3.04         9.41         0         0.400         1.219         EVR         [246]           64 Ni = 100 Mo         134.56         3.34         7.78         0.793         0.246         0.979         EVR         [246]           64 Ni = 113 N         157.61         2.69         8.64         3.062         0.195         0.913         EVR +FF         [248]           64 Ni = 113 N         157.61         3.64         9.37         0         0.000         0.000         EVR +FF         [248]           64 Ni = 118 N         157.41         4.31         9.36         0         0.4481         0.757         EVR +FF         [248]           64 Ni = 112 S         155.99         2.26         9.41         3.600         0.018         0.083         EVR +FF         [248]           64 Ni = 122 S         1.57         0.585         1.154         EVR         [256]           64 Ni = 12	<sup>64</sup> Ni <sup>+</sup> , <sup>4</sup> Ge	104.61	1.79	7.50	1.553	0.856	2.461	EVR	[244]
6 <sup>4</sup> Ni+ <sup>36</sup> Zr         128.96         2.39         8.09         1.763         0.173         0.444         EvR         [253]           6 <sup>4</sup> Ni+ <sup>30</sup> Mo         135.86         3.04         9.41         0         0.400         1.219         EvR         [246]           6 <sup>4</sup> Ni+ <sup>100</sup> Mo         134.55         3.34         7.78         0.793         0.246         0.979         EvR         [248]           6 <sup>4</sup> Ni+ <sup>112</sup> Sn         157.61         2.69         8.64         3.062         0.195         0.913         EvR+FF         [248]           6 <sup>4</sup> Ni+ <sup>114</sup> Sn         158.85         4.08         9.37         0         0.000         0.000         EvR+FF         [248]           6 <sup>4</sup> Ni+ <sup>116</sup> Sn         157.41         4.31         9.36         0         0.481         0.757         EvR+FF         [248]           6 <sup>4</sup> Ni+ <sup>122</sup> Sn         156.44         3.54         9.33         0         0.036         0.172         EvR+FF         [248]           6 <sup>4</sup> Ni+ <sup>124</sup> Sn         154.87         2.85         9.60         0.011         0.044         EvR         [257]           6 <sup>4</sup> Ni+ <sup>124</sup> Sn         154.87         2.85         9.60         0.011         0.044         EvR         [258] <tr< td=""><td><sup>64</sup>Ni+<sup>92</sup>Zr</td><td>131.72</td><td>3.09</td><td>7.39</td><td>0.167</td><td>0.169</td><td>0.605</td><td>EvR</td><td>[253]</td></tr<>	<sup>64</sup> Ni+ <sup>92</sup> Zr	131.72	3.09	7.39	0.167	0.169	0.605	EvR	[253]
6 <sup>4</sup> Ni+ <sup>102</sup> Mo         133.86         3.04         9.41         0         0.400         1.219         EvR         [246]           6 <sup>4</sup> Ni+ <sup>102</sup> Mo         134.56         3.34         7.78         0.793         0.246         0.979         EvR         [246]           6 <sup>4</sup> Ni+ <sup>112</sup> Sn         157.61         2.69         8.64         3.062         0.195         0.913         EvR+FF         [248]           6 <sup>4</sup> Ni+ <sup>114</sup> Sn         158.85         4.08         9.37         0         0.000         0.000         EvR+FF         [248]           6 <sup>4</sup> Ni+ <sup>116</sup> Sn         158.47         3.92         10.02         0         0.481         0.757         EvR+FF         [248]           6 <sup>4</sup> Ni+ <sup>118</sup> Sn         157.41         4.31         9.36         0         0.363         0.172         EvR+FF         [248]           6 <sup>4</sup> Ni+ <sup>124</sup> Sn         156.44         3.54         9.33         0         0.014         0.083         EvR+FF         [248]           6 <sup>4</sup> Ni+ <sup>124</sup> Sn         156.43         3.54         9.33         0         0.336         0.172         EvR +FF         [248]           6 <sup>4</sup> Ni+ <sup>124</sup> Sn         156.41         4.39         7.58         0         0.011         0.044         EvR <td><sup>64</sup>Ni+<sup>96</sup>Zr</td> <td>128.96</td> <td>2.39</td> <td>8.09</td> <td>1.763</td> <td>0.173</td> <td>0.444</td> <td>EvR</td> <td>[253]</td>	<sup>64</sup> Ni+ <sup>96</sup> Zr	128.96	2.39	8.09	1.763	0.173	0.444	EvR	[253]
<sup>64</sup> Ni+ <sup>100</sup> Mo       134.56       3.34       7.78       0.793       0.246       0.979       EvR       [246] <sup>64</sup> Ni+ <sup>112</sup> Sn       157.61       2.69       8.64       3.062       0.195       0.913       EvR+FF       [248] <sup>64</sup> Ni+ <sup>114</sup> Sn       158.85       4.08       9.37       0       0.000       0.000       EvR+FF       [248] <sup>64</sup> Ni+ <sup>116</sup> Sn       158.47       3.92       10.02       0       0.180       0.843       EvR+FF       [248] <sup>64</sup> Ni+ <sup>116</sup> Sn       157.41       4.31       9.36       0       0.036       0.178       EvR+FF       [248] <sup>64</sup> Ni+ <sup>120</sup> Sn       156.44       3.54       9.33       0       0.036       0.178       EvR+FF       [248] <sup>64</sup> Ni+ <sup>122</sup> Sn       155.99       2.26       9.41       3.600       0.018       0.083       EvR+FF       [248] <sup>74</sup> Ce+ <sup>74</sup> Ce       122.45       3.47       8.21       1.515       0.585       1.154       EvR       [256] <sup>81</sup> Br+ <sup>94</sup> Zr       156.41       4.39       7.58       0       0.011       0.044       EvR       [257] <sup>86</sup> Kr <sup>176</sup> Ce       131.48       2.43       9.27       2	<sup>64</sup> Ni+ <sup>92</sup> Mo	135.86	3.04	9.41	0	0.400	1.219	EvR	[246]
<sup>64</sup> Ni+ <sup>112</sup> Sn       157.61       2.69       8.64       3.062       0.195       0.913       EVR+FF       [248] <sup>64</sup> Ni+ <sup>114</sup> Sn       158.85       4.08       9.37       0       0.000       0.000       EVR+FF       [248] <sup>64</sup> Ni+ <sup>116</sup> Sn       158.847       3.92       10.02       0       0.180       0.843       EVR+FF       [248] <sup>64</sup> Ni+ <sup>113</sup> Sn       157.41       4.31       9.36       0       0.481       0.757       EVR+FF       [248] <sup>64</sup> Ni+ <sup>112</sup> Sn       156.44       3.54       9.33       0       0.036       0.178       EVR+FF       [248] <sup>64</sup> Ni+ <sup>122</sup> Sn       155.99       2.26       9.41       3.600       0.018       0.083       EVR+FF       [248] <sup>64</sup> Ni+ <sup>124</sup> Sn       154.87       2.85       9.60       0       0.034       0.172       EVR+FF       [248] <sup>64</sup> Ni+ <sup>124</sup> Sn       154.87       2.85       9.60       0       0.011       0.044       EVR       [256] <sup>86</sup> Kr+ <sup>76</sup> Ge       133.71       2.88       9.10       1.737       7.133       7.799       EVR       [258] <sup>124</sup> Sn+ <sup>48</sup> Ca       131.69       1.80       9.99 <td< td=""><td><sup>64</sup>Ni+<sup>100</sup>Mo</td><td>134.56</td><td>3.34</td><td>7.78</td><td>0.793</td><td>0.246</td><td>0.979</td><td>EvR</td><td>[246]</td></td<>	<sup>64</sup> Ni+ <sup>100</sup> Mo	134.56	3.34	7.78	0.793	0.246	0.979	EvR	[246]
1.11.11.00.040.040.000.100.100.100.1010.110.0000.0000.0000.0000.0000.0000.0000.0000.0010.0010.0010.0010.0010.0010.0010.0010.0010.0010.0010.010.0010.010.0010.010.001	<sup>64</sup> Ni+ <sup>112</sup> Sn	157.61	2 69	8 64	3 062	0 195	0 913	FvR+FF	[248]
Nr51138.34.009.3700.0000.0000.0000.0000.0070.0071245164Ni+16Sn158.473.9210.0200.1800.8410.757EVR+FF[248]64Ni+120Sn156.443.549.3300.0360.178EVR+FF[248]64Ni+122Sn155.992.269.413.6000.0180.083EVR+FF[248]64Ni+124Sn154.872.859.6000.0340.172EVR+FF[248]64Ni+124Sn154.872.859.6000.0340.172EVR+FF[248]81Br+94Zr156.414.397.5800.0110.044EVR[257]86Kr+76Ge131.482.439.272.1011.9600.587EVR[258]86Kr+76Ga131.691.809.991.2732.5091.601EVR[259]124Sn+48Ca113.691.809.991.2732.5091.601EVR[259]132Sn+40Ca115.242.9811.061.2411.2352.956EVR[259]132Sn+64Ni151.095.838.2300.2210.418EVR+FF[261]132Sn+64Ni151.095.838.2300.5310.426EVR[261]132Sn+64Ni15.613.0811.973.8650.0900.198EVR+FF[262]132Sn+64Ni15.613.0811.973.865	64 Ni+114 Cp	157.01	2.05	0.04	0.002	0.155	0.010	EVICTI	[240]
	64 NI 116 C-	150.03	4.00	J.J/	0	0.000	0.000		[240]
<sup>64</sup> Ni+ <sup>110</sup> Sn         157.41         4.31         9.36         0         0.481         0.757         EVR+FF         [254,255] <sup>64</sup> Ni+ <sup>120</sup> Sn         156.44         3.54         9.33         0         0.036         0.178         EVR+FF         [248] <sup>64</sup> Ni+ <sup>122</sup> Sn         155.99         2.26         9.41         3.600         0.018         0.083         EVR+FF         [248] <sup>64</sup> Ni+ <sup>122</sup> Sn         154.87         2.85         9.60         0         0.034         0.172         EVR+FF         [248] <sup>74</sup> Ce+ <sup>74</sup> Ge         122.45         3.47         8.21         1.515         0.585         1.154         EvR         [256] <sup>81</sup> Br+ <sup>94</sup> Zr         156.41         4.39         7.58         0         0.011         0.044         EvR         [258] <sup>86</sup> Kr <sup>70</sup> Ge         133.71         2.88         9.10         1.737         7.133         7.799         EvR         [258] <sup>124</sup> Sn+ <sup>44</sup> Ca         113.18         2.38         9.66         0.889         0.582         0.362         EvR         [259] <sup>124</sup> Sn+ <sup>44</sup> Ca         113.69         1.80         9.99         1.273         2.509         1.601         Ev	64NF 118 C	158.47	3.92	10.02	0	0.180	0.843	EVK+FF	[248]
b <sup>4</sup> Ni+ <sup>120</sup> Sn       156.44       3.54       9.33       0       0.036       0.178       EvR+FF       [248]         6 <sup>4</sup> Ni+ <sup>122</sup> Sn       155.99       2.26       9.41       3.600       0.018       0.083       EvR+FF       [248]         6 <sup>4</sup> Ni+ <sup>124</sup> Sn       154.87       2.85       9.60       0       0.034       0.172       EvR+FF       [248]         7 <sup>4</sup> Ge+ <sup>74</sup> Ge       122.45       3.47       8.21       1.515       0.585       1.154       EvR       [256] <sup>81</sup> Br+ <sup>94</sup> Zr       156.41       4.39       7.58       0       0.011       0.044       EvR       [258] <sup>86</sup> Kr+ <sup>76</sup> Ge       131.48       2.43       9.27       2.101       1.960       0.587       EvR       [258] <sup>124</sup> Sn+ <sup>40</sup> Ca       113.18       2.38       9.66       0.889       0.582       0.362       EvR       [259] <sup>124</sup> Sn+ <sup>40</sup> Ca       113.69       1.80       9.99       1.273       2.509       1.601       EvR       [259] <sup>124</sup> Sn+ <sup>40</sup> Ca       115.24       2.98       11.06       1.241       1.235       2.956       EvR KFF       [260] <sup>132</sup> Sn+ <sup>54</sup> Ni       151.09       5.83       8.23 <t< td=""><td><sup>64</sup>Ni+<sup>118</sup>Sn</td><td>157.41</td><td>4.31</td><td>9.36</td><td>0</td><td>0.481</td><td>0.757</td><td>EvR+FF</td><td>254,255</td></t<>	<sup>64</sup> Ni+ <sup>118</sup> Sn	157.41	4.31	9.36	0	0.481	0.757	EvR+FF	254,255
64 Ni+ <sup>122</sup> Sn       155.99       2.26       9.41       3.600       0.018       0.083       EvR+FF       [248]         64 Ni+ <sup>124</sup> Sn       154.87       2.85       9.60       0       0.034       0.172       EvR+FF       [248]         74 Ge+ <sup>74</sup> Ge       122.45       3.47       8.21       1.515       0.585       1.154       EvR       [256]         8 <sup>1</sup> Br+ <sup>94</sup> Zr       156.41       4.39       7.58       0       0.011       0.044       EvR       [257]         8 <sup>6</sup> Kr+ <sup>70</sup> Ge       133.71       2.88       9.10       1.737       7.133       7.799       EvR       [258]         8 <sup>6</sup> Kr+ <sup>76</sup> Ge       131.48       2.43       9.27       2.101       1.960       0.582       0.362       EvR       [258]         1 <sup>124</sup> Sn+ <sup>40</sup> Ca       113.18       2.38       9.66       0.889       0.582       0.362       EvR       [259]         1 <sup>124</sup> Sn+ <sup>40</sup> Ca       113.69       1.80       9.99       1.273       2.509       1.601       EvR       [259]         1 <sup>124</sup> Sn+ <sup>40</sup> Ca       115.24       2.98       11.06       1.241       1.235       2.956       EvR +FF       [260]         1 <sup>132</sup> Sn+ <sup>64</sup> Ni       151.09       5.83	<sup>64</sup> Ni+ <sup>120</sup> Sn	156.44	3.54	9.33	0	0.036	0.178	EvR+FF	[248]
<sup>64</sup> Ni+ <sup>124</sup> Sn154.872.859.6000.0340.172EvR+FF[248] <sup>74</sup> Ge+ <sup>74</sup> Ge122.453.478.211.5150.5851.154EvR[256] <sup>81</sup> Br+ <sup>94</sup> Zr156.414.397.5800.0110.044EvR[257] <sup>86</sup> Kr+ <sup>70</sup> Ge133.712.889.101.7377.1337.799EvR[258] <sup>86</sup> Kr+ <sup>76</sup> Ge131.482.439.272.1011.9600.587EvR[258] <sup>124</sup> Sn+ <sup>40</sup> Ca113.182.389.660.8890.5820.362EvR[259] <sup>124</sup> Sn+ <sup>40</sup> Ca113.691.809.991.2732.5091.601EvR[259] <sup>124</sup> Sn+ <sup>40</sup> Ca115.242.9811.061.2411.2352.956EvR[259] <sup>123</sup> Sn+ <sup>40</sup> Ni150.454.2611.3200.1520.199EvR+FF[260] <sup>132</sup> Sn+ <sup>64</sup> Ni151.095.838.2300.2210.418EvR[261] <sup>132</sup> Sn+ <sup>64</sup> Ni157.613.0811.973.8650.0900.198EvR+FF[262] <sup>134</sup> Te+ <sup>64</sup> Ni164.212.679.221.8160.3170.455EvR[263] <sup>208</sup> Pb+ <sup>50</sup> Ti194.552.227.832.7910.7970.675FF(48]	<sup>64</sup> Ni+ <sup>122</sup> Sn	155.99	2.26	9.41	3.600	0.018	0.083	EvR+FF	[248]
<sup>74</sup> Ge <sup>+74</sup> Ge       122.45       3.47       8.21       1.515       0.585       1.154       EvR       [256] <sup>81</sup> Br+ <sup>94</sup> Zr       156.41       4.39       7.58       0       0.011       0.044       EvR       [257] <sup>86</sup> Kr+ <sup>70</sup> Ge       133.71       2.88       9.10       1.737       7.133       7.799       EvR       [258] <sup>86</sup> Kr+ <sup>76</sup> Ge       131.48       2.43       9.27       2.101       1.960       0.587       EvR       [258] <sup>124</sup> Sn+ <sup>40</sup> Ca       113.18       2.38       9.66       0.889       0.582       0.362       EvR       [259] <sup>124</sup> Sn+ <sup>40</sup> Ca       113.69       1.80       9.99       1.273       2.509       1.601       EvR       [259] <sup>124</sup> Sn+ <sup>40</sup> Ca       115.24       2.98       11.06       1.241       1.235       2.956       EvR       [259] <sup>132</sup> Sn+ <sup>40</sup> Ca       115.24       2.98       11.06       1.241       1.235       2.956       EvR+FF       [260] <sup>132</sup> Sn+ <sup>54</sup> Ni       159.45       4.26       11.32       0.708       0.152       0.199       EvR+FF       [261] <sup>132</sup> Sn+ <sup>64</sup> Ni       151.09       5.83       8.23	<sup>64</sup> Ni+ <sup>124</sup> Sn	154.87	2.85	9.60	0	0.034	0.172	EvR+FF	248
81Br+94Zr       156.41       4.39       7.58       0       0.011       0.044       EvR       [257]         86Kr+ <sup>70</sup> Ge       133.71       2.88       9.10       1.737       7.133       7.799       EvR       [258]         86Kr+ <sup>76</sup> Ge       131.48       2.43       9.27       2.101       1.960       0.587       EvR       [258]         124Sn+ <sup>40</sup> Ca       113.18       2.38       9.66       0.889       0.582       0.362       EvR       [259]         124Sn+ <sup>40</sup> Ca       113.69       1.80       9.99       1.273       2.509       1.601       EvR       [259]         132Sn+ <sup>40</sup> Ca       115.24       2.98       11.06       1.241       1.235       2.956       EvR       [259]         1 <sup>32</sup> Sn+ <sup>40</sup> Ca       115.24       2.98       11.06       1.241       1.235       2.956       EvR       [259]         1 <sup>32</sup> Sn+ <sup>40</sup> Ca       115.24       2.98       1.061       1.241       1.235       2.956       EvR       [261]         1 <sup>32</sup> Sn+ <sup>64</sup> Ni       151.09       5.83       8.23       0       0.221       0.418       EvR       [261]         1 <sup>32</sup> Sn+ <sup>64</sup> Ni       157.61       3.08       11.97       3.865       <	<sup>74</sup> Ce+ <sup>74</sup> Ce	122 45	3 47	8 2 1	1 5 1 5	0.585	1 154	FvR	[256]
h1 + 21       150,41       4.35       7.38       0       0.011       0.044       EVR       [257]         86 Kr+70 Ge       133,71       2.88       9.10       1.737       7.133       7.799       EvR       [258]         86 Kr+76 Ge       131,48       2.43       9.27       2.101       1.960       0.587       EvR       [259]         124 Sn+40 Ca       113,18       2.38       9.66       0.889       0.582       0.362       EvR       [259]         124 Sn+48 Ca       113.69       1.80       9.99       1.273       2.509       1.601       EvR       [259]         132 Sn+40 Ca       115.24       2.98       11.06       1.241       1.235       2.956       EvR       [259]         132 Sn+40 Ca       115.24       2.98       11.06       1.241       1.235       2.956       EvR (261)         132 Sn+40 Ca       115.24       2.98       11.06       1.241       1.235       2.956       EvR (261)         132 Sn+64 Ni       151.09       5.83       8.23       0       0.221       0.418       EvR (262)         132 Sn+64 Ni       157.61       3.08       11.97       3.865       0.090       0.198       EvR+FF <td><sup>81</sup> Pr+<sup>94</sup>7r</td> <td>156 /1</td> <td>4 20</td> <td>7.59</td> <td>0</td> <td>0.011</td> <td>0.044</td> <td>EVR</td> <td>[250]</td>	<sup>81</sup> Pr+ <sup>94</sup> 7r	156 /1	4 20	7.59	0	0.011	0.044	EVR	[250]
N° GC133.7 12.889.101.7377.1337.799EVR[258] $^{86}$ Kr+76Ge131.482.439.272.1011.9600.587EvR[259] $^{124}$ Sn+40Ca113.182.389.660.8890.5820.362EvR[259] $^{124}$ Sn+40Ca113.691.809.991.2732.5091.601EvR[259] $^{122}$ Sn+40Ca115.242.9811.061.2411.2352.956EvR[259] $^{122}$ Sn+58Ni159.454.2611.320.7080.1520.199EvR+FF[260] $^{122}$ Sn+64Ni151.095.838.2300.2210.418EvR[261] $^{132}$ Sn+64Ni157.613.0811.973.8650.0900.198EvR+FF[262] $^{134}$ Te+44OCa116.792.288.7900.5310.426EvR[263] $^{134}$ Te+64Ni164.212.679.221.8160.3170.455EvR[264] $^{208}$ Pb+50Ti194.552.227.832.7910.7970.675FF[48]	86Vr+70Co	100.41	1.00	7.50	1 7 7 7	0.011	7 700	EVIN	[257]
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	NT Ge	100./1	2.88	9.10	1./3/	1.022	1.199	EVK	[258]
$^{124}$ Sn+"*Ca113.182.389.660.8890.5820.362EvR[259] $1^{124}$ Sn+ <sup>48</sup> Ca113.691.809.991.2732.5091.601EvR[259] $1^{32}$ Sn+ <sup>40</sup> Ca115.242.9811.061.2411.2352.956EvR * [260] $1^{32}$ Sn+ <sup>58</sup> Ni159.454.2611.320.7080.1520.199EvR+FF[260] $1^{32}$ Sn+ <sup>64</sup> Ni151.095.838.2300.2210.418EvR * [261] $1^{32}$ Sn+ <sup>64</sup> Ni157.613.0811.973.8650.0900.198EvR+FF[262] $1^{34}$ Te+ <sup>40</sup> Ca116.792.288.7900.5310.426EvR[263] $1^{34}$ Te+ <sup>64</sup> Ni164.212.679.221.8160.3170.455EvR[264] $2^{08}$ Pb+ <sup>50</sup> Ti194.552.227.832.7910.7970.675FF[48]	<sup>55</sup> Kr+ <sup>75</sup> Ge	131.48	2.43	9.27	2.101	1.960	0.587	EVR	[258]
124 Sn+48 Ca113.691.809.991.2732.5091.601EvR[259]132 Sn+40 Ca115.242.9811.061.2411.2352.956EvR[259]132 Sn+58 Ni159.454.2611.320.7080.1520.199EvR+FF[260]132 Sn+64 Ni151.095.838.2300.2210.418EvR[261]132 Sn+64 Ni157.613.0811.973.8650.0900.198EvR+FF[262]134 Te+40 Ca116.792.288.7900.5310.426EvR[263]134 Te+64 Ni164.212.679.221.8160.3170.455EvR[264]208 Pb+50 Ti194.552.227.832.7910.7970.675FF[48]	<sup>124</sup> Sn+ <sup>40</sup> Ca	113.18	2.38	9.66	0.889	0.582	0.362	EvR	[259]
132 Sn+40 Ca115.242.9811.061.2411.2352.956EvR[259]132 Sn+58 Ni159.454.2611.320.7080.1520.199EvR+FF[260]132 Sn+64 Ni151.095.838.2300.2210.418EvR[261]132 Sn+64 Ni157.613.0811.973.8650.0900.198EvR+FF[262]134 Te+40 Ca116.792.288.7900.5310.426EvR[263]134 Te+64 Ni164.212.679.221.8160.3170.455EvR[264]208 Pb+50 Ti194.552.227.832.7910.7970.675FF[48]	<sup>124</sup> Sn+ <sup>48</sup> Ca	113.69	1.80	9.99	1.273	2.509	1.601	EvR	[259]
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	<sup>132</sup> Sn+ <sup>40</sup> Ca	115.24	2.98	11.06	1.241	1.235	2.956	EvR	[259]
132 Sn+64 Ni151.095.838.2300.210.418EvR[261]132 Sn+64 Ni157.613.0811.973.8650.0900.198EvR+FF[262]134 Te+40 Ca116.792.288.7900.5310.426EvR[263]134 Te+64 Ni164.212.679.221.8160.3170.455EvR[264]208 Pb+50 Ti194.552.227.832.7910.7970.675FF[48]	<sup>132</sup> Sn+ <sup>58</sup> Ni	159.45	4.26	11.32	0.708	0.152	0.199	EvR+FF	[260]
132 Sn+64Ni         157.61         3.05         6.22         0.416         EVR         [201]           132 Sn+64Ni         157.61         3.08         11.97         3.865         0.090         0.198         EvR+FF         [262]           134 Te+ <sup>40</sup> Ca         116.79         2.28         8.79         0         0.531         0.426         EvR         [263]           134 Te+ <sup>64</sup> Ni         164.21         2.67         9.22         1.816         0.317         0.455         EvR         [264]           208 Pb+ <sup>50</sup> Ti         194.55         2.22         7.83         2.791         0.797         0.675         FF         [48]	132 Sn+64 Ni	151.00	5.83	8.22	0.700 N	0.132	0 / 19	EvR	[261]
Silt13/103.0811.975.8650.0900.198EVR+FF[262] $1^{34}$ Te+ $^{40}$ Ca116.792.288.7900.5310.426EvR[263] $1^{34}$ Te+ $^{64}$ Ni164.212.679.221.8160.3170.455EvR[264] $2^{208}$ Pb+ $^{50}$ Ti194.552.227.832.7910.7970.675FF[48]	132 cm + 64 Ni	151.05	2.02	0.20	2005	0.221	0.410	EVIN	[201]
$^{10}$ Te+**Ca116./92.288./900.5310.426EvR[263] $^{134}$ Te+ $^{64}$ Ni164.212.679.221.8160.3170.455EvR[264] $^{208}$ Pb+ $^{50}$ Ti194.552.227.832.7910.7970.675FF[48]	311T INI 134T 40 C	10/.01	5.08	11.97	5.00.0	0.090	0.198	EVK+FF	[202]
1°47 Te+°4 Ni         164.21         2.67         9.22         1.816         0.317         0.455         EvR         [264]           208 Pb+ <sup>50</sup> Ti         194.55         2.22         7.83         2.791         0.797         0.675         FF         [48]	124 E4	116.79	2.28	8.79	U	0.531	0.426	EVR	[263]
<sup>2us</sup> Pb+ <sup>3u</sup> Ti 194.55 2.22 7.83 2.791 0.797 0.675 FF [48]	<sup>134</sup> Te+ <sup>04</sup> Ni	164.21	2.67	9.22	1.816	0.317	0.455	EvR	[264]
	<sup>208</sup> Pb+ <sup>50</sup> Ti	194.55	2.22	7.83	2.791	0.797	0.675	FF	[48]

#### **Declaration of competing interest**

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Ning Wang reports financial support was provided by National Natural Science Foundation of China. Min Liu reports financial support was provided by National Natural Science Foundation of China. Ning Wang reports financial support was provided by Natural Science Foundation of Guangxi. Junlong Tian reports financial support was provided by Natural Science Foundation of Guangxi.

# Data availability

Data available at http://www.imgmd.com/fusion/MSW\_barrie r.txt.

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### Appendix

See Table A.

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