Atomic Data and Nuclear Data Tables 99 (2013) 69–95

Contents lists available at SciVerse ScienceDirect

Atomic Data and Nuclear Data Tables

journal homepage: www.elsevier.com/locate/adt

# Table of experimental nuclear ground state charge radii: An update

I. Angeli [a], K.P. Marinova [b,*]

[a] Institute of Experimental Physics, University of Debrecen, H-4010 Debrecen Pf. 105, Hungary

[b] Joint Institute for Nuclear Research, 141980 Dubna, Moscow Region, Russia

ARTICLE INFO

*Article history:*
Received 9 August 2011
Received in revised form
10 November 2011
Accepted 2 December 2011
Available online 12 December 2012

*Keywords:*
Nuclear charge radii
Radii changes
Optical isotope shifts
$K_\alpha$ X-ray isotope shifts
Electron scattering
Muonic atom spectra

ABSTRACT

The present table contains experimental root-mean-square (*rms*) nuclear charge radii $R$ obtained by combined analysis of two types of experimental data: (i) radii changes determined from optical and, to a lesser extent, $K_\alpha$ X-ray isotope shifts and (ii) absolute radii measured by muonic spectra and electronic scattering experiments. The table combines the results of two working groups, using respectively two different methods of evaluation, published in ADNDT earlier. It presents an updated set of *rms* charge radii for 909 isotopes of 92 elements from $_1$H to $_{96}$Cm together, when available, with the radii changes from optical isotope shifts. Compared with the last published tables of $R$-values from 2004 (799 ground states), many new data are added due to progress recently achieved by laser spectroscopy up to early 2011. The radii changes in isotopic chains for He, Li, Be, Ne, Sc, Mn, Y, Nb, Bi have been first obtained in the last years and several isotopic sequences have been recently extended to regions far off stability, (e.g., Ar, Mo, Sn, Te, Pb, Po).



* Corresponding author. Tel.: +7 4962162084; fax: +7 49621 65083.
*E-mail address:* marinova@nrmail.jinr.ru (K.P. Marinova).

0092-640X/$ – see front matter © 2012 Elsevier Inc. All rights reserved.
doi:10.1016/j.adt.2011.12.006

**Contents**



## 1. Introduction

The nuclear charge radius is one of the most obvious and important nuclear parameters that give information about the nuclear shell model and the influence of effective interactions on nuclear structure. Experimental information on root-mean-square (*rms*) nuclear charge radii can be derived from different sources and has been published several times. The results from electron scattering ($e^-$) experiments are expressed in terms of the *rms* radius, and, for some nuclei, in parameters of the Fermi-distribution [1,2]. Muonic X-ray energies are another source of information. These probe somewhat different moments of nuclear distribution, the so called “Barrett moments” $\langle r^k e^{-\alpha r}\rangle$, nevertheless the results are quoted also in terms of $\langle r^2\rangle$ [3,4]. Optical and $K_\alpha$ X-ray isotope shifts are sensitive to the same nuclear parameters and provide an important source of complementary information on mean square (*ms*) radii changes $\delta\langle r^2\rangle$. The $K_\alpha$X results are easier to interpret; however, these measurements can be performed only on stable isotopes since the experimental method requires several tens of milligrams of target. The same refers to experiments with $\mu^-$ atoms and electron scattering $e^-$, while optical isotope shifts (OIS) can be measured with negligible quantities of radioactive atoms, inclusive single ones, with lifetimes down to 1 ms, and thus give access to long chains of radioactive isotopes extending far off stability [5,6].

The four electromagnetic methods are sensitive to different properties of the nuclear ground-state charge distributions. For this reason, a combination of data from different experimental methods generally yields more detailed and accurate knowledge of the nuclear radii than is available from any single method alone.

Many new data on isotope shift measurements have been published in recent years; therefore, it is again the right moment to see another summary of facts and trends in the field. This is already done in the recent paper [7], which presents and discusses not only the isotopic trend of nuclear charge radii but also a full systematic of isotonic shifts extracted from the wealth of data. Special attention is paid to the structural evolution along the isotonic and isotopic chains around the “traditional” magic numbers 8, 20, 28, 50, 82 and 126 and to the appearance of new non-traditional magic numbers especially in the region of light nuclei. However, discussing the consequences of the *R*-tabulation, the paper [7] does not give numerical values of *R*’s. The latter, together with short explanations, are accessible online in the database of the Lomonosov Moscow State University, Skobeltsyn Institute of Nuclear Physics and are presented as three different data sets (see Refs. [8–10]). A modified and updated version can be found in the site Data Library of NDS IAEA [11] as a single data set.

The purpose of this paper is to present in a compact form the numerical values of the experimental *rms* charge radii obtained by a combined treatment of the experimental data of both types — *R* and $\delta\langle r^2\rangle$. The results of two different methods of data evaluation [12,13] are combined into a single data set (Table 1). This is for the benefit of data users, who generally prefer a single, unified data set to several separate tables. Also a few new data are added, due to the last achievements of laser spectroscopy (see references to Table 2). Therefore, the resulting tabulation of radii covers a broader range of *Z* and *N* than most recently published tables [10,11]: it contains 909 isotopes for 92 elements.

## 2. Evaluation procedures

The principle of a combined treatment is obvious: a simple relation

$$R^2(A) = R^2(A') + \delta\left\langle r^2\right\rangle^{A'A} \tag{1}$$

links the data on *rms* radii *R* ($R = \langle r^2\rangle^{1/2}$) of a stable reference isotope $A'$ with the radius change

$$\delta\langle r^2\rangle^{A'A} = \langle r^2\rangle^{A} - \langle r^2\rangle^{A'} \tag{2}$$

between $A'$ and a radioactive isotope *A*, giving the $R(A)$ value of any isotope *A* in a long isotopic sequence. The extraction of *R* according to this simple equation meets with serious statistical and computational problems in cases where there exist data on $R(A)$ for many isotopes and especially on $\delta\langle r^2\rangle$ in long isotopic chains. So far three essentially different methods of combined analysis have been developed and the tabulated *rms* charge radii have been published [4,12–14]. Details of the different data treatments can be found in the original papers. Below only a brief description is given.

In Ref. [12] an algorithm is suggested for averaging the data for all known radii of isotopes and for all known chains of radii changes between isotopic pairs of the same element. It is a least square fit procedure in which the experimental data from electron scattering ($e^-$) and muonic atom X-rays ($\mu^-$) are fitted to the more accurate radii changes in an isotopic sequence. Therefore, Ref. [12] lays stress on the ms radii changes and the resulting *R* values along long isotopic sequences correspond exactly to Eq. (1). The method has two disadvantages: (1) due to averaging over many different isotopic chains, it underestimated slightly the total uncertainties and (2) using the input data on $R_{e\mu}$ as given by [15], it doesn’t take into account any isotonic or isobaric $R_{e\mu}$ dependence.

On the contrary, in the evaluation procedure of Ref. [13], first *R* and $\delta R$ values (also from non-isotopes) were taken into account from electron scattering ($e^-$), muonic atom X-rays ($\mu^-$), $K_\alpha$ X-ray isotope shifts (*KIS*) and from optical isotope shifts *along the valley of stability*. Owing to the large number of independent and redundant *R* and $\delta R$ data, weighted averaging and several constraints were applied resulting in a more accurate and consistent set of average $R_{e\mu KO}$ and $\delta R_{e\mu KO}$ data for stable nuclei. This data set can be regarded as a “*backbone*” for the next step. The uncertainty $\Delta\delta R_{e\mu KO}$ of the average differences $\delta R_{e\mu KO}$ is significantly less than that of the input data (e.g., it is less than the (total) error $\Delta\delta R_{OIS}$

of $\delta R_{OIS}$). The reduction of the total error from $\Delta\delta R_{OIS}$ to $\Delta\delta R_{e\mu KO}$ varied from element to element between 0.2 and 0.6. As $\delta R$ values of a given isotopic series with $n$ members are linearly interrelated with each other,

$$\delta R^{A',A_k} = \delta R^{A',A} \times \sqrt{\frac{\delta\nu_{FS}^{A',A_k}}{\delta\nu_{FS}^{A',A}}} \quad k = 1, 2, \ldots, n-1 \tag{3}$$

correction factors $\delta R_{e\mu KO}/\delta R_{OIS}$ were formed; their values varied between 0.9 and 1.3 depending on the element. These factors were used to multiply those $\delta R_{OIS}$ values of the isotopic chain, for which only OIS measurements were available, thus correcting for the common – $Z$-dependent – systematic errors. These corrected series of differences ("*wings*") were added to the *backbone*. In this way a set of *rms* radii $R$ was obtained. As the correction factor has the same value for a given element, this correction does not change the *relative* trend of $R_Z(N)$ isotopic dependence. However it improves the *absolute* $R$ values, which are important for the investigation of the radius surface $R(N, Z)$ (e.g., for isotonic dependence). It is evident from the above that the $\delta R_{OIS}$ values as obtained by OIS measurements, are not to be expected to fit exactly into the system of $R$ data so derived. Thus, the algorithm [13] improves the links between different isotopic series, helping the study of isotonic and isobaric behaviour. This is its main advantage.

Fricke et al. [4,14] proposed a "model independent" way to determine parameters needed to extract radii changes from OIS using the so called King-plot [16]. This procedure essentially correlates OIS-data via King-plots with $R$, extracted from isotopic shift measurements in muonic atoms. Additional input enters from elastic electron scattering experiments wherever data are available; this concerns higher radial moments of the nuclear charge distribution. In the majority of cases the results from this model independent analysis agree passably with those obtained from electron shell data.

In all cases, the combined treatment is applicable to those elements for which both types of data, on $R$ and $\delta\langle r^2\rangle$, exist. The differences in the absolute $R$-values between these data sets are usually less than or around one percent. Although small, these differences lead to unexpected charge radii behavior in some cases of Ref. [14] which is not consistent with nuclear ground state properties. The problem is already discussed in Refs. [7,17]. On the contrary, the data sets of Refs. [8,9] are very close. Both data sets show the same fundamental properties and, what is of special importance, are consistent with gross nuclear radii trend and other nuclear ground state characteristics.

All the source data of Refs. [8,9] are carefully checked and even, when necessary, re-evaluated and updated. A careful analysis of the results has been performed, showing that the simple average values, $R_{av,}$ of the two data sets can be regarded as "the best" experimental $R$ tabulation. $R = R_{av}$ expresses in a great extent the advantages of both algorithms of combined analysis: improves the radii of stable nuclei replacing $R_{e\mu}$ by the more accurate $R_{e\mu KO}$ according to the algorithm of Ref. [13] and comprises the exact values of $\delta\langle r^2\rangle$ according to the algorithm of Ref. [12]. The uncertainties $\Delta R_{tot} = \Delta\delta R_{e\mu KO,tot}$ of the *rms* radii $R$ account for the total, statistical and systematic errors of both types of source data, as calculated by the method of Refs. [12,13]. To reflect the possible systematic discrepancies between two different evaluations we adopt a single unified set of uncertainties defined as

$$\Delta R_{tot} = \max(\Delta R\,[12], \Delta R\,[13], 0.5 \times |R\,[12] - R\,[13]|). \tag{4}$$

Only in 4% of all cases the differences between the two data sets of $R$ are dominant. This is probably due to the statistical nature of data.

The new radii tabulation (Ref. [7] and the present work) permits to draw not only qualitative but also quantitative conclusions about the isotopic and isotonic radii trend for an extended range of $Z$ and $N$: $1 \le Z \le 96$ and $1 \le N \le 152$. Let us emphasize that both data sets [8,9] on which Table 1 is based are not a result of a simple compilation of individual measurements, but contains self-consistent set of $R$ values giving a global survey of nuclear charge radii over the whole nuclide chart.

## 3. Data sources

### 3.1. Radii changes from optical isotope shift

In the algorithms of Refs. [12,13], the sources of data on nuclear parameters $\lambda$ and $\delta\langle r^2\rangle$ published before 1989 are the compilations Refs. [5,18]. Only a limited number of original papers after 1989 are used in Ref. [12], while the tables of Ref. [13] take into account a large amount of more recent results. The reference list to Table 2 of this work presents the updated data sources on $\delta\langle r^2\rangle$. About 25% of the OIS data are published or found since the previous tables from 2004 covering 799 ground states. Compared to 2004 [13], and even compared to 2008 [10], many new data are added in the present table including information up to mid 2011. The radii changes in isotopic chains for He, Li, Be, Ne, Sc, Mn, Y, Nb, Ir, Bi are either first obtained or revised in the last years and, several isotopic sequences are recently extended to regions far off stability (e.g., Ar, Mo, Sn, Te, Pb, Po). In some cases (Ca, La, Eu, Gd, Hf) only single additional radioactive isotopes are added to the already existing data. In recent papers new results on *rms* charge radii are published based on OIS measurements: $^{74}$Rb [19], $^{21-32}$Mg [20], $^{12}$Be [21] and $^{63-82}$Ga [22].

Given the fact that the previous evaluation of $\delta\langle r^2\rangle$ all over the nuclide chart [5] is already more than two decades old, we display in Table 1 also the source data on charge radii changes reflecting today's status in this research area. As many changes and improvements are included, we believe that the information on $\delta\langle r^2\rangle$ may be of general usefulness to many researchers from experimental and theoretical point of view. The details about the choice of these data and on how the displayed $\delta\langle r^2\rangle$ values have been derived are given in Table 2.

For extraction of nuclear radii changes from experimental OIS one needs to know two parameters, the so called electronic factor, $F$, related to the change in the electronic density at the nucleus for the optical transition and the mass shift constant, $MS$, accounting for the finite mass of the nucleus. The latter consists of two terms: normal, $N$, and specific, $S$, mass shift constants: $MS = N + S$. The procedure of extraction of nuclear radii changes from OIS is well known and described many times. For this reason, without going into details, we only present the equations which have been used for evaluation of $\delta\langle r^2\rangle$.

The isotope shift, i.e. the difference in frequency

$$\delta\nu^{A',A} = \nu^A - \nu^{A'} \tag{5}$$

of a particular atomic transition between two isotopes with masses $m_A$ and $m_{A'}$ can be decomposed into mass shift, $\delta\nu_{MS}$, arising from the change of the nuclear mass, and field shift $\delta\nu_{FS}$, sensitive to a change in the charge distribution inside the nucleus. It is caused by the additional neutrons and is proportional to the nuclear parameter $\lambda$:

$$\delta\nu^{A',A} = \delta\nu_{FS}^{A',A} + \delta\nu_{MS}^{A',A} = F\lambda^{A',A} + \frac{m_A - m_{A'}}{m_A m_{A'}}(N + S). \tag{6}$$

The nuclear parameter $\lambda$ takes into account the change of the electronic wave function over the nuclear volume. This requires an expansion into a power series of the radial moments of the nuclear charge distribution [23]

$$\begin{aligned}\lambda^{A',A} &= \delta\left\langle r^2\right\rangle^{A',A} + \sum \frac{C_k(Z)}{C_1(Z)}\delta\left\langle r^2\right\rangle^{2k} \\ &= \delta\left\langle r^2\right\rangle^{A',A}\left[1 + \sum_{k=1}\frac{C_k}{C_1}\delta\left\langle r^2\right\rangle^{2k}/\delta\left\langle r^2\right\rangle^{A',A}\right].\end{aligned} \tag{7}$$

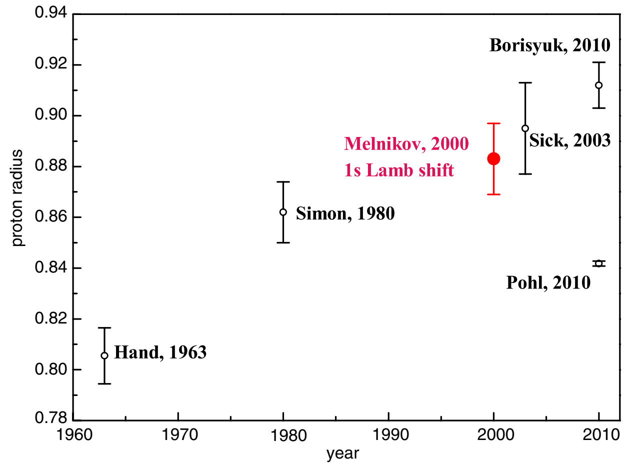


**Fig. 1.** Development of the experimental values of the proton radius during the years: Hand, 1963 [33], Simon, 1980 [34], Melnikov, 2000 [35], Sick, 2003 [36], Borisyuk, 2010 [37] and Pohl, 2010 [38].

For light nuclei, the contribution of higher order moments, the so called higher moments correction (HM), is vanishingly small, usually less than the experimental errors, and therefore $\lambda \approx \delta\langle r^2\rangle$. For the heaviest nuclei the radial moments higher than $\delta\langle r^2\rangle$ contribute almost 10%. A well developed procedure has been applied [13,14] to convert the experimental $\lambda$ into $\delta\langle r^2\rangle$. This is done for all isotopes with $Z \geq 36$.

Traditionally, $F$ has been evaluated from atomic electron shell data using either semi-empirical procedures and/or Hartree–Fock methods for calculating the relevant electronic density at the site of the nucleus. The normal mass shift constant, given by $N = \nu m_e$, is calculated with the transition frequency $\nu$ and the electronic mass $m_e$. The specific mass shift constant, $S$, accounting for the correlations of the electronic motion, can be calculated reliably only for very light elements. In all cases of medium mass and heavy elements, different kinds of semi-empirical methods have been used. These methods of $F$ and $MS$ evaluation have yielded very consistent sets of $\delta\langle r^2\rangle^{A',A}$-values [5] all over the nuclear chart and even for very long isotopic chains. They didn't produce (e.g., unreasonable crossings of the isotopic course of nuclear radii between different elements). More importantly, the results could be interpreted in quantitative agreement with other well established experimental facts of nuclear structure. For extracting the nuclear parameter $\lambda$ from OIS, the semi-empirical approach using optical information was preferred whenever possible (see Table 2 and the corresponding references).

When more than one data set on OIS is available, generally the most precise value that has been published was used. In many cases it was necessary to compile data from different sources and to reanalyze them.

### 3.2. Radii differences between isotopes from $K_\alpha$ isotope shifts

Most of the 89 $K_\alpha$ X-ray IS data are from Table II of Ref. [4], which is an extended version of Ref. [24]. Original papers have also been taken into account [25–27]. Two modifications were performed in Table II of Ref. [4]: (1) For uranium the correct mass interval is $^{233-238}$U instead of $^{235-238}$U (see Ref. [28]). (2) Regarding the results of a $\chi^2/n'$ test [29], the shift for $^{121-123}$Sb [30] was omitted and some errors increased. In the table and papers referred above, energy shifts $\delta E_{Coul}$ are given, which can be expressed in terms of even moments of the charge distribution: $\delta E_{Coul} = C_1\lambda$, where the nuclear parameter $\lambda$ contains the information on the size of the nucleus. Exploiting the wealth of $\delta R$ data from $e^-$ and $\mu^-$ experiments, it was possible to compare the theoretically calculated $C_1$ value to experiment in a wide range of atomic numbers, and to perform a small (0.965) correction on it. For more details see Section 2.5 of Ref. [13].

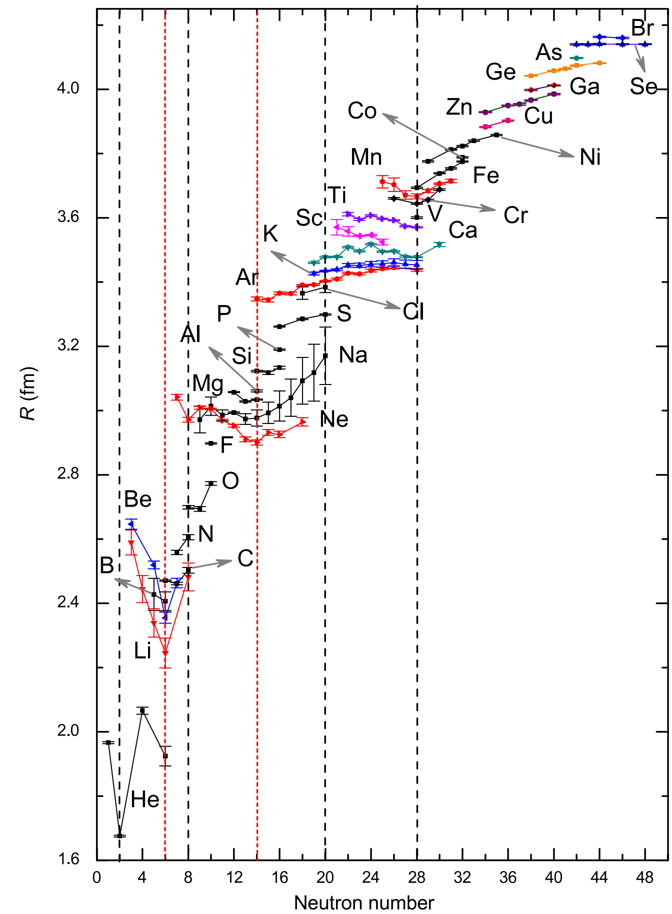


**Fig. 2.** Isotopic behaviour of *rms* charge radii for light elements from $_2$He to $_{35}$Br. For the sake of completeness the $R$-values obtained by non-optical methods are also shown. The error bars include the total, statistical and systematic uncertainties of the input data. The dashed vertical lines denote the conventional shell closures, while the small-dashed lines indicate the appearance of non-traditional magic numbers (see Ref. [7]).

### 3.3. *rms* radii from $e^-$ and $\mu^-$ experiments

The main source for the $R$ values is the table of Ref. [15] which summarizes data from a large number of $e^-$ and $\mu^-$ experiments, explaines in detail the sources and selection of these data, as well as the statistical procedure of the combined treatment of both data types. Here we briefly mention only the changes. *Change in the evaluation*: for the absolute $R$ data from $e^-$ and $\mu^-$ methods, the simpler and more transparent averaging formulae were used (*EXCEL*) instead of the lengthy (*FORTRAN*) procedure (see Chapter 4 in Ref. [15]). This resulted in small changes in the mean $R$ values. *New data*: for the stable isotopes of 9 elements, the table [15] contains *rms* radius values evaluated model independently by combining electron scattering, muonic atoms X-ray and optical isotope shifts. These are: Ca, Kr, Sr, Zr, Mo, Sn, Sm, Gd and Pb. In the first step of the present updated version of combined treatment, the $R$ values for these isotopes are recalculated using only $e^-$ and $\mu^-$ data sources and then, in a second step, two different procedures [12,13] of combined analysis with OIS data are performed. The radii of U and Th isotopes are also recalculated in view of critical remarks from Kozhedub [31].

Special attention deserves the new value for the radius of $^6$Li obtained by analysis of electronic scattering experiments data and

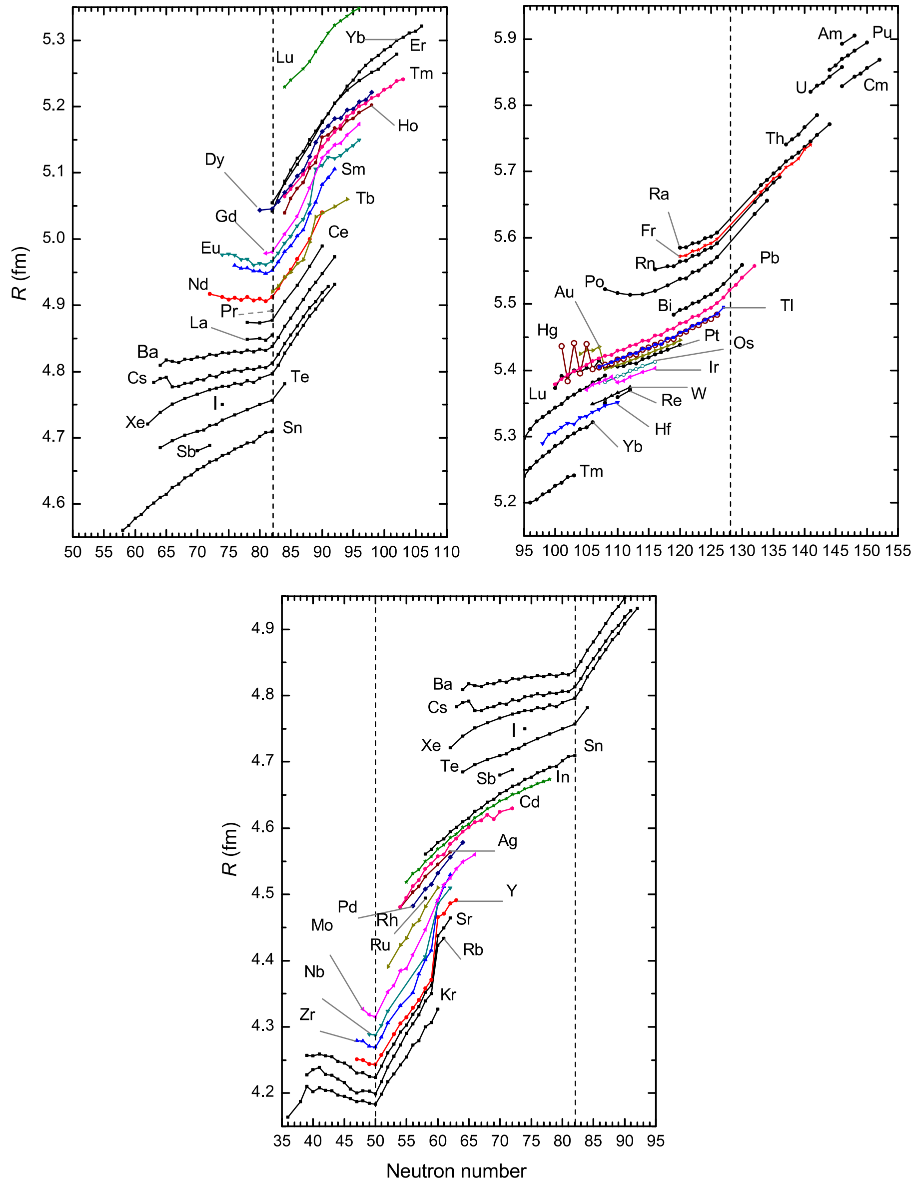


**Fig. 3.** Isotopic behaviour of *rms* charge radii for medium mass and heavy elements: from $_{36}$Kr to $_{96}$Cm. For clear presentation, these elements are grouped in three panels with identical $R$ and $N$ scales in such a way that the major neutron shell closures at $N = 50$, 82 and 126 are well pronounced.

theoretical calculations [32]. Nörtershäuser et al. [32] used this value as absolute reference for the radii in the Li isotopic chain and their results, the most correct existing data for Li, are displayed without any changes in Table 1.

Let us note that for Re, Po, Rn, Fr, Ra and Cm there are no experimental $R$ data. Reference radii $R_0$ are calculated by the formula

$$R_0 = \left( r + \frac{r_1}{A_0^{2/3}} + \frac{r_2}{A_0^{4/3}} \right) \times A_0^{1/3} \qquad (8)$$

with parameters: $r_0 = 0.9071(13)$ fm, $r_1 = 1.105(25)$ fm, $r_2 = -0.548(34)$ fm, which are the results of a least-squares fit to radii along the line of stability (see Table 2 in Ref. [13]). These parameters are correlated. Therefore for safety's sake, for the uncertainty $\Delta R_0$ the value $2 \times (\Delta R_{0,unc})$ was used, where $\Delta R_{0,unc}$ is the value calculated by the assumption of uncorrelated parameters.

It is worth considering the problems connected with the proton radius the experimental value of which strongly changed during the years (see Fig. 1 and references therein [33–38]). In 2010, a measurement of *muonic* hydrogen atom Lamb shift [38] resulted in an *rms* charge radius value $r_{p,\mu} = 0.84184(67)$ fm, which differs significantly from the earlier values obtained by electronic measurements (see e.g. 2nd paragraph in Section 2.1. of Ref. [13] and Section 5 in Ref. [7]). This strong deviation between electronic and muonic results may question the correctness of some quantum electrodynamic (QED) calculations or even the validity of the Standard Model of particle physics [39], and produced an active interest in the literature [40–44]. As this problem is not yet settled, it seems advisable to remain on the safe side, and to restrict ourselves to data derived from electronic measurements. See also [45].

## 4. Global behaviour of *rms* nuclear charge radii

Transforming $\delta\langle r^2\rangle$ into absolute *rms* radii values, one receives a global overlook on the charge radii trend in an extended region of nuclei from He to Cm. The accuracy of the combined data is high compared to that of the directly measured radii values for the same element.

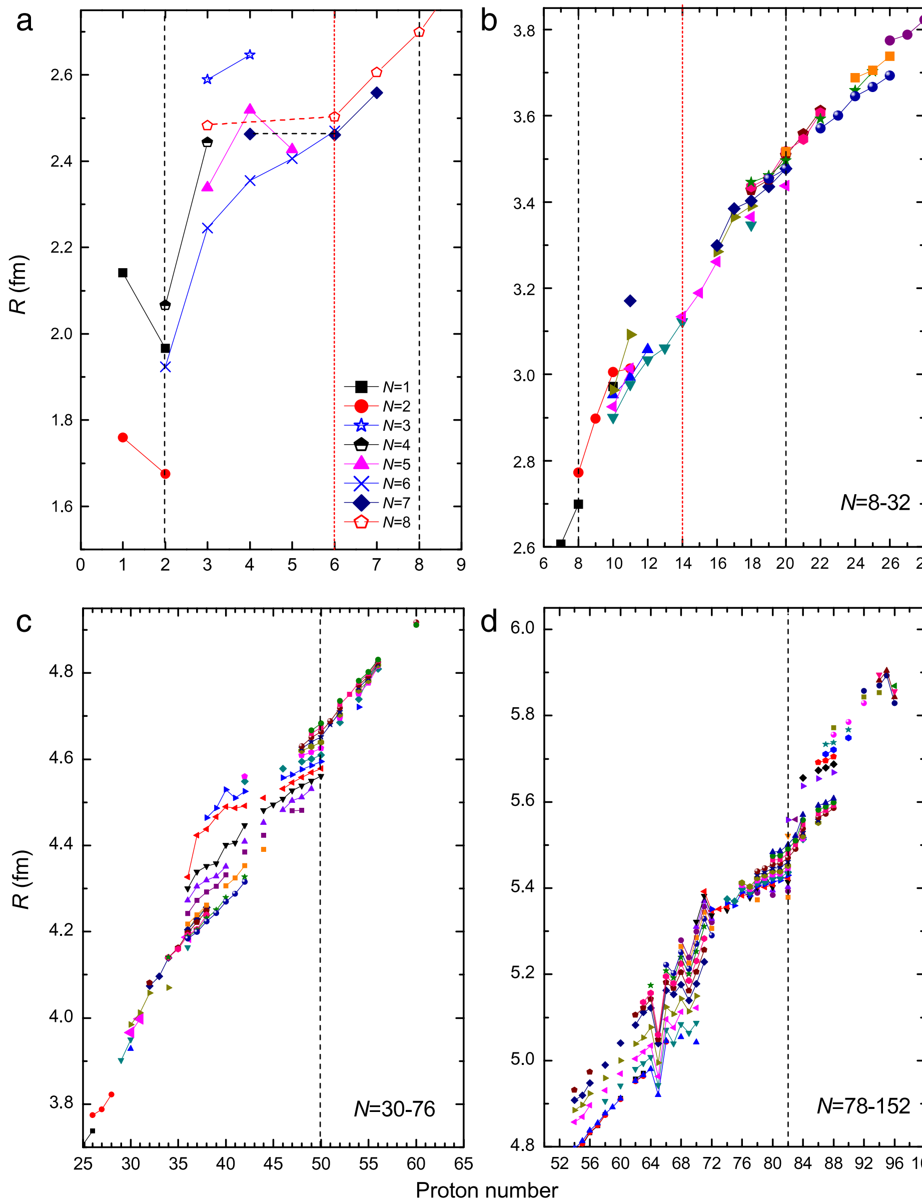


**Fig. 4.** Isotonic behaviour of *rms* radii $R$ over the whole nuclide chart. In this case only the $R$-scales in all panels are identical. For visual simplicity only even $N$ curves are drawn in panels (b)–(d). Special attention is paid to the region of light elements: panel (a), elements from $_1$H to $_8$O where isotonic curves for all odd and even $N$-values are drawn.

The dependences of the *rms* nuclear radii on neutron number $N$ and proton number $Z$ are demonstrated in Figs. 2–4. Adding new data to that of Ref. [10] does not influence the global features of the isotopic (Figs. 2 and 3) and the isotonic (Fig. 4a–d) radii developments. Different aspects of the nuclear radii tabulation can be considered. Those include (i) general features of the isotopic and isotonic trends; (ii) appearance of non-traditional magic numbers; (iii) new exotic phenomena that have been observed in the region of light nuclei; (iv) influence of the deformations; (v) data reliability, and (vi) comparison between theory and experiment. As all consequences of the radii tabulation are already discussed in detail in our previous work [7], here we summarize briefly only those which refer to the appearance or disappearance of magic numbers.

The conventional nucleon magic numbers 2, 28, 50 and 82 are evident from the charge radii development. The effect can be seen in Figs. 2–4 showing that the slope of the isotopic and isotonic curves is steeper at the beginning of an interval between two magic numbers and tends to saturate at the end. Therefore, the shell closure effect on the charge radii manifests itself in characteristic slope changes (kinks) of radii at magic neutron and proton numbers. As has been shown in our previous work [7], a quantitative criterium of finding shell closure effects can be applied even if the eye is uncertain in deciding about its existence. This is the case for $N = 126$ and for most of the isotonic series.

New data in the region of light nuclei are of great importance, showing interesting peculiarities. Some of those are already discussed in Ref. [7]. For example, there is a strong indication that for nuclei with $Z$ around 10, the neutron numbers $N = 6$ and $N = 14$ (or $N = 16$) may be magic or magic like instead of the conventional magic numbers $N = 8$ and $N = 20$ (see subsection 3.2 of Ref. [7]). From the point of view of isotopic nuclear radii behavior, the magic number $N = 20$ has no visible influence on the development of the charge radii in the case of stable nuclei in the Ca region (see Fig. 2). In the mass region $A = 100$, the double magicity of $^{96}$Zr [46] is also confirmed by the *rms* charge radii trend [7].

Here we call the attention on Fig. 4a, where a characteristic slope change of the isotonic curve at $Z = 6$ for $N = 8$ and also

**Table A**
Comparison of $J^\pi = 2^+$ and $4^+$ level energies, transition probabilities $B(E2)\uparrow$ and the parameters of the quadrupole deformation in the isotonic series $N = 8$ confirming the double magicity of $^{14}$C [48].

| Element | $Z$ | $E(2^+)$ (keV) | $E(4^+)/E(2^+)$ | $B(E2)\uparrow(e^2b^2)$ | $\beta_2$ |
|---|---|---|---|---|---|
| $^{12}$Be | 4 | 2102 | – | – | – |
| $^{14}$C | 6 | **7012** | **1.53** | **0.00187** | **0.360(24)** |
| $^{16}$O | 8 | 6917 | 1.72 | 0.00406 | 0.364(17) |
| $^{18}$Ne | 10 | 1887 | 1.79 | 0.0269 | 0.640(27) |

for $N = 7$ appears. It corresponds to the closure of the proton $1p_{3/2}$ subshell and is in agreement with other ground state nuclear properties, signifying magicity of the $(Z, N)$ pair $Z = 6$, $N = 8$ [47,48]. Table A illustrates some of them. The local maximum of the energy $E_1(2^+)$ of the first $2^+$ excited state, the minimum of the ratio $E_1(4^+)/E_1(2^+)$ of the energies of the first $J^\pi = 4^+$ and $J^\pi = 2^+$ states and the minimum of $B(E2)\uparrow$ transition probability at $^{14}$C are even more pronounced that in the case of the classical double magic $^{16}$O. The two isotones $^{14}$C and $^{16}$O has the same quadrupole deformation parameter $\beta_2$ smaller than $\beta_2$ for the neigbouring isotone $^{18}$Ne. As can be seen from Table A and is already shown in our previous work [7] as well as by other authors (see, e.g., Refs. [6, 49]), nuclear charge radii as a function of neutron (or proton) number correlate with other experimental spectroscopic and mass observables. Up to now there are not many attempts for searching such correlations, but they "would be highly desirable in view of the need for reliable nuclear models" [6] involving nuclei far from stability. This would provide a new perspective to study the structural evolution of nuclear ground states with $N$ and/or $Z$.

Not all conclusions in Ref. [7] are unambiguous. However this work, in a combination with the present nuclear radii tabulation, gives a ground for a more general nuclear physics discussion and is a challenge for further experiments. The data present the *status quo* of our knowledge about experimental radii values.

## Acknowledgments

The authors are grateful to W. Nörtershäuser for providing data on Li charge radii before its publishing. Thanks are due to Yu. Gangrsky for the helpful suggestions.

## References


[1] R. Hofstadter, H.R. Fechter, J.A. McIntyre, Phys. Rev. 92 (1953) 978.
[2] H. de Vries, C.W. de Jager, C. De Vries, At. Data Nucl. Data Tables 36 (1987) 495.
[3] R. Engfer, H. Schneuwly, J.L. Vuilleumier, H.K. Walter, A. Zehnder, At. Data Nucl. Data Tables 14 (1974) 409.
[4] G. Friecke, C. Bernhardt, K. Heilig, L.A. Schaller, L. Schellenberg, E.B. Shera, C.W. de Jager, At. Data Nucl. Data Tables 60 (1995) 177.
[5] E.W. Otten, in: D.A. Bromley (Ed.), Treatise on Heavy-Ion Science, 1989, pp. 517–638.
[6] H.-J. Kluge, Hyperfine Interact. 196 (2010) 295.
[7] I. Angeli, Yu.P. Gangrsky, K.P. Marinova, I.N. Boboshin, S.Yu. Komarov, B.S. Ishkhanov, V.V. Varlamov, J. Phys. G 36 (2009) 085102.
[8] I. Angeli, Recommended values of nuclear charge radii, 2008, http://cdfe.sinp.msu.ru/services/radchart/radhelp.html#rad.
[9] Yu. Gangrsky, K. Marinova, Nuclear charge radii, 2008. http://cdfe.sinp.msu.ru/services/radchart/radhelp.html#rad.
[10] Database of the Lomonosov Moscow State University, Skobeltsyn Institute of Nuclear Physics. http://cdfe.sinp.msu.ru/services/radchart/radmain.html.
[11] I. Angeli, K. Marinova, Nuclear charge radii – 2010, A newsletter of the Nuclear Data Section (NDS) Issue No. 50, 2010, 3 http://www.pub.iaea.org/MTCD/publications/PDF/Newsletters/ND-NL-50.pdf (p. 3) (see also http://www-nds.iaea.org/livechart/).
[12] E.G. Nadjakov, K.P. Marinova, Yu.P. Gangrsky, At. Data Nucl. Data Tables 56 (1994) 133.
[13] I. Angeli, At. Data Nucl. Data Tables 87 (2004) 185.
[14] G. Fricke, K. Heilig, Landolt-Börnstein: Num. Data and Funct. Relat. in Science and Tech., in: New Series, Group I: Elem. Part., Nuclei and Atoms, vol. 20, Springer Verlag, 2004, 324 pages.
[15] I. Angeli, Table of nuclear root mean square charge radii, INDC(HUN)-033, IAEA Nuclear Data Section, Vienna, 1999.
[16] W.H. King, Isotope Shift in Atomic Spectra, Plenum Press, New York, 1984.
[17] J. Libert, B. Roussière, J. Sauvage, Nuclear Phys. A 786 (2007) 47.
[18] P. Aufmuth, K. Heilig, A. Steudel, At. Data Nucl. Data Tables 87 (1987) 455.
[19] E. Mané, et al., Phys. Rev. Lett. 107 (2011) 212502.
[20] D.T. Yordanov, et al., Phys. Rev. Lett. 108 (2012) 042504.
[21] A. Krieger, et al., Phys. Rev. Lett. 108 (2012) 142501.
[22] T.J. Procter, et al., Phys. Rev. C68 (2012) 034329.
[23] E.C. Seltzer, Phys. Rev. 188 (1969) 1916.
[24] F. Boehm, P.L. Lee, At. Data Nucl. Data Tables 14 (1974) 605.
[25] P.L. Lee, F. Boehm, A.A. Hahn, Phys. Rev. C 17 (1978) 185.
[26] C.W.E. Eijk, J. Wijnhorst, M.A. Popelier, W.A. Gillespie, J. Phys. G 5 (1979) 315.
[27] S.R. Elliott, P. Beiersdorfer, M.H. Chen, Phys. Rev. Lett. 76 (1996) 1031.
[28] R.T. Brockmeier, F. Boehm, E.N. Hatch, Phys. Rev. Lett. 15 (1965) 132.
[29] I. Angeli, Hyperfine Interact. 136 (2001) 17.
[30] A.S. Rylnikov, A.I. Egorov, G.A. Ivanov, V.I. Marushenko, A.F. Mezentsev, A.I. Smirnov, O.I. Sumbaev, V.V. Fyodorov, J. Exp. Theor. Phys. 63 (1972) 53.
[31] Yu. Kozhedub, (St. Petersburg State University), private communication, 2007.
[32] W. Nörtershäuser, T. Neff, R. Sánchez, I. Sick, Phys. Rev. C 84 (2011) 024307.
[33] L.N. Hand, D.G. Miller, R. Wilson, Rev. Modern Phys. 35 (1963) 335.
[34] G.G. Simon, Ch. Schmitt, F. Borkowski, V.H. Walther, Nuclear Phys. A 333 (1980) 381.
[35] K. Melnikov, T. van Ritbergen, Phys. Rev. Lett. 84 (2000) 1673.
[36] I. Sick, Phys. Lett. B 576 (2003) 62.
[37] D. Borisyuk, Nuclear Phys. A 843 (2010) 59.
[38] R. Pohl, A. Antognini, F. Nez, et al., Nature 466 (2010) 213.
[39] J. Flowers, Nature 466 (2010) 195.
[40] M.O. Distler, J.C. Bernauer, Th. Walcher, Phys. Lett. B 696 (2011) 343.
[41] A. De Rujula, Phys. Lett. B 697 (2011) 26.
[42] U.D. Jentschura, Ann. Phys. 326 (2011) 500.
[43] U.D. Jentschura, Ann. Phys. 326 (2011) 516.
[44] G.A. Miller, A.W. Thomas, J.D. Carroll, J. Rafelski, Natural resolution of the proton size puzzle. arXiv:1101.4073v1 [physics.atom-ph] 21 Jan 2011.
[45] J.C. Bernauer, et al., Phys. Rev. Lett. 105 (2010) 242001.
[46] I.N. Boboshin, V.V. Varlamov, B.S. Ishkhanov, E.A. Romanovsky, Phys. Atomic Nuclei 70 (2007) 1363.
[47] B.A. Brown, W.A. Richter, Phys. Rev. C 72 (2005) 057301.
[48] O. Sorlin, M.-G. Porquet, Prog. Part. Nucl. Phys. 61 (2008) 602.
[49] R.B. Cakirli, R.F. Casten, K. Blaum, Phys. Rev. C 82 (2010) 061306(R).
[50] W. Nörtershäuser, Hyperfine Interact. 198 (2010) 73.

## Explanation of Tables

**Table 1.** **Nuclear radii changes and *rms* nuclear charge radii.** (The IS and charge radii changes in the isotopic sequence $^{21-32}$Mg are already measured by the Mainz-COLLAPS collaboration (see Ref. [50]) but are as yet not published. For this reason Table 1 include only $R$-values of stable Mg isotopes as given in Ref. [15].)

| | |
|---|---|
| $Z$ | Atomic (proton) number of the element |
| El | Chemical symbol of the element |
| $A$ | Mass number |
| $N$ | Neutron number |
| $\delta\langle r^2\rangle^{A',A}$ | Nuclear radii changes from OIS (column 5). $\delta\langle r^2\rangle^{A',A} = \lambda^{A',A}$ for $Z \leq 35$; in all cases with $Z \geq 36$ the higher moment (HM) corrections have been taken into account. This is done either by the authors themselves or recalculated using the average values of HM as given by Ref. [14]. |
| $\Delta\delta\langle r^2\rangle^{A',A}$ | Errors of radius changes (column 6). Only statistical errors are presented thus demonstrating the accuracy of optical isotope shift measurements. Some exceptions are explicitly pointed in Table 2. |
| $R$ | The average *rms* $R = R_{e\mu KO}$-values of both procedures of combined analysis [12,13] (column 7). Note that the experimental bases and evaluation procedures underlying these $R$ values are not identical with those for $\delta\langle r^2\rangle^{A,A'}$; see Chapter 2. |
| $\Delta_{tot}R$ | The total errors of $R$ (column 8) defined by Eq. (4). It includes the uncertainties $\Delta R$ of absolute radii, statistical and systematic errors of $\delta\langle r^2\rangle$ as obtained by the evaluation procedure of Ref. [13] and the deviation between the results of the two procedures (see Section 2). In the case if the latter are dominant, these errors are underlined. |
| $\Delta_{rel}R$ | Relative error of $R_{e\mu KO}$ with respect to the reference isotope for radii changes (Column 9). |

**Table 2.** **Parameters used for extraction of radii changes from OIS**

*Note:* References given by number are from the reference list to the main text; references given by abbreviations of name and year are from the reference list to Table 2.

| | |
|---|---|
| $F$ | Electronic factor |
| $N$ | Normal mass shift |
| $S$ | Specific mass shift |
| $MS$ | Mass shift, where $MS = N + S$ |

**Abbreviation related to the electronic factor F and the total mass shift MS**

| | |
|---|---|
| *cal* | Atomic theory calculation; for the theoretical method used (see the corresponding papers) |
| *se* | Semi-empirical procedure using optical data (e.g., Ref. [5]) |
| $e^-$, $\mu^-$, $e\mu$ | Calculated via King plot [16] of OIS versus $e^-$, $\mu^-$ or $e\mu$ radii |
| *phen* | Estimated using $\delta\langle r^2\rangle^{N',N}$ of neighboring isotones. |

**Errors of F and MS**

| | |
|---|---|
| $dF_{cal}$, $dMS_{cal}$ | Accepted 10% if not theoretically estimated |
| $dF_{se}$ | Between 1% [Bl85, table reference] and 10% (in most cases) |
| $dMS_{se}$ | For medium mass and heavy elements [He74], where $dMS_{se} = 0.5N$ for s$^2$–sp transitions with $S = (0 \pm 0.5)N$, $dMS_{se} = 0.9N$ for s–p transitions with $S = (0.3 \pm 0.9)N$ |
| $dF_{e\mu}$, $dMS_{e\mu}$ | Obtained in the least square fit procedure of King plot. |
| $dF_{phen}$, $dMS_{phen}$ | Estimations. |

**Table 1**
Nuclear radii changes and *rms* nuclear charge radii. For the neutron the entry is $\langle r^2 \rangle$ ($fm^2$).

| $Z$ | el. | $A$ | $N$ | $\delta\langle r^2\rangle$ ($fm^2$) | $\Delta\delta\langle r^2\rangle$ ($fm^2$) | $R$ (fm) | $\Delta_{tot}R$ (fm) | $\Delta R_{rel}$ |
|---|---|---|---|---|---|---|---|---|
| 0 | *n* | 1 | 1 | | | −0.1149 | 0.0027 | |
| 1 | H | **1** | **0** | **0** | **0** | **0.8783** | **0.0086** | |
| | | 2 | 1 | 3.82007 | 0.00065 | 2.1421 | 0.0088 | |
| | | 3 | 2 | | | 1.7591 | 0.0363 | |
| 2 | He | 3 | 1 | 1.059 | 0.003 | 1.9661 | 0.0030 | 0.0008 |
| | | **4** | **2** | **0** | **0** | **1.6755** | **0.0028** | **0** |
| | | 6 | 4 | 1.466 | 0.034 | 2.0660 | 0.0111 | 0.0082 |
| | | 8 | 6 | 0.911 | 0.095 | 1.9239 | 0.0306 | 0.0247 |
| 3 | Li | **6** | 3 | **0** | **0** | **2.5890** | **0.0390** | **0** |
| | | 7 | 4 | −0.731 | 0.022 | 2.4440 | 0.0420 | 0.0046 |
| | | 8 | 5 | −1.230 | 0.032 | 2.3390 | 0.0440 | 0.0070 |
| | | 9 | 6 | −1.663 | 0.032 | 2.2450 | 0.0460 | 0.0073 |
| | | 11 | 8 | −0.543 | 0.069 | 2.4820 | 0.0430 | 0.0141 |
| 4 | Be | 7 | 3 | 0.66 | 0.05 | 2.6460 | 0.0160 | 0.0094 |
| | | **9** | **5** | **0** | **0** | **2.5190** | **0.0120** | **0** |
| | | 10 | 6 | −0.79 | 0.08 | 2.3550 | 0.0170 | 0.0170 |
| | | 11 | 7 | −0.28 | 0.05 | 2.4630 | 0.0150 | 0.0102 |
| 5 | B | 10 | 5 | | | 2.4277 | 0.0499 | |
| | | 11 | 6 | | | 2.4060 | 0.0294 | |
| 6 | C | 12 | 6 | | | 2.4702 | 0.0022 | |
| | | 13 | 7 | | | 2.4614 | 0.0034 | |
| | | 14 | 8 | | | 2.5025 | 0.0087 | |
| 7 | N | 14 | 7 | | | 2.5582 | 0.0070 | |
| | | 15 | 8 | | | 2.6058 | 0.0080 | |
| 8 | O | 16 | 8 | | | 2.6991 | 0.0052 | |
| | | 17 | 9 | | | 2.6932 | 0.0075 | |
| | | 18 | 10 | | | 2.7726 | 0.0056 | |
| 9 | F | 19 | 10 | | | 2.8976 | 0.0025 | |
| 10 | Ne | 17 | 7 | 0.221 | 0.029 | 3.0413 | 0.0088 | 0.0048 |
| | | 18 | 8 | −0.207 | 0.015 | 2.9714 | 0.0076 | 0.0025 |
| | | 19 | 9 | 0.017 | 0.019 | 3.0082 | 0.0040 | 0.0032 |
| | | **20** | **10** | **0** | **0** | **3.0055** | **0.0021** | **0** |
| | | 21 | 11 | −0.217 | 0.014 | 2.9695 | 0.0033 | 0.0023 |
| | | 22 | 12 | −0.322 | 0.004 | 2.9525 | 0.0040 | 0.0034 |
| | | 23 | 13 | −0.572 | 0.034 | 2.9104 | 0.0071 | 0.0057 |
| | | 24 | 14 | −0.628 | 0.019 | 2.9007 | 0.0078 | 0.0032 |
| | | 25 | 15 | −0.431 | 0.016 | 2.9316 | 0.0088 | 0.0027 |
| | | 26 | 16 | −0.485 | 0.018 | 2.9251 | 0.0100 | 0.0030 |
| | | 28 | 18 | −0.241 | 0.035 | 2.9642 | 0.0134 | 0.0059 |
| 11 | Na | 20 | 9 | −0.130 | 0.070 | 2.9718 | 0.0420 | 0.0117 |
| | | 21 | 10 | 0.120 | 0.050 | 3.0136 | 0.0284 | 0.0083 |
| | | 22 | 11 | −0.050 | 0.040 | 2.9852 | 0.0169 | 0.0067 |
| | | **23** | **12** | **0** | **0** | **2.9936** | **0.0021** | **0** |
| | | 24 | 13 | −0.120 | 0.040 | 2.9735 | 0.0169 | 0.0067 |
| | | 25 | 14 | −0.100 | 0.030 | 2.9769 | 0.0252 | 0.0050 |
| | | 26 | 15 | −0.005 | 0.018 | 2.9928 | 0.0331 | 0.0030 |
| | | 27 | 16 | 0.120 | 0.040 | 3.0136 | 0.0467 | 0.0067 |
| | | 28 | 17 | 0.280 | 0.050 | 3.0400 | 0.0581 | 0.0083 |
| | | 29 | 18 | 0.600 | 0.080 | 3.0922 | 0.0723 | 0.0132 |
| | | 30 | 19 | 0.760 | 0.120 | 3.1180 | 0.0884 | 0.0197 |
| | | 31 | 20 | 1.090 | 0.070 | 3.1704 | 0.0893 | 0.0116 |
| 12 | Mg | 24 | 12 | | | 3.0570 | 0.0016 | |
| | | 25 | 13 | | | 3.0284 | 0.0022 | |
| | | 26 | 14 | | | 3.0337 | 0.0018 | |
| 13 | Al | 27 | 14 | | | 3.0610 | 0.0031 | |
| 14 | Si | 28 | 14 | | | 3.1224 | 0.0024 | |
| | | 29 | 15 | | | 3.1176 | 0.0052 | |
| | | 30 | 16 | | | 3.1336 | 0.0040 | |
| 15 | P | 31 | 16 | | | 3.1889 | 0.0019 | |
| 16 | S | 32 | 16 | | | 3.2611 | 0.0018 | |
| | | 34 | 18 | | | 3.2847 | 0.0021 | |
| | | 36 | 20 | | | 3.2985 | 0.0024 | |
| 17 | Cl | 35 | 18 | | | 3.3654 | 0.0191 | |
| | | 37 | 20 | | | 3.3840 | 0.0170 | |
| 18 | Ar | 32 | 14 | −0.375 | 0.038 | 3.3468 | 0.0062 | 0.0056 |
| | | 33 | 15 | −0.395 | 0.021 | 3.3438 | 0.0058 | 0.0031 |
| | | 34 | 16 | −0.251 | 0.006 | 3.3654 | 0.0040 | 0.0009 |

(*continued on next page*)

Table 1 (*continued*)

| $Z$ | el. | $A$ | $N$ | $\delta\langle r^2\rangle$ ($fm^2$) | $\Delta\delta\langle r^2\rangle$ ($fm^2$) | $R$ (fm) | $\Delta_{tot}R$ (fm) | $\Delta R_{rel}$ |
|---|---|---|---|---|---|---|---|---|
| | | 35 | 17 | −0.263 | 0.026 | 3.3636 | 0.0042 | 0.0038 |
| | | 36 | 18 | −0.084 | 0.018 | 3.3905 | 0.0023 | 0.0017 |
| | | 37 | 19 | −0.081 | 0.009 | 3.3908 | 0.0022 | 0.0012 |
| | | **38** | **20** | **0** | **0** | **3.4028** | **0.0019** | **0** |
| | | 39 | 21 | 0.044 | 0.067 | 3.4093 | 0.0031 | 0.0025 |
| | | 40 | 22 | 0.167 | 0.009 | 3.4274 | 0.0026 | 0.0013 |
| | | 41 | 23 | 0.151 | 0.012 | 3.4251 | 0.0030 | 0.0018 |
| | | 43 | 25 | 0.262 | 0.012 | 3.4414 | 0.0041 | 0.0018 |
| | | 42 | 24 | 0.221 | 0.014 | 3.4354 | 0.0039 | 0.0020 |
| | | 44 | 26 | 0.289 | 0.009 | 3.4454 | 0.0046 | 0.0013 |
| | | 46 | 28 | 0.237 | 0.022 | 3.4377 | 0.0044 | 0.0032 |
| 19 | K | 38 | 19 | −0.058 | 0.041 | 3.4264 | 0.0051 | 0.0060 |
| | | **39** | **20** | **0** | **0** | **3.4349** | **0.0019** | **0** |
| | | 40 | 21 | 0.022 | 0.002 | 3.4381 | 0.0028 | 0.0003 |
| | | 41 | 22 | 0.117 | 0.006 | 3.4518 | 0.0055 | 0.0009 |
| | | 42 | 23 | 0.116 | 0.015 | 3.4517 | 0.0070 | 0.0022 |
| | | 43 | 24 | 0.143 | 0.009 | 3.4556 | 0.0086 | 0.0013 |
| | | 44 | 25 | 0.148 | 0.011 | 3.4563 | 0.0101 | 0.0016 |
| | | 45 | 26 | 0.176 | 0.013 | 3.4605 | 0.0118 | 0.0019 |
| | | 46 | 27 | 0.143 | 0.012 | 3.4558 | 0.0126 | 0.0017 |
| | | 47 | 28 | 0.126 | 0.013 | 3.4534 | 0.0138 | 0.0019 |
| 20 | Ca | 39 | 19 | −0.127 | 0.016 | 3.4595 | 0.0025 | 0.0023 |
| | | **40** | **20** | **0** | **0** | **3.4776** | **0.0019** | **0** |
| | | 41 | 21 | 0.003 | 0.003 | 3.4780 | 0.0019 | 0.0004 |
| | | 42 | 22 | 0.215 | 0.005 | 3.5081 | 0.0021 | 0.0007 |
| | | 43 | 23 | 0.125 | 0.003 | 3.4954 | 0.0019 | 0.0005 |
| | | 44 | 24 | 0.283 | 0.006 | 3.5179 | 0.0021 | 0.0009 |
| | | 45 | 25 | 0.119 | 0.006 | 3.4944 | 0.0021 | 0.0008 |
| | | 46 | 26 | 0.124 | 0.005 | 3.4953 | 0.0020 | 0.0007 |
| | | 47 | 27 | 0.005 | 0.001 | 3.4783 | 0.0024 | 0.0002 |
| | | 48 | 28 | −0.004 | 0.006 | 3.4771 | 0.0020 | 0.0009 |
| | | 50 | 30 | 0.276 | 0.035 | 3.5168 | 0.0064 | 0.0050 |
| 21 | Sc | 42 | 21 | 0.172 | 0.031 | 3.5702 | 0.0238 | 0.0044 |
| | | 43 | 22 | 0.082 | 0.014 | 3.5575 | 0.0147 | 0.0020 |
| | | 44 | 23 | −0.019 | 0.011 | 3.5432 | 0.0016 | 0.0016 |
| | | **45** | **24** | **0** | **0** | **3.5459** | **0.0025** | **0** |
| | | 46 | 25 | −0.154 | 0.008 | 3.5243 | 0.0089 | 0.0011 |
| 22 | Ti | 44 | 22 | 0.143 | 0.037 | 3.6115 | 0.0051 | 0.0049 |
| | | 45 | 23 | 0.013 | 0.017 | 3.5939 | 0.0032 | 0.0024 |
| | | 46 | 24 | 0.110 | 0.007 | 3.6070 | 0.0022 | 0.0010 |
| | | 47 | 25 | 0.030 | 0.004 | 3.5962 | 0.0019 | 0.0006 |
| | | **48** | **26** | **0** | **0** | **3.5921** | **0.0017** | **0** |
| | | 49 | 27 | −0.139 | 0.009 | 3.5733 | 0.0021 | 0.0013 |
| | | 50 | 28 | −0.160 | 0.007 | 3.5704 | 0.0022 | 0.0010 |
| 23 | V | 51 | 28 | | | 3.6002 | 0.0022 | |
| 24 | Cr | 50 | 26 | 0.099 | 0.037 | 3.6588 | 0.0065 | 0.0051 |
| | | **52** | **28** | **0** | **0** | **3.6452** | **0.0042** | **0** |
| | | 53 | 29 | 0.043 | 0.045 | 3.6511 | 0.0075 | 0.0062 |
| | | 54 | 30 | 0.317 | 0.045 | 3.6885 | 0.0074 | 0.0061 |
| 25 | Mn | 50 | 25 | 0.046 | 0.003 | 3.7120 | 0.0196 | 0.0004 |
| | | 51 | 26 | −0.023 | 0.045 | 3.7026 | 0.0212 | 0.0061 |
| | | 52 | 27 | −0.259 | 0.013 | 3.6706 | 0.0128 | 0.0018 |
| | | 53 | 28 | −0.292 | 0.004 | 3.6662 | 0.0076 | 0.0005 |
| | | 54 | 29 | −0.165 | 0.007 | 3.6834 | 0.0049 | 0.0009 |
| | | **55** | **30** | **0** | **0** | **3.7057** | **0.0022** | **0** |
| | | 56 | 31 | 0.066 | 0.010 | 3.7146 | 0.0052 | 0.0013 |
| 26 | Fe | 54 | 28 | −0.330 | 0.001 | 3.6933 | 0.0019 | 0.0001 |
| | | **56** | **30** | **0** | **0** | **3.7377** | **0.0016** | **0** |
| | | 57 | 31 | 0.108 | 0.001 | 3.7532 | 0.0017 | 0.0001 |
| | | 58 | 32 | 0.274 | 0.002 | 3.7745 | 0.0014 | 0.0003 |
| 27 | Co | 59 | 32 | | | 3.7875 | 0.0021 | |
| 28 | Ni | 58 | 30 | −0.267 | 0.005 | 3.7757 | 0.0020 | 0.0007 |
| | | **60** | **32** | **0** | **0** | **3.8118** | **0.0016** | **0** |
| | | 61 | 33 | 0.082 | 0.007 | 3.8225 | 0.0019 | 0.0010 |
| | | 62 | 34 | 0.211 | 0.007 | 3.8399 | 0.0021 | 0.0009 |
| | | 64 | 36 | 0.338 | 0.010 | 3.8572 | 0.0023 | 0.0013 |
| 29 | Cu | 63 | 34 | | | 3.8823 | 0.0015 | |
| | | 65 | 36 | | | 3.9022 | 0.0014 | |
| 30 | Zn | 64 | 34 | −0.162 | 0.002 | 3.9283 | 0.0015 | 0.0003 |
| | | **66** | **36** | **0** | **0** | **3.9491** | **0.0014** | **0** |
| | | 67 | 37 | 0.032 | 0.003 | 3.9530 | 0.0027 | 0.0004 |

(*continued on next page*)

Table 1 (*continued*)

| $Z$ | el. | $A$ | $N$ | $\delta\langle r^2\rangle$ (fm$^2$) | $\Delta\delta\langle r^2\rangle$ (fm$^2$) | $R$ (fm) | $\Delta_{tot}R$ (fm) | $\Delta R_{rel}$ |
|---|---|---|---|---|---|---|---|---|
| | | 68 | 38 | 0.131 | 0.002 | 3.9658 | 0.0014 | 0.0003 |
| | | 70 | 40 | 0.286 | 0.003 | 3.9845 | 0.0019 | 0.0004 |
| 31 | Ga | 69 | 38 | | | 3.9973 | 0.0017 | |
| | | 71 | 40 | | | 4.0118 | 0.0018 | |
| 32 | Ge | 70 | 38 | | | 4.0414 | 0.0012 | |
| | | 72 | 40 | | | 4.0576 | 0.0013 | |
| | | 73 | 41 | | | 4.0632 | 0.0014 | |
| | | 74 | 42 | | | 4.0742 | 0.0012 | |
| | | 76 | 44 | | | 4.0811 | 0.0012 | |
| 33 | As | 75 | 42 | | | 4.0968 | 0.0020 | |
| 34 | Se | 74 | 40 | | | 4.0700 | 0.0200 | |
| | | 76 | 42 | | | 4.1395 | 0.0016 | |
| | | 77 | 43 | | | 4.1395 | 0.0018 | |
| | | 78 | 44 | | | 4.1406 | 0.0017 | |
| | | 80 | 46 | | | 4.1400 | 0.0018 | |
| | | 82 | 48 | | | 4.1400 | 0.0019 | |
| 35 | Br | 79 | 44 | | | 4.1629 | 0.0021 | |
| | | 81 | 46 | | | 4.1599 | 0.0021 | |
| 36 | Kr | 72 | 36 | −0.168 | 0.018 | 4.1635 | 0.0060 | 0.0022 |
| | | 74 | 38 | 0.030 | 0.005 | 4.1870 | 0.0041 | 0.0006 |
| | | 75 | 39 | 0.221 | 0.007 | 4.2097 | 0.0041 | 0.0008 |
| | | 76 | 40 | 0.156 | 0.004 | 4.2020 | 0.0036 | 0.0005 |
| | | 77 | 41 | 0.209 | 0.005 | 4.2082 | 0.0037 | 0.0006 |
| | | 78 | 42 | 0.172 | 0.003 | 4.2038 | 0.0033 | 0.0004 |
| | | 79 | 43 | 0.168 | 0.004 | 4.2034 | 0.0032 | 0.0005 |
| | | 80 | 44 | 0.114 | 0.007 | 4.1970 | 0.0029 | 0.0008 |
| | | 81 | 45 | 0.099 | 0.004 | 4.1952 | 0.0026 | 0.0005 |
| | | 82 | 46 | 0.071 | 0.003 | 4.1919 | 0.0025 | 0.0004 |
| | | 83 | 47 | 0.031 | 0.003 | 4.1871 | 0.0023 | 0.0004 |
| | | 84 | 48 | 0.042 | 0.001 | 4.1884 | 0.0022 | 0.0001 |
| | | 85 | 49 | 0.009 | 0.004 | 4.1846 | 0.0022 | 0.0004 |
| | | **86** | **50** | **0** | **0** | **4.1835** | **0.0021** | **0** |
| | | 87 | 51 | 0.125 | 0.003 | 4.1984 | 0.0027 | 0.0004 |
| | | 88 | 52 | 0.282 | 0.004 | 4.2171 | 0.0043 | 0.0005 |
| | | 89 | 53 | 0.379 | 0.004 | 4.2286 | 0.0054 | 0.0005 |
| | | 90 | 54 | 0.495 | 0.010 | 4.2423 | 0.0069 | 0.0012 |
| | | 91 | 55 | 0.597 | 0.006 | 4.2543 | 0.0081 | 0.0007 |
| | | 92 | 56 | 0.751 | 0.005 | 4.2724 | 0.0099 | 0.0006 |
| | | 93 | 57 | 0.811 | 0.004 | 4.2794 | 0.0107 | 0.0005 |
| | | 94 | 58 | 0.989 | 0.004 | 4.3002 | 0.0129 | 0.0005 |
| | | 95 | 59 | 1.045 | 0.003 | 4.3067 | 0.0136 | 0.0004 |
| | | 96 | 60 | 1.217 | 0.010 | 4.3267 | 0.0158 | 0.0012 |
| 37 | Rb | 76 | 39 | 0.2241 | 0.0270 | 4.2273 | 0.0070 | 0.0032 |
| | | 77 | 40 | 0.2884 | 0.0069 | 4.2356 | 0.0080 | 0.0008 |
| | | 78 | 41 | 0.3118 | 0.0023 | 4.2385 | 0.0083 | 0.0004 |
| | | 79 | 42 | 0.2291 | 0.0023 | 4.2284 | 0.0065 | 0.0003 |
| | | 80 | 43 | 0.2207 | 0.0068 | 4.2271 | 0.0061 | 0.0008 |
| | | 81 | 44 | 0.1730 | 0.0022 | 4.2213 | 0.0051 | 0.0003 |
| | | 82 | 45 | 0.1347 | 0.0065 | 4.2160 | 0.0042 | 0.0008 |
| | | 83 | 46 | 0.0522 | 0.0015 | 4.2058 | 0.0028 | 0.0002 |
| | | 84 | 47 | 0.0079 | 0.0032 | 4.1999 | 0.0023 | 0.0004 |
| | | 85 | 48 | 0.0362 | 0.0022 | 4.2036 | 0.0024 | 0.0003 |
| | | 86 | 49 | 0.0276 | 0.0031 | 4.2025 | 0.0023 | 0.0004 |
| | | **87** | **50** | **0** | **0** | **4.1989** | **0.0021** | **0** |
| | | 88 | 51 | 0.1390 | 0.0078 | 4.2170 | 0.0038 | 0.0010 |
| | | 89 | 52 | 0.3109 | 0.0031 | 4.2391 | 0.0074 | 0.0004 |
| | | 90 | 53 | 0.4370 | 0.0080 | 4.2554 | 0.0102 | 0.0010 |
| | | 91 | 54 | 0.5685 | 0.0035 | 4.2723 | 0.0131 | 0.0007 |
| | | 92 | 55 | 0.7094 | 0.0080 | 4.2903 | 0.0163 | 0.0010 |
| | | 93 | 56 | 0.9340 | 0.0035 | 4.3048 | 0.0187 | 0.0010 |
| | | 94 | 57 | 1.0984 | 0.0056 | 4.3184 | 0.0211 | 0.0011 |
| | | 95 | 58 | 1.1856 | 0.0074 | 4.3391 | 0.0248 | 0.0014 |
| | | 96 | 59 | 1.7719 | 0.0062 | 4.3501 | 0.0267 | 0.0015 |
| | | 97 | 60 | 1.8553 | 0.0150 | 4.4231 | 0.0395 | 0.0023 |
| | | 98 | 61 | 1.8553 | 0.0150 | 4.4336 | 0.0414 | 0.0024 |
| 38 | Sr | 77 | 39 | 0.253 | 0.012 | 4.2569 | 0.0044 | 0.0014 |
| | | 78 | 40 | 0.247 | 0.008 | 4.2561 | 0.0040 | 0.0009 |
| | | 79 | 41 | 0.266 | 0.006 | 4.2586 | 0.0039 | 0.0007 |
| | | 80 | 42 | 0.248 | 0.007 | 4.2562 | 0.0037 | 0.0008 |
| | | 81 | 43 | 0.236 | 0.006 | 4.2547 | 0.0034 | 0.0007 |
| | | 82 | 44 | 0.182 | 0.006 | 4.2478 | 0.0030 | 0.0007 |
| | | 83 | 45 | 0.165 | 0.004 | 4.2455 | 0.0027 | 0.0005 |

(*continued on next page*)

Table 1 (*continued*)

| $Z$ | el. | $A$ | $N$ | $\delta\langle r^2\rangle$ (fm$^2$) | $\Delta\delta\langle r^2\rangle$ (fm$^2$) | $R$ (fm) | $\Delta_{tot}R$ (fm) | $\Delta R_{rel}$ |
|---|---|---|---|---|---|---|---|---|
| | | 84 | 46 | 0.118 | 0.003 | 4.2394 | 0.0024 | 0.0004 |
| | | 85 | 47 | 0.049 | 0.003 | 4.2304 | 0.0021 | 0.0004 |
| | | 86 | 48 | 0.051 | 0.002 | 4.2307 | 0.0020 | 0.0002 |
| | | 87 | 49 | 0.007 | 0.002 | 4.2249 | 0.0019 | 0.0002 |
| | | **88** | **50** | **0** | **0** | **4.2240** | **0.0018** | **0** |
| | | 89 | 51 | 0.126 | 0.001 | 4.2407 | 0.0023 | 0.0001 |
| | | 90 | 52 | 0.282 | 0.004 | 4.2611 | 0.0037 | 0.0005 |
| | | 91 | 53 | 0.381 | 0.003 | 4.2740 | 0.0046 | 0.0004 |
| | | 92 | 54 | 0.522 | 0.005 | 4.2924 | 0.0064 | 0.0006 |
| | | 93 | 55 | 0.601 | 0.004 | 4.3026 | 0.0075 | 0.0005 |
| | | 94 | 56 | 0.728 | 0.006 | 4.3191 | 0.0091 | 0.0007 |
| | | 95 | 57 | 0.817 | 0.005 | 4.3305 | 0.0102 | 0.0006 |
| | | 96 | 58 | 0.986 | 0.006 | 4.3522 | 0.0125 | 0.0007 |
| | | 97 | 59 | 1.067 | 0.007 | 4.3625 | 0.0135 | 0.0009 |
| | | 98 | 60 | 1.656 | 0.006 | 4.4377 | 0.0214 | 0.0008 |
| | | 99 | 61 | 1.750 | 0.008 | 4.4495 | 0.0226 | 0.0011 |
| | | 100 | 62 | 1.867 | 0.015 | 4.4640 | 0.0240 | 0.0019 |
| 39 | Y | 86 | 47 | 0.071 | 0.003 | 4.2513 | 0.0023 | 0.0008 |
| | | 87 | 48 | 0.058 | 0.002 | 4.2498 | 0.0022 | 0.0007 |
| | | 88 | 49 | 0.009 | 0.001 | 4.2441 | 0.0021 | 0.0001 |
| | | **89** | **50** | **0** | **0** | **4.2430** | **0.0021** | **0** |
| | | 90 | 51 | 0.123 | 0.001 | 4.2573 | 0.0026 | 0.0014 |
| | | 92 | 53 | 0.393 | 0.001 | 4.2887 | 0.0050 | 0.0045 |
| | | 93 | 54 | 0.537 | 0.002 | 4.3052 | 0.0065 | 0.0061 |
| | | 94 | 55 | 0.614 | 0.001 | 4.3142 | 0.0074 | 0.0070 |
| | | 95 | 56 | 0.738 | 0.002 | 4.3284 | 0.0087 | 0.0083 |
| | | 96 | 57 | 0.840 | 0.001 | 4.3402 | 0.0099 | 0.0095 |
| | | 97 | 58 | 0.996 | 0.002 | 4.3580 | 0.0116 | 0.0112 |
| | | 98 | 59 | 1.110 | 0.001 | 4.3711 | 0.0129 | 0.0124 |
| | | 99 | 60 | 1.943 | 0.001 | 4.4658 | 0.0223 | 0.0213 |
| | | 100 | 61 | 1.985 | 0.001 | 4.4705 | 0.0228 | 0.0218 |
| | | 101 | 62 | 2.127 | 0.001 | 4.4863 | 0.0244 | 0.0232 |
| | | 102 | 63 | 2.173 | 0.002 | 4.4911 | 0.0249 | 0.0237 |
| 40 | Zr | 87 | 47 | 0.059 | 0.005 | 4.2789 | 0.0030 | 0.0006 |
| | | 88 | 48 | 0.061 | 0.005 | 4.2787 | 0.0025 | 0.0006 |
| | | 89 | 49 | 0.006 | 0.005 | 4.2706 | 0.0010 | 0.0006 |
| | | **90** | **50** | **0** | **0** | **4.2694** | **0.0010** | **0** |
| | | 91 | 51 | 0.132 | 0.003 | 4.2845 | 0.0013 | 0.0011 |
| | | 92 | 52 | 0.314 | 0.004 | 4.3057 | 0.0013 | 0.0025 |
| | | 94 | 54 | 0.546 | 0.003 | 4.3320 | 0.0013 | 0.0032 |
| | | 96 | 56 | 0.72 | 0.006 | 4.3512 | 0.0015 | 0.0034 |
| | | 97 | 57 | 0.835 | 0.005 | 4.3792 | 0.0136 | 0.0006 |
| | | 98 | 58 | 1.002 | 0.005 | 4.4012 | 0.0164 | 0.0006 |
| | | 99 | 59 | 1.113 | 0.004 | 4.4156 | 0.0181 | 0.0006 |
| | | 100 | 60 | 1.669 | 0.004 | 4.4891 | 0.0289 | 0.0006 |
| | | 101 | 61 | 1.847 | 0.005 | 4.5119 | 0.0318 | 0.0007 |
| | | 102 | 62 | 1.983 | 0.005 | 4.5292 | 0.0340 | 0.0008 |
| 41 | Nb | 90 | 49 | −0.301 | 0.004 | 4.2891 | 0.0040 | 0.0004 |
| | | 91 | 50 | −0.312 | 0.001 | 4.2878 | 0.0040 | 0.0001 |
| | | 92 | 51 | −0.185 | 0.002 | 4.3026 | 0.0043 | 0.0003 |
| | | **93** | **52** | **0** | **0** | **4.3240** | **0.0017** | **0** |
| | | 99 | 58 | 0.716 | 0.009 | 4.4062 | 0.0125 | 0.0010 |
| | | 101 | 60 | 1.419 | 0.002 | 4.4861 | 0.0203 | 0.0002 |
| | | 103 | 62 | 1.630 | 0.002 | 4.5097 | 0.0227 | 0.0002 |
| 42 | Mo | 90 | 48 | 0.113 | 0.001 | 4.3265 | 0.0016 | 0.0001 |
| | | 91 | 49 | 0.033 | 0.002 | 4.3182 | 0.0012 | 0.0001 |
| | | **92** | **50** | **0** | **0** | **4.3151** | **0.0012** | **0** |
| | | 94 | 52 | 0.334 | 0.001 | 4.3529 | 0.0013 | 0.0001 |
| | | 95 | 53 | 0.421 | 0.001 | 4.3628 | 0.0018 | 0.0001 |
| | | 96 | 54 | 0.617 | 0.001 | 4.3847 | 0.0015 | 0.0001 |
| | | 97 | 55 | 0.644 | 0.001 | 4.3880 | 0.0015 | 0.0001 |
| | | 98 | 56 | 0.834 | 0.001 | 4.4091 | 0.0018 | 0.0001 |
| | | 100 | 58 | 1.177 | 0.001 | 4.4468 | 0.0025 | 0.0001 |
| | | 102 | 60 | 1.585 | 0.003 | 4.4914 | 0.0038 | 0.0001 |
| | | 103 | 61 | 1.798 | 0.003 | 4.5145 | 0.0046 | 0.0002 |
| | | 104 | 62 | 1.893 | 0.002 | 4.5249 | 0.0051 | 0.0002 |
| | | 105 | 63 | 2.021 | 0.003 | 4.5389 | 0.0057 | 0.0003 |
| | | 106 | 64 | 2.113 | 0.003 | 4.5490 | 0.0058 | 0.0003 |
| | | 108 | 66 | 2.213 | 0.003 | 4.5602 | 0.0067 | 0.0003 |
| 44 | Ru | 96 | 52 | −1.069 | 0.003 | 4.3908 | 0.0047 | 0.0003 |
| | | 98 | 54 | −0.772 | 0.005 | 4.4229 | 0.0055 | 0.0005 |
| | | 99 | 55 | −0.68 | 0.004 | 4.4338 | 0.0042 | 0.0004 |
| | | 100 | 56 | −0.506 | 0.003 | 4.4531 | 0.0031 | 0.0004 |

(*continued on next page*)

Table 1 (*continued*)

| $Z$ | el. | $A$ | $N$ | $\delta\langle r^2\rangle$ (fm$^2$) | $\Delta\delta\langle r^2\rangle$ (fm$^2$) | $R$ (fm) | $\Delta_{tot}R$ (fm) | $\Delta R_{rel}$ |
|---|---|---|---|---|---|---|---|---|
| | | 101 | 57 | −0.444 | 0.005 | 4.4606 | 0.0020 | 0.0006 |
| | | 102 | 58 | −0.263 | 0.004 | 4.4809 | 0.0018 | 0.0005 |
| | | **104** | **60** | **0** | **0** | **4.5098** | **0.0020** | **0** |
| 45 | Rh | 103 | 58 | | | 4.4945 | 0.0023 | |
| 46 | Pd | 102 | 56 | −0.675 | 0.003 | 4.4827 | 0.0044 | 0.0003 |
| | | 104 | 58 | −0.445 | 0.002 | 4.5078 | 0.0027 | 0.0002 |
| | | 105 | 59 | −0.377 | 0.002 | 4.5150 | 0.0030 | 0.0002 |
| | | 106 | 60 | −0.227 | 0.001 | 4.5318 | 0.0029 | 0.0001 |
| | | **108** | **62** | **0** | **0** | **4.5563** | **0.0027** | **0** |
| | | 110 | 64 | 0.205 | 0.001 | 4.5782 | 0.0030 | 0.0001 |
| 47 | Ag | 101 | 54 | −0.670 | 0.003 | 4.4799 | 0.0088 | 0.0003 |
| | | 103 | 56 | −0.482 | 0.002 | 4.5036 | 0.0065 | 0.0002 |
| | | 104 | 57 | −0.416 | 0.002 | 4.5119 | 0.0058 | 0.0002 |
| | | 105 | 58 | −0.296 | 0.002 | 4.5269 | 0.0045 | 0.0002 |
| | | 107 | 60 | −0.148 | 0.001 | 4.5454 | 0.0031 | 0.0001 |
| | | **109** | **62** | **0** | **0** | **4.5638** | **0.0025** | **0** |
| 48 | Cd | 102 | 54 | −1.010 | 0.045 | 4.4810 | 0.0122 | 0.0050 |
| | | 103 | 55 | −0.901 | 0.027 | 4.4951 | 0.0105 | 0.0030 |
| | | 104 | 56 | −0.765 | 0.048 | 4.5122 | 0.0083 | 0.0053 |
| | | 105 | 57 | −0.692 | 0.034 | 4.5216 | 0.0070 | 0.0038 |
| | | 106 | 58 | −0.576 | 0.008 | 4.5383 | 0.0036 | 0.0009 |
| | | 107 | 59 | −0.495 | 0.030 | 4.5466 | 0.0039 | 0.0033 |
| | | 108 | 60 | −0.412 | 0.011 | 4.5577 | 0.0031 | 0.0012 |
| | | 109 | 61 | −0.387 | 0.039 | 4.5601 | 0.0035 | 0.0043 |
| | | 110 | 62 | −0.252 | 0.005 | 4.5765 | 0.0026 | 0.0005 |
| | | 111 | 63 | −0.130 | 0.013 | 4.5845 | 0.0058 | 0.0014 |
| | | 112 | 64 | −0.103 | 0.003 | 4.5944 | 0.0024 | 0.0003 |
| | | 113 | 65 | −0.008 | 0.004 | 4.6012 | 0.0028 | 0.0004 |
| | | **114** | **66** | **0** | **0** | **4.6087** | **0.0023** | **0** |
| | | 115 | 67 | 0.024 | 0.046 | 4.6114 | 0.0046 | 0.0050 |
| | | 116 | 68 | 0.088 | 0.003 | 4.6203 | 0.0059 | 0.0003 |
| | | 117 | 69 | 0.083 | 0.018 | 4.6136 | 0.0025 | 0.0020 |
| | | 118 | 70 | 0.129 | 0.022 | 4.6246 | 0.0060 | 0.0024 |
| | | 120 | 72 | 0.174 | 0.043 | 4.6300 | 0.0069 | 0.0046 |
| 49 | In | 104 | 55 | −0.866 | 0.015 | 4.5184 | 0.0117 | 0.0017 |
| | | 105 | 56 | −0.754 | 0.014 | 4.5311 | 0.0103 | 0.0015 |
| | | 106 | 57 | −0.698 | 0.012 | 4.5375 | 0.0095 | 0.0013 |
| | | 107 | 58 | −0.592 | 0.010 | 4.5494 | 0.0082 | 0.0011 |
| | | 108 | 59 | −0.524 | 0.005 | 4.5571 | 0.0071 | 0.0006 |
| | | 109 | 60 | −0.422 | 0.007 | 4.5685 | 0.0061 | 0.0008 |
| | | 110 | 61 | −0.371 | 0.008 | 4.5742 | 0.0056 | 0.0009 |
| | | 111 | 62 | −0.270 | 0.005 | 4.5856 | 0.0044 | 0.0005 |
| | | 112 | 63 | −0.224 | 0.006 | 4.5907 | 0.0041 | 0.0007 |
| | | 113 | 64 | −0.1317 | 0.0003 | 4.6010 | 0.0031 | 0.0001 |
| | | 114 | 65 | −0.090 | 0.002 | 4.6056 | 0.0029 | 0.0002 |
| | | **115** | **66** | **0** | **0** | **4.6156** | **0.0026** | **0** |
| | | 116 | 67 | 0.049 | 0.001 | 4.6211 | 0.0027 | 0.0001 |
| | | 117 | 68 | 0.122 | 0.004 | 4.6292 | 0.0032 | 0.0004 |
| | | 118 | 69 | 0.162 | 0.002 | 4.6335 | 0.0033 | 0.0002 |
| | | 119 | 70 | 0.226 | 0.004 | 4.6407 | 0.0040 | 0.0004 |
| | | 120 | 71 | 0.259 | 0.002 | 4.6443 | 0.0042 | 0.0002 |
| | | 121 | 72 | 0.315 | 0.003 | 4.6505 | 0.0047 | 0.0003 |
| | | 122 | 73 | 0.342 | 0.004 | 4.6534 | 0.0051 | 0.0004 |
| | | 123 | 74 | 0.396 | 0.003 | 4.6594 | 0.0056 | 0.0003 |
| | | 124 | 75 | 0.424 | 0.004 | 4.6625 | 0.0060 | 0.0007 |
| | | 125 | 76 | 0.465 | 0.005 | 4.6670 | 0.0064 | 0.0005 |
| | | 126 | 77 | 0.494 | 0.007 | 4.6702 | 0.0068 | 0.0008 |
| | | 127 | 78 | 0.523 | 0.007 | 4.6733 | 0.0071 | 0.0008 |
| 50 | Sn | 108 | 58 | −0.825 | 0.003 | 4.5605 | 0.0029 | 0.0003 |
| | | 109 | 59 | −0.764 | 0.006 | 4.5679 | 0.0027 | 0.0007 |
| | | 110 | 60 | −0.666 | 0.002 | 4.5785 | 0.0025 | 0.0002 |
| | | 111 | 61 | −0.612 | 0.005 | 4.5836 | 0.0024 | 0.0005 |
| | | 112 | 62 | −0.520 | 0.005 | 4.5948 | 0.0022 | 0.0005 |
| | | 113 | 63 | −0.458 | 0.001 | 4.6015 | 0.0021 | 0.0001 |
| | | 114 | 64 | −0.3838 | 0.0001 | 4.6099 | 0.0020 | 0.0001 |
| | | 115 | 65 | −0.3360 | 0.0001 | 4.6148 | 0.0019 | 0.0001 |
| | | 116 | 66 | −0.2471 | 0.0001 | 4.6250 | 0.0019 | 0.0001 |
| | | 117 | 67 | −0.1971 | 0.0001 | 4.6302 | 0.0019 | 0.0001 |
| | | 118 | 68 | −0.1174 | 0.0001 | 4.6393 | 0.0019 | 0.0001 |
| | | 119 | 69 | −0.0724 | 0.0001 | 4.6438 | 0.0020 | 0.0001 |
| | | **120** | **70** | **0** | **0** | **4.6519** | **0.0021** | **0** |
| | | 121 | 71 | 0.045 | 0.001 | 4.6566 | 0.0021 | 0.0001 |
| | | 122 | 72 | 0.1055 | 0.0001 | 4.6634 | 0.0022 | 0.0001 |

(*continued on next page*)

Table 1 (*continued*)

| $Z$ | el. | $A$ | $N$ | $\delta\langle r^2\rangle$ (fm$^2$) | $\Delta\delta\langle r^2\rangle$ (fm$^2$) | $R$ (fm) | $\Delta_{tot}R$ (fm) | $\Delta R_{rel}$ |
|---|---|---|---|---|---|---|---|---|
| | | 123 | 73 | 0.140 | 0.001 | 4.6665 | 0.0023 | 0.0001 |
| | | 124 | 74 | 0.2008 | 0.0001 | 4.6735 | 0.0023 | 0.0001 |
| | | 125 | 75 | 0.235 | 0.003 | 4.6765 | 0.0026 | 0.0003 |
| | | 126 | 76 | 0.290 | 0.003 | 4.6833 | 0.0043 | 0.0003 |
| | | 127 | 77 | 0.322 | 0.003 | 4.6867 | 0.0048 | 0.0003 |
| | | 128 | 78 | 0.372 | 0.004 | 4.6921 | 0.0054 | 0.0004 |
| | | 129 | 79 | 0.384 | 0.003 | 4.6934 | 0.0058 | 0.0003 |
| | | 130 | 80 | 0.464 | 0.003 | 4.7019 | 0.0066 | 0.0003 |
| | | 131 | 81 | 0.520 | 0.004 | 4.7078 | 0.0073 | 0.0004 |
| | | 132 | 82 | 0.534 | 0.002 | 4.7093 | 0.0076 | 0.0002 |
| 51 | Sb | 121 | 70 | | | 4.6802 | 0.0026 | |
| | | 123 | 72 | | | 4.6879 | 0.0025 | |
| 52 | Te | 116 | 64 | −0.563 | 0.027 | 4.6847 | 0.0128 | 0.0094 |
| | | 118 | 66 | −0.457 | 0.027 | 4.6956 | 0.0105 | 0.0075 |
| | | 120 | 68 | −0.377 | 0.006 | 4.7038 | 0.0088 | 0.0070 |
| | | 122 | 70 | −0.305 | 0.010 | 4.7095 | 0.0031 | 0.0053 |
| | | 123 | 71 | −0.289 | 0.011 | 4.7117 | 0.0035 | 0.0048 |
| | | 124 | 72 | −0.227 | 0.009 | 4.7183 | 0.0029 | 0.0039 |
| | | 125 | 73 | −0.208 | 0.011 | 4.7204 | 0.0030 | 0.0033 |
| | | 126 | 74 | −0.153 | 0.009 | 4.7266 | 0.0032 | 0.0025 |
| | | 128 | 76 | −0.077 | 0.004 | 4.7346 | 0.0029 | 0.0012 |
| | | **130** | **78** | **0** | **0** | **4.7423** | **0.0025** | **0** |
| | | 132 | 80 | 0.076 | 0.016 | 4.7500 | 0.0031 | 0.0017 |
| | | 134 | 82 | 0.144 | 0.016 | 4.7569 | 0.0041 | 0.0032 |
| | | 136 | 84 | 0.389 | 0.019 | 4.7815 | 0.0089 | 0.0071 |
| 53 | I | 127 | 74 | | | 4.7500 | 0.0081 | |
| 54 | Xe | 116 | 62 | −0.599 | 0.009 | 4.7211 | 0.0096 | 0.0009 |
| | | 118 | 64 | −0.460 | 0.007 | 4.7387 | 0.0070 | 0.0007 |
| | | 120 | 66 | −0.363 | 0.007 | 4.7509 | 0.0063 | 0.0007 |
| | | 122 | 68 | −0.299 | 0.006 | 4.7590 | 0.0059 | 0.0006 |
| | | 124 | 70 | −0.242 | 0.005 | 4.7661 | 0.0055 | 0.0005 |
| | | 126 | 72 | −0.193 | 0.007 | 4.7722 | 0.0052 | 0.0007 |
| | | 127 | 73 | −0.181 | 0.020 | 4.7747 | 0.0038 | 0.0021 |
| | | 128 | 74 | −0.152 | 0.004 | 4.7774 | 0.0050 | 0.0004 |
| | | 129 | 75 | −0.151 | 0.001 | 4.7775 | 0.0050 | 0.0003 |
| | | 130 | 76 | −0.117 | 0.003 | 4.7818 | 0.0049 | 0.0003 |
| | | 131 | 77 | −0.125 | 0.001 | 4.7808 | 0.0049 | 0.0002 |
| | | 132 | 78 | −0.0844 | 0.0017 | 4.7859 | 0.0048 | 0.0002 |
| | | 133 | 79 | −0.106 | 0.005 | 4.7831 | 0.0048 | 0.0005 |
| | | 134 | 80 | −0.0518 | 0.0013 | 4.7899 | 0.0047 | 0.0001 |
| | | **136** | **82** | **0** | **0** | **4.7964** | **0.0047** | **0** |
| | | 137 | 83 | 0.105 | 0.003 | 4.8094 | 0.0049 | 0.0003 |
| | | 138 | 84 | 0.254 | 0.003 | 4.8279 | 0.0079 | 0.0003 |
| | | 139 | 85 | 0.359 | 0.006 | 4.8409 | 0.0100 | 0.0006 |
| | | 140 | 86 | 0.486 | 0.002 | 4.8566 | 0.0125 | 0.0002 |
| | | 141 | 87 | 0.591 | 0.004 | 4.8694 | 0.0147 | 0.0004 |
| | | 142 | 88 | 0.710 | 0.009 | 4.8841 | 0.0169 | 0.0009 |
| | | 143 | 89 | 0.794 | 0.004 | 4.8942 | 0.0187 | 0.0004 |
| | | 144 | 90 | 0.908 | 0.005 | 4.9082 | 0.0208 | 0.0005 |
| | | 146 | 92 | 1.100 | 0.005 | 4.9315 | 0.0245 | 0.0005 |
| 55 | Cs | 118 | 63 | −0.2044 | 0.0021 | 4.7832 | 0.0092 | 0.0002 |
| | | 119 | 64 | −0.1411 | 0.0062 | 4.7896 | 0.0089 | 0.0006 |
| | | 120 | 65 | −0.1229 | 0.0015 | 4.7915 | 0.0075 | 0.0002 |
| | | 121 | 66 | −0.2650 | 0.0009 | 4.7769 | 0.0078 | 0.0001 |
| | | 122 | 67 | −0.2618 | 0.0016 | 4.7773 | 0.0070 | 0.0002 |
| | | 123 | 68 | −0.2156 | 0.0006 | 4.7820 | 0.0070 | 0.0001 |
| | | 124 | 69 | −0.2083 | 0.0012 | 4.7828 | 0.0062 | 0.0001 |
| | | 125 | 70 | −0.1574 | 0.0006 | 4.7880 | 0.0062 | 0.0001 |
| | | 126 | 71 | −0.1645 | 0.0009 | 4.7872 | 0.0056 | 0.0001 |
| | | 127 | 72 | −0.1022 | 0.0007 | 4.7936 | 0.0055 | 0.0001 |
| | | 128 | 73 | −0.1173 | 0.0004 | 4.7921 | 0.0052 | 0.0001 |
| | | 129 | 74 | −0.0582 | 0.0011 | 4.7981 | 0.0050 | 0.0001 |
| | | 130 | 75 | −0.0482 | 0.0010 | 4.7992 | 0.0049 | 0.0001 |
| | | 131 | 76 | −0.0146 | 0.0007 | 4.8026 | 0.0047 | 0.0001 |
| | | 132 | 77 | −0.0383 | 0.0006 | 4.8002 | 0.0046 | 0.0001 |
| | | **133** | **78** | **0** | **0** | **4.8041** | **0.0046** | **0** |
| | | 134 | 79 | −0.0100 | 0.0011 | 4.8031 | 0.0046 | 0.0001 |
| | | 135 | 80 | 0.0259 | 0.0009 | 4.8067 | 0.0047 | 0.0001 |
| | | 136 | 81 | 0.0174 | 0.0015 | 4.8059 | 0.0052 | 0.0002 |
| | | 137 | 82 | 0.0852 | 0.0011 | 4.8128 | 0.0050 | 0.0001 |
| | | 138 | 83 | 0.2099 | 0.0008 | 4.8255 | 0.0050 | 0.0001 |
| | | 139 | 84 | 0.3739 | 0.0012 | 4.8422 | 0.0069 | 0.0001 |
| | | 140 | 85 | 0.5051 | 0.0013 | 4.8554 | 0.0088 | 0.0001 |

(*continued on next page*)

Table 1 (*continued*)

| $Z$ | el. | $A$ | $N$ | $\delta\langle r^2\rangle$ (fm$^2$) | $\Delta\delta\langle r^2\rangle$ (fm$^2$) | $R$ (fm) | $\Delta_{tot}R$ (fm) | $\Delta R_{rel}$ |
|---|---|---|---|---|---|---|---|---|
| | | 141 | 86 | 0.6389 | 0.0015 | 4.8689 | 0.0108 | 0.0002 |
| | | 142 | 87 | 0.7732 | 0.0007 | 4.8825 | 0.0132 | 0.0001 |
| | | 143 | 88 | 0.9127 | 0.0005 | 4.8965 | 0.0151 | 0.0002 |
| | | 144 | 89 | 1.0030 | 0.0007 | 4.9055 | 0.0161 | 0.0002 |
| | | 145 | 90 | 1.1362 | 0.0010 | 4.9188 | 0.0191 | 0.0003 |
| | | 146 | 91 | 1.2293 | 0.0021 | 4.9281 | 0.0193 | 0.0003 |
| 56 | Ba | 120 | 64 | −0.267 | 0.010 | 4.8092 | 0.0058 | 0.0010 |
| | | 121 | 65 | −0.189 | 0.012 | 4.8176 | 0.0052 | 0.0012 |
| | | 122 | 66 | −0.212 | 0.002 | 4.8153 | 0.0054 | 0.0002 |
| | | 123 | 67 | −0.228 | 0.002 | 4.8135 | 0.0055 | 0.0002 |
| | | 124 | 68 | −0.1819 | 0.0003 | 4.8185 | 0.0052 | 0.0001 |
| | | 125 | 69 | −0.189 | 0.002 | 4.8177 | 0.0052 | 0.0002 |
| | | 126 | 70 | −0.1479 | 0.0002 | 4.8221 | 0.0050 | 0.0001 |
| | | 127 | 71 | −0.1641 | 0.0010 | 4.8204 | 0.0051 | 0.0001 |
| | | 128 | 72 | −0.1160 | 0.0003 | 4.8255 | 0.0048 | 0.0001 |
| | | 129 | 73 | −0.1219 | 0.0004 | 4.8248 | 0.0049 | 0.0001 |
| | | 130 | 74 | −0.0895 | 0.0002 | 4.8283 | 0.0047 | 0.0001 |
| | | 131 | 75 | −0.0960 | 0.0003 | 4.8276 | 0.0048 | 0.0001 |
| | | 132 | 76 | −0.0700 | 0.0001 | 4.8303 | 0.0047 | 0.0001 |
| | | 133 | 77 | −0.0873 | 0.0002 | 4.8286 | 0.0047 | 0.0001 |
| | | 134 | 78 | −0.0547 | 0.0001 | 4.8322 | 0.0047 | 0.0001 |
| | | 135 | 79 | −0.0812 | 0.0003 | 4.8294 | 0.0047 | 0.0001 |
| | | 136 | 80 | −0.0422 | 0.0002 | 4.8334 | 0.0046 | 0.0001 |
| | | 137 | 81 | −0.0609 | 0.0002 | 4.8314 | 0.0047 | 0.0001 |
| | | **138** | **82** | **0** | **0** | **4.8378** | **0.0046** | **0** |
| | | 139 | 83 | 0.129 | 0.001 | 4.8513 | 0.0049 | 0.0001 |
| | | 140 | 84 | 0.292 | 0.001 | 4.8684 | 0.0059 | 0.0001 |
| | | 141 | 85 | 0.410 | 0.001 | 4.8807 | 0.0069 | 0.0001 |
| | | 142 | 86 | 0.550 | 0.001 | 4.8953 | 0.0083 | 0.0001 |
| | | 143 | 87 | 0.679 | 0.002 | 4.9087 | 0.0096 | 0.0002 |
| | | 144 | 88 | 0.823 | 0.003 | 4.9236 | 0.0112 | 0.0003 |
| | | 145 | 89 | 0.928 | 0.002 | 4.9345 | 0.0123 | 0.0002 |
| | | 146 | 90 | 1.058 | 0.003 | 4.9479 | 0.0138 | 0.0003 |
| | | 148 | 92 | 1.304 | 0.006 | 4.9731 | 0.0167 | 0.0006 |
| 57 | La | 135 | 78 | −0.061 | 0.006 | 4.8488 | 0.0060 | 0.0006 |
| | | 137 | 80 | −0.048 | 0.001 | 4.8496 | 0.0053 | 0.0001 |
| | | 138 | 81 | −0.067 | 0.001 | 4.8473 | 0.0051 | 0.0001 |
| | | **139** | **82** | **0** | **0** | **4.8550** | **0.0049** | **0** |
| 58 | Ce | 136 | 78 | −0.031 | 0.002 | 4.8739 | 0.0018 | 0.0002 |
| | | 138 | 80 | −0.033 | 0.002 | 4.8737 | 0.0018 | 0.0002 |
| | | **140** | **82** | **0** | **0** | **4.8771** | **0.0018** | **0** |
| | | 142 | 84 | 0.281 | 0.002 | 4.9063 | 0.0020 | 0.0002 |
| | | 144 | 86 | 0.513 | 0.002 | 4.9303 | 0.0024 | 0.0002 |
| | | 146 | 88 | 0.793 | 0.002 | 4.9590 | 0.0028 | 0.0002 |
| | | 148 | 90 | 1.089 | 0.002 | 4.9893 | 0.0035 | 0.0002 |
| 59 | Pr | 141 | 82 | | | 4.8919 | 0.0050 | |
| 60 | Nd | 132 | 72 | 0.050 | 0.030 | 4.9174 | 0.0026 | 0.0031 |
| | | 134 | 74 | 0.005 | 0.021 | 4.9128 | 0.0026 | 0.0021 |
| | | 135 | 75 | −0.037 | 0.033 | 4.9086 | 0.0026 | 0.0034 |
| | | 136 | 76 | −0.012 | 0.027 | 4.9111 | 0.0026 | 0.0027 |
| | | 137 | 77 | −0.043 | 0.016 | 4.9080 | 0.0026 | 0.0016 |
| | | 138 | 78 | −0.006 | 0.021 | 4.9123 | 0.0026 | 0.0021 |
| | | 139 | 79 | −0.047 | 0.014 | 4.9076 | 0.0025 | 0.0014 |
| | | 140 | 80 | −0.022 | 0.027 | 4.9101 | 0.0026 | 0.0027 |
| | | 141 | 81 | −0.066 | 0.014 | 4.9057 | 0.0026 | 0.0014 |
| | | **142** | **82** | **0** | **0** | **4.9123** | **0.0025** | **0** |
| | | 143 | 83 | 0.130 | 0.005 | 4.9254 | 0.0026 | 0.0005 |
| | | 144 | 84 | 0.296 | 0.003 | 4.9421 | 0.0027 | 0.0003 |
| | | 145 | 85 | 0.410 | 0.005 | 4.9535 | 0.0028 | 0.0005 |
| | | 146 | 86 | 0.571 | 0.004 | 4.9696 | 0.0030 | 0.0004 |
| | | 148 | 88 | 0.876 | 0.004 | 4.9999 | 0.0036 | 0.0004 |
| | | 150 | 90 | 1.282 | 0.005 | 5.0400 | 0.0044 | 0.0005 |
| 62 | Sm | 138 | 76 | 0.067 | 0.015 | 4.9599 | 0.0034 | 0.0015 |
| | | 139 | 77 | 0.027 | 0.014 | 4.9556 | 0.0034 | 0.0014 |
| | | 140 | 78 | 0.037 | 0.015 | 4.9565 | 0.0034 | 0.0015 |
| | | 141 | 79 | 0.030 | 0.023 | 4.9517 | 0.0034 | 0.0023 |
| | | 142 | 80 | −0.007 | 0.013 | 4.9518 | 0.0034 | 0.0013 |
| | | 143 | 81 | −0.043 | 0.015 | 4.9479 | 0.0034 | 0.0015 |
| | | **144** | **82** | **0** | **0** | **4.9524** | **0.0034** | **0** |
| | | 145 | 83 | 0.1167 | 0.0016 | 4.9651 | 0.0034 | 0.0005 |
| | | 146 | 84 | 0.2732 | 0.0008 | 4.9808 | 0.0035 | 0.0010 |
| | | 147 | 85 | 0.3669 | 0.0004 | 4.9892 | 0.0035 | 0.0016 |
| | | 148 | 86 | 0.5199 | 0.0004 | 5.0042 | 0.0034 | 0.0021 |

(continued on next page)

Table 1 (*continued*)

| $Z$ | el. | $A$ | $N$ | $\delta\langle r^2\rangle$ (fm$^2$) | $\Delta\delta\langle r^2\rangle$ (fm$^2$) | $R$ (fm) | $\Delta_{tot}R$ (fm) | $\Delta R_{rel}$ |
|---|---|---|---|---|---|---|---|---|
| | | 149 | 87 | 0.6125 | 0.0004 | 5.0134 | 0.0035 | 0.0024 |
| | | 150 | 88 | 0.8240 | 0.0004 | 5.0387 | 0.0048 | 0.0031 |
| | | 151 | 89 | 0.9800 | 0.0008 | 5.0550 | 0.0057 | 0.0038 |
| | | 152 | 90 | 1.2493 | 0.0003 | 5.0819 | 0.0060 | 0.0038 |
| | | 153 | 91 | 1.3490 | 0.0005 | 5.0925 | 0.0068 | 0.0002 |
| | | 154 | 92 | 1.4806 | 0.0004 | 5.1053 | 0.0067 | 0.0040 |
| 63 | Eu | 137 | 74 | 0.099 | 0.043 | 4.9762 | 0.0095 | 0.0046 |
| | | 138 | 75 | 0.115 | 0.042 | 4.9779 | 0.0094 | 0.0045 |
| | | 139 | 76 | 0.081 | 0.046 | 4.9760 | 0.0093 | 0.0048 |
| | | 140 | 77 | 0.0295 | 0.0021 | 4.9695 | 0.0091 | 0.0017 |
| | | 141 | 78 | 0.0323 | 0.0011 | 4.9697 | 0.0091 | 0.0013 |
| | | 142 | 79 | −0.056 | 0.003 | 4.9607 | 0.0091 | 0.0010 |
| | | 143 | 80 | −0.027 | 0.001 | 4.9636 | 0.0091 | 0.0007 |
| | | 144 | 81 | −0.051 | 0.002 | 4.9612 | 0.0091 | 0.0004 |
| | | **145** | **82** | **0** | **0** | **4.9663** | **0.0091** | **0** |
| | | 146 | 83 | 0.1248 | 0.0019 | 4.9789 | 0.0092 | 0.0004 |
| | | 147 | 84 | 0.2718 | 0.001 | 4.9938 | 0.0094 | 0.0006 |
| | | 148 | 85 | 0.3787 | 0.0017 | 5.0045 | 0.0097 | 0.0010 |
| | | 149 | 86 | 0.5338 | 0.001 | 5.0202 | 0.0103 | 0.0013 |
| | | 150 | 87 | 0.6278 | 0.0013 | 5.0296 | 0.0108 | 0.0016 |
| | | 151 | 88 | 0.8538 | 0.0011 | 5.0522 | 0.0046 | 0.0018 |
| | | 152 | 89 | 1.3989 | 0.0034 | 5.1064 | 0.0066 | 0.0021 |
| | | 153 | 90 | 1.4554 | 0.0017 | 5.1115 | 0.0062 | 0.0024 |
| | | 154 | 91 | 1.588 | 0.006 | 5.1239 | 0.0079 | 0.0006 |
| | | 155 | 92 | 1.567 | 0.008 | 5.1221 | 0.0069 | 0.0008 |
| | | 156 | 93 | 1.612 | 0.008 | 5.1264 | 0.0071 | 0.0009 |
| | | 157 | 94 | 1.702 | 0.007 | 5.1351 | 0.0075 | 0.0010 |
| | | 158 | 95 | 1.765 | 0.008 | 5.1413 | 0.0078 | 0.0011 |
| | | 159 | 96 | 1.852 | 0.008 | 5.1498 | 0.0084 | 0.0012 |
| 64 | Gd | 145 | 81 | −1.915 | 0.029 | 4.9786 | 0.0077 | 0.0029 |
| | | 146 | 82 | −1.914 | 0.015 | 4.9801 | 0.0140 | 0.0015 |
| | | 148 | 84 | −1.617 | 0.015 | 5.0080 | 0.0171 | 0.0015 |
| | | 150 | 86 | −1.358 | 0.015 | 5.0342 | 0.0159 | 0.0015 |
| | | 152 | 88 | −1.01 | 0.001 | 5.0774 | 0.0048 | 0.0001 |
| | | 154 | 90 | −0.5338 | 0.0003 | 5.1223 | 0.0040 | 0.0001 |
| | | 155 | 91 | −0.4309 | 0.0002 | 5.1319 | 0.0041 | 0.0001 |
| | | 156 | 92 | −0.3229 | 0.0002 | 5.1420 | 0.0042 | 0.0001 |
| | | 157 | 93 | −0.2918 | 0.0001 | 5.1449 | 0.0042 | 0.0001 |
| | | 158 | 94 | −0.1643 | 0.0001 | 5.1569 | 0.0043 | 0.0001 |
| | | **160** | **96** | **0** | **0** | **5.1734** | **0.0044** | **0** |
| 65 | Tb | 147 | 82 | −1.393 | 0.012 | 4.9201 | 0.1508 | 0.0032 |
| | | 148 | 83 | −1.304 | 0.011 | 4.9291 | 0.1507 | 0.0030 |
| | | 149 | 84 | −1.175 | 0.009 | 4.9427 | 0.1506 | 0.0027 |
| | | 150 | 85 | −1.100 | 0.009 | 4.9499 | 0.1505 | 0.0025 |
| | | 151 | 86 | −0.969 | 0.008 | 4.9630 | 0.1504 | 0.0022 |
| | | 152 | 87 | −0.909 | 0.008 | 4.9689 | 0.1504 | 0.0021 |
| | | 153 | 88 | −0.655 | 0.008 | 4.9950 | 0.1502 | 0.0016 |
| | | 154 | 89 | −0.272 | 0.018 | 5.0333 | 0.1501 | 0.0019 |
| | | 155 | 90 | −0.215 | 0.009 | 5.0391 | 0.1500 | 0.0010 |
| | | 157 | 92 | −0.116 | 0.008 | 5.0489 | 0.1500 | 0.0009 |
| | | **159** | **94** | **0** | **0** | **5.0600** | **0.1500** | **0** |
| 66 | Dy | 146 | 80 | −0.018 | 0.002 | 5.0438 | 0.2389 | 0.0002 |
| | | **148** | **82** | **0** | **0** | **5.0455** | **0.2389** | **0** |
| | | 149 | 83 | 0.119 | 0.013 | 5.0567 | 0.2394 | 0.0012 |
| | | 150 | 84 | 0.268 | 0.026 | 5.0706 | 0.2413 | 0.0026 |
| | | 151 | 85 | 0.370 | 0.037 | 5.0801 | 0.2435 | 0.0036 |
| | | 152 | 86 | 0.530 | 0.053 | 5.0950 | 0.2482 | 0.0051 |
| | | 153 | 87 | 0.621 | 0.062 | 5.1035 | 0.2516 | 0.0060 |
| | | 154 | 88 | 0.844 | 0.084 | 5.1241 | 0.2618 | 0.0082 |
| | | 155 | 89 | 1.077 | 0.108 | 5.1457 | 0.2751 | 0.0103 |
| | | 156 | 90 | 1.257 | 0.126 | 5.1622 | 0.2869 | 0.0123 |
| | | 157 | 91 | 1.352 | 0.135 | 5.1709 | 0.2936 | 0.0133 |
| | | 158 | 92 | 1.468 | 0.147 | 5.1815 | 0.3023 | 0.0144 |
| | | 159 | 93 | 1.478 | 0.148 | 5.1825 | 0.3031 | 0.0144 |
| | | 160 | 94 | 1.616 | 0.162 | 5.1951 | 0.3139 | 0.0155 |
| | | 161 | 95 | 1.647 | 0.165 | 5.1962 | 0.0459 | 0.0159 |
| | | 162 | 96 | 1.753 | 0.175 | 5.2074 | 0.0172 | 0.0169 |
| | | 163 | 97 | 1.806 | 0.181 | 5.2099 | 0.0120 | 0.0169 |
| | | 164 | 98 | 1.901 | 0.190 | 5.2218 | 0.0106 | 0.0179 |
| 67 | Ho | 151 | 84 | −1.709 | 0.008 | 5.0398 | 0.0354 | 0.0008 |
| | | 152 | 85 | −1.486 | 0.006 | 5.0614 | 0.0343 | 0.0006 |
| | | 153 | 86 | −1.324 | 0.005 | 5.0760 | 0.0339 | 0.0005 |
| | | 154 | 87 | −1.234 | 0.003 | 5.0856 | 0.0333 | 0.0003 |

(*continued on next page*)

Table 1 (*continued*)

| $Z$ | el. | $A$ | $N$ | $\delta\langle r^2\rangle$ (fm$^2$) | $\Delta\delta\langle r^2\rangle$ (fm$^2$) | $R$ (fm) | $\Delta_{tot}R$ (fm) | $\Delta R_{rel}$ |
|---|---|---|---|---|---|---|---|---|
| | | 155 | 88 | −1.003 | 0.003 | 5.1076 | 0.0326 | 0.0003 |
| | | 156 | 89 | −0.881 | 0.003 | 5.1156 | 0.0326 | 0.0003 |
| | | 157 | 90 | −0.518 | 0.002 | 5.1535 | 0.0316 | 0.0002 |
| | | 158 | 91 | −0.48 | 0.004 | 5.1571 | 0.0316 | 0.0004 |
| | | 159 | 92 | −0.37 | 0.002 | 5.1675 | 0.0314 | 0.0002 |
| | | 160 | 93 | −0.384 | 0.003 | 5.1662 | 0.0315 | 0.0003 |
| | | 161 | 94 | −0.253 | 0.002 | 5.1785 | 0.0313 | 0.0002 |
| | | 162 | 95 | −0.219 | 0.008 | 5.1817 | 0.0313 | 0.0008 |
| | | 163 | 96 | −0.123 | 0.006 | 5.1907 | 0.0313 | 0.0006 |
| | | **165** | **98** | **0** | **0** | **5.2022** | **0.0312** | **0** |
| 68 | Er | 150 | 82 | −2.114 | 0.013 | 5.0548 | 0.0254 | 0.0030 |
| | | 152 | 84 | −1.846 | 0.013 | 5.0843 | 0.0257 | 0.0027 |
| | | 154 | 86 | −1.584 | 0.002 | 5.1129 | 0.0268 | 0.0021 |
| | | 156 | 88 | −1.307 | 0.001 | 5.1429 | 0.0285 | 0.0018 |
| | | 158 | 90 | −1.001 | 0.001 | 5.1761 | 0.0312 | 0.0015 |
| | | 160 | 92 | −0.738 | 0.001 | 5.2045 | 0.0336 | 0.0012 |
| | | 162 | 94 | −0.551 | 0.001 | 5.2246 | 0.0040 | 0.0010 |
| | | 164 | 96 | −0.392 | 0.001 | 5.2389 | 0.0035 | 0.0007 |
| | | 166 | 98 | −0.263 | 0.001 | 5.2516 | 0.0031 | 0.0005 |
| | | 167 | 99 | −0.218 | 0.001 | 5.2560 | 0.0031 | 0.0004 |
| | | 168 | 100 | −0.132 | 0.001 | 5.2644 | 0.0035 | 0.0002 |
| | | **170** | **102** | **0** | **0** | **5.2789** | **0.0041** | **0** |
| 69 | Tm | 153 | 84 | −1.708 | 0.033 | 5.0643 | 0.0190 | 0.0030 |
| | | 154 | 85 | −1.609 | 0.015 | 5.0755 | 0.0166 | 0.0019 |
| | | 156 | 87 | −1.359 | 0.009 | 5.0976 | 0.0135 | 0.0006 |
| | | 157 | 88 | −1.157 | 0.005 | 5.1140 | 0.0074 | 0.0008 |
| | | 158 | 89 | −1.058 | 0.006 | 5.1235 | 0.0069 | 0.0007 |
| | | 159 | 90 | −0.898 | 0.003 | 5.1392 | 0.0060 | 0.0004 |
| | | 160 | 91 | −0.783 | 0.003 | 5.1504 | 0.0055 | 0.0004 |
| | | 161 | 92 | −0.667 | 0.002 | 5.1616 | 0.0050 | 0.0003 |
| | | 162 | 93 | −0.567 | 0.003 | 5.1713 | 0.0048 | 0.0005 |
| | | 163 | 94 | −0.427 | 0.002 | 5.1849 | 0.0042 | 0.0002 |
| | | 164 | 95 | −0.368 | 0.003 | 5.1906 | 0.0042 | 0.0006 |
| | | 165 | 96 | −0.265 | 0.002 | 5.2004 | 0.0038 | 0.0002 |
| | | 166 | 97 | −0.221 | 0.003 | 5.2046 | 0.0038 | 0.0003 |
| | | 167 | 98 | −0.134 | 0.002 | 5.2129 | 0.0036 | 0.0003 |
| | | 168 | 99 | −0.092 | 0.004 | 5.2170 | 0.0036 | 0.0004 |
| | | **169** | **100** | **0** | **0** | **5.2256** | **0.0035** | **0** |
| | | 170 | 101 | 0.048 | 0.001 | 5.2303 | 0.0036 | 0.0005 |
| | | 171 | 102 | 0.139 | 0.005 | 5.2388 | 0.0037 | 0.0006 |
| | | 172 | 103 | 0.164 | 0.022 | 5.2411 | 0.0052 | 0.0030 |
| 70 | Yb | 152 | 82 | −2.746 | 0.004 | 5.0423 | 0.0146 | 0.0028 |
| | | 154 | 84 | −2.335 | 0.005 | 5.0875 | 0.0105 | 0.0026 |
| | | 155 | 85 | −2.181 | 0.007 | 5.1040 | 0.0110 | 0.0010 |
| | | 156 | 86 | −2.015 | 0.002 | 5.1219 | 0.0103 | 0.0023 |
| | | 157 | 87 | −1.908 | 0.009 | 5.1324 | 0.0100 | 0.0035 |
| | | 158 | 88 | −1.737 | 0.001 | 5.1498 | 0.0088 | 0.0006 |
| | | 159 | 89 | −1.618 | 0.009 | 5.1629 | 0.0084 | 0.0022 |
| | | 160 | 90 | −1.462 | 0.001 | 5.1781 | 0.0076 | 0.0004 |
| | | 161 | 91 | −1.353 | 0.001 | 5.1889 | 0.0072 | 0.0003 |
| | | 162 | 92 | −1.191 | 0.001 | 5.2054 | 0.0067 | 0.0003 |
| | | 163 | 93 | −1.089 | 0.001 | 5.2157 | 0.0064 | 0.0002 |
| | | 164 | 94 | −0.942 | 0.001 | 5.2307 | 0.0060 | 0.0003 |
| | | 165 | 95 | −0.8473 | 0.0003 | 5.2399 | 0.0058 | 0.0002 |
| | | 166 | 96 | −0.7220 | 0.0004 | 5.2525 | 0.0057 | 0.0001 |
| | | 167 | 97 | −0.6252 | 0.0003 | 5.2621 | 0.0056 | 0.0001 |
| | | 168 | 98 | −0.5406 | 0.0003 | 5.2702 | 0.0056 | 0.0001 |
| | | 169 | 99 | −0.4692 | 0.0003 | 5.2771 | 0.0056 | 0.0007 |
| | | 170 | 100 | −0.3845 | 0.0001 | 5.2853 | 0.0056 | 0.0001 |
| | | 171 | 101 | −0.3273 | 0.0001 | 5.2906 | 0.0057 | 0.0001 |
| | | 172 | 102 | −0.2366 | 0.0001 | 5.2995 | 0.0058 | 0.0002 |
| | | 173 | 103 | −0.1810 | 0.0001 | 5.3046 | 0.0059 | 0.0002 |
| | | 174 | 104 | −0.1159 | 0.0001 | 5.3108 | 0.0060 | 0.0003 |
| | | 175 | 105 | −0.0827 | 0.0074 | 5.3135 | 0.0061 | 0.0002 |
| | | **176** | **106** | **0** | **0** | **5.3215** | **0.0062** | **0** |
| 71 | Lu | 161 | 90 | −1.5083 | 0.0013 | 5.2293 | 0.0320 | 0.0003 |
| | | 162 | 91 | −1.3966 | 0.0012 | 5.2398 | 0.0317 | 0.0003 |
| | | 163 | 92 | −1.2174 | 0.0012 | 5.2567 | 0.0312 | 0.0003 |
| | | 164 | 93 | −1.1006 | 0.0012 | 5.2677 | 0.0310 | 0.0002 |
| | | 165 | 94 | −0.9372 | 0.0007 | 5.2830 | 0.0307 | 0.0002 |
| | | 166 | 95 | −0.7851 | 0.0008 | 5.2972 | 0.0305 | 0.0001 |
| | | 167 | 96 | −0.6397 | 0.0007 | 5.3108 | 0.0303 | 0.0001 |
| | | 168 | 97 | −0.5124 | 0.0010 | 5.3227 | 0.0302 | 0.0001 |

(*continued on next page*)

Table 1 (*continued*)

| $Z$ | el. | $A$ | $N$ | $\delta\langle r^2\rangle$ (fm$^2$) | $\Delta\delta\langle r^2\rangle$ (fm$^2$) | $R$ (fm) | $\Delta_{tot}R$ (fm) | $\Delta R_{rel}$ |
|---|---|---|---|---|---|---|---|---|
| | | 169 | 98 | −0.4443 | 0.0006 | 5.3290 | 0.0302 | 0.0001 |
| | | 170 | 99 | −0.3644 | 0.0006 | 5.3364 | 0.0302 | 0.0001 |
| | | 171 | 100 | −0.2863 | 0.0007 | 5.3436 | 0.0302 | 0.0001 |
| | | 172 | 101 | −0.2323 | 0.0007 | 5.3486 | 0.0302 | 0.0001 |
| | | 173 | 102 | −0.1340 | 0.0010 | 5.3577 | 0.0303 | 0.0001 |
| | | 174 | 103 | −0.0718 | 0.0006 | 5.3634 | 0.0303 | 0.0001 |
| | | **175** | **104** | **0** | **0** | **5.3700** | **0.0304** | **0** |
| | | 176 | 105 | 0.0425 | 0.0010 | 5.3739 | 0.0304 | 0.0002 |
| | | 177 | 106 | 0.1248 | 0.0009 | 5.3815 | 0.0305 | 0.0002 |
| | | 178 | 107 | 0.1714 | 0.0010 | 5.3857 | 0.0306 | 0.0002 |
| | | 179 | 108 | 0.2357 | 0.0010 | 5.3917 | 0.0307 | 0.0002 |
| 72 | Hf | 170 | 98 | −0.494 | 0.009 | 5.2898 | 0.0055 | 0.0009 |
| | | 171 | 99 | −0.366 | 0.005 | 5.3041 | 0.0049 | 0.0008 |
| | | 172 | 100 | −0.322 | 0.006 | 5.3065 | 0.0043 | 0.0007 |
| | | 173 | 101 | −0.244 | 0.004 | 5.3140 | 0.0038 | 0.0005 |
| | | 174 | 102 | −0.180 | 0.003 | 5.3201 | 0.0035 | 0.0004 |
| | | 175 | 103 | −0.091 | 0.002 | 5.3191 | 0.0036 | 0.0010 |
| | | 176 | 104 | −0.091 | 0.001 | 5.3286 | 0.0032 | 0.0002 |
| | | 177 | 105 | −0.065 | 0.001 | 5.3309 | 0.0031 | 0.0001 |
| | | **178** | **106** | **0** | **0** | **5.3371** | **0.0031** | **0** |
| | | 179 | 107 | 0.039 | 0.002 | 5.3408 | 0.0031 | 0.0001 |
| | | 180 | 108 | 0.040 | 0.005 | 5.3470 | 0.0032 | 0.0002 |
| | | 182 | 110 | 0.176 | 0.005 | 5.3516 | 0.0036 | 0.0005 |
| 73 | Ta | 181 | 108 | | | 5.3507 | 0.0034 | |
| 74 | W | 180 | 106 | −0.169 | 0.006 | 5.3491 | 0.0022 | 0.0017 |
| | | 182 | 108 | −0.099 | 0.005 | 5.3559 | 0.0017 | 0.0010 |
| | | 183 | 109 | −0.047 | 0.006 | 5.3611 | 0.0020 | 0.0007 |
| | | **184** | **110** | **0** | **0** | **5.3658** | **0.0023** | **0** |
| | | 186 | 112 | 0.086 | 0.004 | 5.3743 | 0.0026 | 0.0009 |
| 75 | Re | **185** | **110** | **0** | **0** | **5.3596** | **0.0172** | **0** |
| | | 187 | 112 | 0.110 | 0.010 | 5.3698 | 0.0173 | 0.0009 |
| 76 | Os | 184 | 108 | −0.320 | 0.018 | 5.3823 | 0.0022 | 0.0017 |
| | | 186 | 110 | −0.231 | 0.015 | 5.3909 | 0.0017 | 0.0014 |
| | | 187 | 111 | −0.205 | 0.016 | 5.3933 | 0.0018 | 0.0015 |
| | | 188 | 112 | −0.144 | 0.011 | 5.3993 | 0.0011 | 0.0010 |
| | | 189 | 113 | −0.119 | 0.012 | 5.4016 | 0.0012 | 0.0011 |
| | | 190 | 114 | −0.068 | 0.006 | 5.4062 | 0.0013 | 0.0006 |
| | | **192** | **116** | **0** | **0** | **5.4126** | **0.0015** | **0** |
| 77 | Ir | 182 | 105 | −0.283 | 0.006 | 5.3705 | 0.1061 | 0.0007 |
| | | 183 | 106 | −0.203 | 0.004 | 5.3780 | 0.1061 | 0.0005 |
| | | 184 | 107 | −0.176 | 0.003 | 5.3805 | 0.1061 | 0.0004 |
| | | 185 | 108 | −0.123 | 0.003 | 5.3854 | 0.1061 | 0.0003 |
| | | 186 | 109 | −0.073 | 0.004 | 5.3900 | 0.1061 | 0.0004 |
| | | 187 | 110 | −0.168 | 0.003 | 5.3812 | 0.1061 | 0.0004 |
| | | 188 | 111 | −0.140 | 0.004 | 5.3838 | 0.1061 | 0.0004 |
| | | 189 | 112 | −0.076 | 0.002 | 5.3898 | 0.1061 | 0.0002 |
| | | **191** | **114** | **0** | **0** | **5.3968** | **0.1061** | **0** |
| | | 193 | 116 | 0.069 | 0.001 | 5.4032 | 0.1061 | 0.0001 |
| 78 | Pt | 178 | 100 | −0.529 | 0.016 | 5.3728 | 0.0066 | 0.0015 |
| | | 179 | 101 | −0.335 | 0.021 | 5.3915 | 0.0050 | 0.0019 |
| | | 180 | 102 | −0.360 | 0.011 | 5.3891 | 0.0049 | 0.0010 |
| | | 181 | 103 | −0.251 | 0.015 | 5.3996 | 0.0041 | 0.0014 |
| | | 182 | 104 | −0.279 | 0.010 | 5.3969 | 0.0041 | 0.0009 |
| | | 183 | 105 | −0.196 | 0.020 | 5.4038 | 0.0036 | 0.0019 |
| | | 184 | 106 | −0.240 | 0.018 | 5.4015 | 0.0036 | 0.0017 |
| | | 185 | 107 | −0.090 | 0.005 | 5.4148 | 0.0028 | 0.0005 |
| | | 186 | 108 | −0.213 | 0.004 | 5.4037 | 0.0036 | 0.0004 |
| | | 187 | 109 | −0.188 | 0.004 | 5.4063 | 0.0037 | 0.0004 |
| | | 188 | 110 | −0.193 | 0.003 | 5.4053 | 0.0034 | 0.0003 |
| | | 189 | 111 | −0.187 | 0.005 | 5.4060 | 0.0035 | 0.0005 |
| | | 190 | 112 | −0.137 | 0.002 | 5.4108 | 0.0030 | 0.0002 |
| | | 191 | 113 | −0.142 | 0.004 | 5.4102 | 0.0031 | 0.0004 |
| | | 192 | 114 | −0.073 | 0.002 | 5.4169 | 0.0028 | 0.0002 |
| | | 193 | 115 | −0.047 | 0.006 | 5.4191 | 0.0027 | 0.0006 |
| | | **194** | **116** | **0** | **0** | **5.4236** | **0.0025** | **0** |
| | | 195 | 117 | 0.036 | 0.002 | 5.4270 | 0.0026 | 0.0002 |
| | | 196 | 118 | 0.075 | 0.002 | 5.4307 | 0.0027 | 0.0002 |
| | | 198 | 120 | 0.154 | 0.002 | 5.4383 | 0.0032 | 0.0002 |
| 79 | Au | 183 | 104 | −0.140 | 0.009 | 5.4247 | 0.0043 | 0.0008 |
| | | 184 | 105 | −0.077 | 0.007 | 5.4306 | 0.0041 | 0.0011 |
| | | 185 | 106 | −0.088 | 0.004 | 5.4296 | 0.0041 | 0.0008 |
| | | 186 | 107 | −0.024 | 0.008 | 5.4354 | 0.0039 | 0.0007 |

(*continued on next page*)

Table 1 (*continued*)

| $Z$ | el. | $A$ | $N$ | $\delta\langle r^2\rangle$ (fm$^2$) | $\Delta\delta\langle r^2\rangle$ (fm$^2$) | $R$ (fm) | $\Delta_{tot}R$ (fm) | $\Delta R_{rel}$ |
|---|---|---|---|---|---|---|---|---|
| | | 187 | 108 | −0.382 | 0.005 | 5.4018 | 0.0058 | 0.0008 |
| | | 188 | 109 | −0.352 | 0.006 | 5.4049 | 0.0055 | 0.0008 |
| | | 189 | 110 | −0.313 | 0.004 | 5.4084 | 0.0052 | 0.0006 |
| | | 190 | 111 | −0.284 | 0.005 | 5.4109 | 0.0049 | 0.0006 |
| | | 191 | 112 | −0.245 | 0.001 | 5.4147 | 0.0046 | 0.0004 |
| | | 192 | 113 | −0.211 | 0.002 | 5.4179 | 0.0044 | 0.0003 |
| | | 193 | 114 | −0.164 | 0.001 | 5.4221 | 0.0042 | 0.0002 |
| | | 194 | 115 | −0.131 | 0.001 | 5.4252 | 0.0040 | 0.0002 |
| | | 195 | 116 | −0.079 | 0.004 | 5.4298 | 0.0040 | 0.0006 |
| | | 196 | 117 | −0.043 | 0.005 | 5.4332 | 0.0039 | 0.0004 |
| | | **197** | **118** | **0** | **0** | **5.4371** | **0.0038** | **0** |
| | | 198 | 119 | 0.031 | 0.002 | 5.4400 | 0.0038 | 0.0002 |
| | | 199 | 120 | 0.090 | 0.001 | 5.4454 | 0.0039 | 0.0001 |
| 80 | Hg | 181 | 101 | −0.114 | 0.004 | 5.4364 | 0.0032 | 0.0004 |
| | | 182 | 102 | −0.693 | 0.021 | 5.3833 | 0.0052 | 0.0020 |
| | | 183 | 103 | −0.070 | 0.004 | 5.4405 | 0.0031 | 0.0004 |
| | | 184 | 104 | −0.550 | 0.002 | 5.3949 | 0.0047 | 0.0002 |
| | | 185 | 105 | −0.077 | 0.001 | 5.4397 | 0.0031 | 0.0001 |
| | | 186 | 106 | −0.477 | 0.001 | 5.4017 | 0.0043 | 0.0001 |
| | | 187 | 107 | −0.447 | 0.002 | 5.4046 | 0.0042 | 0.0002 |
| | | 188 | 108 | −0.404 | 0.001 | 5.4085 | 0.0040 | 0.0001 |
| | | 189 | 109 | −0.387 | 0.002 | 5.4100 | 0.0040 | 0.0002 |
| | | 190 | 110 | −0.326 | 0.001 | 5.4158 | 0.0037 | 0.0001 |
| | | 191 | 111 | −0.313 | 0.004 | 5.4171 | 0.0037 | 0.0004 |
| | | 192 | 112 | −0.246 | 0.001 | 5.4232 | 0.0035 | 0.0001 |
| | | 193 | 113 | −0.242 | 0.009 | 5.4238 | 0.0035 | 0.0008 |
| | | 194 | 114 | −0.164 | 0.001 | 5.4309 | 0.0033 | 0.0001 |
| | | 195 | 115 | −0.126 | 0.005 | 5.4345 | 0.0032 | 0.0005 |
| | | 196 | 116 | −0.0825 | 0.0001 | 5.4385 | 0.0031 | 0.0001 |
| | | 197 | 117 | −0.054 | 0.003 | 5.4412 | 0.0031 | 0.0003 |
| | | **198** | **118** | **0** | **0** | **5.4463** | **0.0031** | **0** |
| | | 199 | 119 | 0.0130 | 0.0001 | 5.4474 | 0.0031 | 0.0002 |
| | | 200 | 120 | 0.0942 | 0.0001 | 5.4551 | 0.0031 | 0.0003 |
| | | 201 | 121 | 0.1258 | 0.0001 | 5.4581 | 0.0032 | 0.0003 |
| | | 202 | 122 | 0.1981 | 0.0001 | 5.4648 | 0.0033 | 0.0003 |
| | | 203 | 123 | 0.231 | 0.004 | 5.4679 | 0.0035 | 0.0003 |
| | | 204 | 124 | 0.3001 | 0.0001 | 5.4744 | 0.0036 | 0.0003 |
| | | 205 | 125 | 0.333 | 0.002 | 5.4776 | 0.0038 | 0.0003 |
| | | 206 | 126 | 0.397 | 0.002 | 5.4837 | 0.0040 | 0.0003 |
| 81 | Tl | 188 | 107 | −0.7708 | 0.0005 | 5.4017 | 0.0072 | 0.0013 |
| | | 190 | 109 | −0.6693 | 0.0003 | 5.4121 | 0.0056 | 0.0013 |
| | | 191 | 110 | −0.6201 | 0.0007 | 5.4169 | 0.0048 | 0.0003 |
| | | 192 | 111 | −0.5967 | 0.0003 | 5.4191 | 0.0051 | 0.0012 |
| | | 193 | 112 | −0.542 | 0.011 | 5.4243 | 0.0042 | 0.0008 |
| | | 194 | 113 | −0.5261 | 0.0005 | 5.4259 | 0.0046 | 0.0010 |
| | | 195 | 114 | −0.457 | 0.007 | 5.4325 | 0.0039 | 0.0006 |
| | | 196 | 115 | −0.4546 | 0.0005 | 5.4327 | 0.0042 | 0.0009 |
| | | 197 | 116 | −0.391 | 0.001 | 5.4388 | 0.0036 | 0.0002 |
| | | 198 | 117 | −0.383 | 0.007 | 5.4396 | 0.0036 | 0.0006 |
| | | 199 | 118 | −0.296 | 0.007 | 5.4479 | 0.0031 | 0.0006 |
| | | 200 | 119 | −0.283 | 0.007 | 5.4491 | 0.0031 | 0.0006 |
| | | 201 | 120 | −0.197 | 0.001 | 5.4573 | 0.0029 | 0.0004 |
| | | 202 | 121 | −0.174 | 0.007 | 5.4595 | 0.0027 | 0.0006 |
| | | 203 | 122 | −0.0978 | 0.0001 | 5.4666 | 0.0027 | 0.0002 |
| | | 204 | 123 | −0.060 | 0.007 | 5.4704 | 0.0028 | 0.0006 |
| | | **205** | **124** | **0** | **0** | **5.4759** | **0.0026** | **0** |
| | | 207 | 126 | 0.0993 | 0.0002 | 5.4853 | 0.0027 | 0.0002 |
| | | 208 | 127 | 0.185 | 0.013 | 5.4946 | 0.0028 | 0.0012 |
| 82 | Pb | 182 | 100 | −1.311 | 0.013 | 5.3788 | 0.0035 | 0.0012 |
| | | 183 | 101 | −1.225 | 0.008 | 5.3869 | 0.0030 | 0.0007 |
| | | 184 | 102 | −1.160 | 0.005 | 5.3930 | 0.0029 | 0.0005 |
| | | 185 | 103 | −1.103 | 0.008 | 5.3984 | 0.0028 | 0.0007 |
| | | 186 | 104 | −1.057 | 0.005 | 5.4027 | 0.0027 | 0.0005 |
| | | 187 | 105 | −1.002 | 0.006 | 5.4079 | 0.0026 | 0.0006 |
| | | 188 | 106 | −0.938 | 0.006 | 5.4139 | 0.0025 | 0.0006 |
| | | 189 | 107 | −0.898 | 0.008 | 5.4177 | 0.0024 | 0.0007 |
| | | 190 | 108 | −0.851 | 0.002 | 5.4222 | 0.0023 | 0.0005 |
| | | 191 | 109 | −0.845 | 0.004 | 5.4229 | 0.0026 | 0.0011 |
| | | 192 | 110 | −0.766 | 0.005 | 5.4300 | 0.0025 | 0.0011 |
| | | 193 | 111 | −0.756 | 0.003 | 5.4310 | 0.0023 | 0.0007 |
| | | 194 | 112 | −0.689 | 0.004 | 5.4372 | 0.0023 | 0.0009 |
| | | 195 | 113 | −0.671 | 0.004 | 5.4389 | 0.0045 | 0.0011 |
| | | 196 | 114 | −0.611 | 0.005 | 5.4444 | 0.0024 | 0.0014 |
| | | 197 | 115 | −0.609 | 0.003 | 5.4446 | 0.0024 | 0.0014 |

(*continued on next page*)

Table 1 (*continued*)

| $Z$ | el. | $A$ | $N$ | $\delta\langle r^2\rangle$ (fm$^2$) | $\Delta\delta\langle r^2\rangle$ (fm$^2$) | $R$ (fm) | $\Delta_{tot}R$ (fm) | $\Delta R_{rel}$ |
|---|---|---|---|---|---|---|---|---|
| | | 198 | 116 | −0.5258 | 0.0002 | 5.4524 | 0.0022 | 0.0012 |
| | | 199 | 117 | −0.5206 | 0.0005 | 5.4529 | 0.0022 | 0.0012 |
| | | 200 | 118 | −0.4322 | 0.0002 | 5.4611 | 0.0020 | 0.0010 |
| | | 201 | 119 | −0.4127 | 0.0003 | 5.4629 | 0.0019 | 0.0009 |
| | | 202 | 120 | −0.3307 | 0.0002 | 5.4705 | 0.0017 | 0.0007 |
| | | 203 | 121 | −0.3071 | 0.0003 | 5.4727 | 0.0017 | 0.0007 |
| | | 204 | 122 | −0.2249 | 0.0001 | 5.4803 | 0.0014 | 0.0005 |
| | | 205 | 123 | −0.1983 | 0.0002 | 5.4828 | 0.0015 | 0.0005 |
| | | 206 | 124 | −0.1189 | 0.0001 | 5.4902 | 0.0014 | 0.0003 |
| | | 207 | 125 | −0.0743 | 0.0001 | 5.4943 | 0.0014 | 0.0002 |
| | | **208** | **126** | **0** | **0** | **5.5012** | **0.0013** | **0** |
| | | 209 | 127 | 0.0945 | 0.0005 | 5.5100 | 0.0014 | 0.0003 |
| | | 210 | 128 | 0.2125 | 0.0002 | 5.5208 | 0.0016 | 0.0007 |
| | | 211 | 129 | 0.3020 | 0.0003 | 5.5290 | 0.0017 | 0.0007 |
| | | 212 | 130 | 0.4178 | 0.0016 | 5.5396 | 0.0019 | 0.0003 |
| | | 214 | 132 | 0.6150 | 0.0011 | 5.5577 | 0.0023 | 0.0002 |
| 83 | Bi | 202 | 119 | −0.408 | 0.002 | 5.4840 | 0.0069 | 0.0002 |
| | | 203 | 120 | −0.330 | 0.002 | 5.4911 | 0.0058 | 0.0002 |
| | | 204 | 121 | −0.305 | 0.003 | 5.4934 | 0.0055 | 0.0003 |
| | | 205 | 122 | −0.224 | 0.001 | 5.5008 | 0.0044 | 0.0001 |
| | | 206 | 123 | −0.196 | 0.001 | 5.5034 | 0.0040 | 0.0001 |
| | | 207 | 124 | −0.119 | 0.002 | 5.5103 | 0.0032 | 0.0002 |
| | | 208 | 125 | −0.071 | 0.002 | 5.5147 | 0.0028 | 0.0002 |
| | | **209** | **126** | **0** | **0** | **5.5211** | **0.0026** | **0** |
| | | 210 | 127 | 0.099 | 0.003 | 5.5300 | 0.0030 | 0.0003 |
| | | 212 | 129 | 0.307 | 0.004 | 5.5489 | 0.0054 | 0.0004 |
| | | 213 | 130 | 0.416 | 0.001 | 5.5586 | 0.0069 | 0.0001 |
| 84 | Po | 192 | 108 | −0.403 | 0.019 | 5.5220 | 0.0178 | 0.0017 |
| | | 194 | 110 | −0.462 | 0.016 | 5.5167 | 0.0178 | 0.0014 |
| | | 196 | 112 | −0.496 | 0.013 | 5.5136 | 0.0178 | 0.0012 |
| | | 198 | 114 | −0.485 | 0.017 | 5.5146 | 0.0178 | 0.0015 |
| | | 200 | 116 | −0.426 | 0.014 | 5.5199 | 0.0178 | 0.0013 |
| | | 202 | 118 | −0.336 | 0.015 | 5.5281 | 0.0177 | 0.0014 |
| | | 204 | 120 | −0.229 | 0.014 | 5.5378 | 0.0177 | 0.0013 |
| | | 205 | 121 | −0.216 | 0.014 | 5.5389 | 0.0177 | 0.0013 |
| | | 206 | 122 | −0.116 | 0.014 | 5.5480 | 0.0177 | 0.0013 |
| | | 207 | 123 | −0.092 | 0.014 | 5.5501 | 0.0177 | 0.0013 |
| | | **208** | **124** | **0** | **0** | **5.5584** | **0.0176** | **0** |
| | | 209 | 125 | 0.049 | 0.012 | 5.5628 | 0.0176 | 0.0011 |
| | | 210 | 126 | 0.134 | 0.010 | 5.5704 | 0.0176 | 0.0009 |
| | | 216 | 132 | 0.867 | 0.014 | 5.6359 | 0.0174 | 0.0012 |
| | | 218 | 134 | 1.092 | 0.015 | 5.6558 | 0.0173 | 0.0013 |
| 86 | Rn | 202 | 116 | −0.4382 | 0.0004 | 5.5521 | 0.0181 | 0.0001 |
| | | 204 | 118 | −0.3860 | 0.0003 | 5.5568 | 0.0180 | 0.0001 |
| | | 205 | 119 | −0.3849 | 0.0003 | 5.5569 | 0.0180 | 0.0001 |
| | | 206 | 120 | −0.3058 | 0.0003 | 5.5640 | 0.0178 | 0.0001 |
| | | 207 | 121 | −0.2926 | 0.0002 | 5.5652 | 0.0178 | 0.0001 |
| | | 208 | 122 | −0.2125 | 0.0002 | 5.5725 | 0.0177 | 0.00004 |
| | | 209 | 123 | −0.1917 | 0.0001 | 5.5743 | 0.0177 | 0.00003 |
| | | 210 | 124 | −0.1143 | 0.0001 | 5.5813 | 0.0177 | 0.00002 |
| | | 211 | 125 | −0.0735 | 0.0001 | 5.5850 | 0.0176 | 0.00001 |
| | | **212** | **126** | **0** | **0** | **5.5915** | **0.0176** | **0** |
| | | 218 | 132 | 0.7000 | 0.0003 | 5.6540 | 0.0187 | 0.0001 |
| | | 219 | 133 | 0.8212 | 0.0003 | 5.6648 | 0.0191 | 0.0001 |
| | | 220 | 134 | 0.9151 | 0.0003 | 5.6731 | 0.0194 | 0.0002 |
| | | 221 | 135 | 1.0320 | 0.0004 | 5.6834 | 0.0199 | 0.0002 |
| | | 222 | 136 | 1.1236 | 0.0004 | 5.6915 | 0.0203 | 0.0002 |
| 87 | Fr | 207 | 120 | −0.21794 | 0.00016 | 5.5720 | 0.0176 | 0.00004 |
| | | 208 | 121 | −0.20804 | 0.00012 | 5.5729 | 0.0176 | 0.00003 |
| | | 209 | 122 | −0.13043 | 0.00008 | 5.5799 | 0.0176 | 0.00002 |
| | | 210 | 123 | −0.10831 | 0.00004 | 5.5818 | 0.0176 | 0.00002 |
| | | 211 | 124 | −0.03757 | 0.00004 | 5.5882 | 0.0176 | 0.00001 |
| | | **212** | **125** | **0** | **0** | **5.5915** | **0.0176** | **0** |
| | | 213 | 126 | 0.06829 | 0.00008 | 5.5977 | 0.0176 | 0.00001 |
| | | 220 | 133 | 0.86725 | 0.00045 | 5.6688 | 0.0177 | 0.0001 |
| | | 221 | 134 | 0.98269 | 0.00033 | 5.6790 | 0.0177 | 0.0002 |
| | | 222 | 135 | 1.09543 | 0.00012 | 5.6890 | 0.0177 | 0.0002 |
| | | 223 | 136 | 1.16507 | 0.00008 | 5.6951 | 0.0178 | 0.0002 |
| | | 224 | 137 | 1.28937 | 0.00004 | 5.7061 | 0.0178 | 0.0002 |
| | | 225 | 138 | 1.34862 | 0.00022 | 5.7112 | 0.0178 | 0.0002 |
| | | 226 | 139 | 1.43700 | 0.00004 | 5.7190 | 0.0178 | 0.0002 |
| | | 227 | 140 | 1.60249 | 0.00008 | 5.7335 | 0.0179 | 0.0002 |

(*continued on next page*)

Table 1 (*continued*)

| $Z$ | el. | $A$ | $N$ | $\delta\langle r^2\rangle$ (fm$^2$) | $\Delta\delta\langle r^2\rangle$ (fm$^2$) | $R$ (fm) | $\Delta_{tot}R$ (fm) | $\Delta R_{rel}$ |
|---|---|---|---|---|---|---|---|---|
| | | 228 | 141 | 1.67522 | 0.00020 | 5.7399 | 0.0179 | 0.0003 |
| 88 | Ra | 208 | 120 | −0.2560 | 0.0002 | 5.5850 | 0.0183 | 0.0024 |
| | | 209 | 121 | −0.2530 | 0.0002 | 5.5853 | 0.0182 | 0.0022 |
| | | 210 | 122 | −0.1820 | 0.0002 | 5.5917 | 0.0180 | 0.0017 |
| | | 211 | 123 | −0.1680 | 0.0001 | 5.5929 | 0.0179 | 0.0015 |
| | | 212 | 124 | −0.0990 | 0.0001 | 5.5991 | 0.0177 | 0.0009 |
| | | 213 | 125 | −0.0660 | 0.0001 | 5.6020 | 0.0177 | 0.0006 |
| | | **214** | **126** | **0** | **0** | **5.6079** | **0.0177** | **0** |
| | | 220 | 132 | 0.6790 | 0.0002 | 5.6683 | 0.0215 | 0.0062 |
| | | 221 | 133 | 0.8050 | 0.0002 | 5.6795 | 0.0228 | 0.0073 |
| | | 222 | 134 | 0.8950 | 0.0002 | 5.6874 | 0.0239 | 0.0081 |
| | | 223 | 135 | 1.0070 | 0.0003 | 5.6973 | 0.0253 | 0.0091 |
| | | 224 | 136 | 1.0900 | 0.0003 | 5.7046 | 0.0263 | 0.0098 |
| | | 225 | 137 | 1.2080 | 0.0003 | 5.7150 | 0.0279 | 0.0108 |
| | | 226 | 138 | 1.2770 | 0.0003 | 5.7211 | 0.0288 | 0.0115 |
| | | 227 | 139 | 1.3650 | 0.0004 | 5.7283 | 0.0300 | 0.0123 |
| | | 228 | 140 | 1.4590 | 0.0004 | 5.7370 | 0.0315 | 0.0131 |
| | | 229 | 141 | 1.5560 | 0.0005 | 5.7455 | 0.0329 | 0.0140 |
| | | 230 | 142 | 1.6670 | 0.0005 | 5.7551 | 0.0346 | 0.0150 |
| | | 232 | 144 | 1.8540 | 0.0005 | 5.7714 | 0.0375 | 0.0166 |
| 90 | Th | 227 | 137 | −0.508 | 0.003 | 5.7404 | 0.0165 | 0.0062 |
| | | 228 | 138 | −0.413 | 0.001 | 5.7488 | 0.0152 | 0.0049 |
| | | 229 | 139 | −0.334 | 0.001 | 5.7557 | 0.0143 | 0.0040 |
| | | 230 | 140 | −0.2050 | 0.0004 | 5.7670 | 0.0131 | 0.0025 |
| | | **232** | **142** | **0** | **0** | **5.7848** | **0.0124** | **0** |
| 92 | U | 233 | 141 | −0.435 | 0.001 | 5.8203 | 0.0049 | 0.0043 |
| | | 234 | 142 | −0.334 | 0.001 | 5.8291 | 0.0052 | 0.0033 |
| | | 235 | 143 | −0.2803 | 0.0002 | 5.8337 | 0.0041 | 0.0027 |
| | | 236 | 144 | −0.1676 | 0.0002 | 5.8431 | 0.0038 | 0.0016 |
| | | **238** | **146** | **0** | **0** | **5.8571** | **0.0033** | **0** |
| 94 | Pu | 238 | 144 | −0.082 | 0.004 | 5.8535 | 0.0378 | 0.0012 |
| | | **239** | **145** | **0** | **0** | **5.8601** | **0.0378** | **0** |
| | | 240 | 146 | 0.122 | 0.003 | 5.8701 | 0.0379 | 0.0016 |
| | | 241 | 147 | 0.179 | 0.004 | 5.8748 | 0.0379 | 0.0019 |
| | | 242 | 148 | 0.273 | 0.004 | 5.8823 | 0.0380 | 0.0024 |
| | | 244 | 150 | 0.426 | 0.008 | 5.8948 | 0.0382 | 0.0032 |
| 95 | Am | 241 | 146 | −0.142 | 0.008 | 5.8928 | 0.0042 | 0.0012 |
| | | **243** | **148** | **0** | **0** | **5.9048** | **0.0035** | **0** |
| 96 | Cm | 242 | 146 | −0.168 | 0.056 | 5.8285 | 0.0192 | 0.0049 |
| | | **244** | **148** | **0** | **0** | **5.8429** | **0.0181** | **0** |
| | | 245 | 149 | 0.054 | 0.011 | 5.8475 | 0.0182 | 0.0010 |
| | | 246 | 150 | 0.156 | 0.022 | 5.8562 | 0.0184 | 0.0020 |
| | | 248 | 152 | 0.303 | 0.054 | 5.8687 | 0.0193 | 0.0040 |

**Table 2**
Parameters used for the extraction of radii changes from OIS.

| | |
|---|---|
| $_{1}$H | IS on 1S → 2S transition; $\delta\langle r^2\rangle^{1,2}$ as given by [Pa10]. |
| $_{2}$He | He I at 389 nm, $2^3S_1 \rightarrow 3^3P_2$ transition; $\delta\langle r^2\rangle$ [Wa04, Mu07]; $F_{cal} = +1.008$ MHz/fm$^2$, $MS_{cal}(^{4,6}$He$) = +43196.217$ MHz (see for details [Dr04]). |
| $_{3}$Li | Li I at 735 nm ($2s^2S_{1/2}$–$3s_2S_{1/2}$—two photon transition); $\delta\langle r^2\rangle$ as given by [Nö11, 28] (see also [Ew04, Sá06, Sá06b]); $F_{cal} = -1.5719(16)$ MHz/fm$^2$, $MS_{cal} = +11452.821(3)$ MHz for $\delta\langle r^2\rangle^{6,7}$ [Nö11, 28] (the latest version of *F* and *MS* calculations); the *OIS* experimental technique is accompanied by high-precision theoretical calculations. |
| $_{4}$Be | Be I at $D_1$ and $D_2$-lines; $\delta\langle r^2\rangle$ [Nö 09, Žá10] ; $F_{cal}(D_1) = -16.912$ MHz/fm$^2$, $MS_{cal}(^{9,7}$Be$) = -49225.765$ MHz [Ya08]; $F_{cal}(D_2) \approx +17$ MHz/fm$^2$ (for details see [Pu08]), $MS_{cal}(^{9,7}$Be$) = -49231.827(39)$ MHz [Ya08]. |
| $_{10}$Ne | IS for Ne I at 614.3 nm, transition $2p^53s[3/2]_2 \rightarrow 2p^53p[3/2]_2$; $\delta\langle r^2\rangle$ as given by [Ge08, Ma11]; $F_{se} = -40(4)$ MHz/fm$^2$, $MS_{\mu} = +363(42)$ GHz u calibrated via King plot with $R_{\mu}$-data of [4]. |
| $_{11}$Na | IS for Na I at $D_1$-line; $\delta\langle r^2\rangle$[5]; $F_{se} = -47$ MHz/fm$^2$; $MS_{se} = +385.5$ GHz u [Hu82]. |
| $_{18}$Ar | IS for Ar I at 763.7 nm, transition $3p^54s[3/2]_2 \rightarrow 3p^54p[3/2]_2$ [Kl96, Bl08]; $\delta\langle r^2\rangle$ [Bl08] with $F_{se} = -104(10)$ MHz/fm$^2$; $MS_{\mu} = +189.0(1.9)$—calibrated via King plot using $R_{\mu}$-data of [4]. |
| $_{19}$K | IS for K I at $D_1$-line; $\delta\langle r^2\rangle$ [To82], $F_{se} = -128$ MHz/fm$^2$; $MS_{e\mu} = +198.4(3.9)$ GHz u—King plot procedure using model independent $R_{e\mu}$ data from [Wo81]. |
| $_{20}$Ca | IS for $^{40-48}$Ca I at different transition; $\delta\langle r^2\rangle$ from [Pa84], $F_{e\mu}$, $MS_{e\mu}$—via King plot procedure using $R_{e\mu}$ data from [Wo81]; IS($^{40,39}$Ca) [Ve96] and IS($^{44,50}$Ca) [Ve92] for CaII at 397 nm, transition $3p^64s^2S_{1/2} \rightarrow 3p^64p^2P_{1/2}$; $F_{cal} = -283(6)$ MHz/fm$^2$ [Må92], $MS_{e\mu} = +405.1(3.8)$ GHz u from King-plot procedure versuss OIS data of [Pa84]. |
| $_{21}$Sc | Sc II at 363.1 nm, transition $3d4s^3D_2 \rightarrow 3d4p^3F_3$, $F_{cal} = -355(50)$ MHz/fm$^2$, $MS_{cal} = +583(30)$ GHz u [Av11]. |
| $_{22}$Ti | IS for Ti II at 324.2 nm, transition $d^2s\,^4F_{3/2} \rightarrow d^2p\,^4F_{3/2}$ [Ga04]; $F_{cal} = -460(46)$ MHz/fm$^2$, $MS_{e\mu} = +788(6)$ GHz u calibrated by model independent $R_{e\mu}$-data of [Wo81]. |
| $_{24}$Cr | $\delta\langle r^2\rangle$ recalculated with isotopic shifts of Cr I—projected values on 520.8 nm (transition $3d^54s\,^5S_2 \rightarrow 3d^54p\,^5P_3$) [14], $F_{e\mu} = +244.6(34.5)$ MHz/fm$^2$, $MS_{e\mu} = -475.4(9.4)$ GHz u calibrated via King-plot using $R_{e\mu}$-data of [15]. |
| $_{25}$Mn | IS for Mn II at 294.9 nm, transition $3d^54s\,^5S_2 \rightarrow 3d^54p\,^5P_3$, $\delta\langle r^2\rangle$ calculated with $F_{cal} = -572$ MHz/fm$^2$, $MS_{cal} = +852$ GHz u [Ch10]. |
| $_{26}$Fe | IS for Fe I at 304.76 nm, transition $3d^64s^2\,^5D_2 \rightarrow 3d^74p\,^5D_3$ [Be97]; $\delta\langle r^2\rangle$ recalculated with $F_{e\mu} = -920(114)$ MHz/fm$^2$, $MS_{e\mu} = +2992(50)$ GHz u-calibration via King plot using $R_{e\mu}$ data of [15]. |
| $_{28}$Ni | IS for Ni I at 361.05 nm, transition $3d^94s\,^3D_2 \rightarrow 3d^94p\,^3P_2$ [St80]; $\delta\langle r^2\rangle$ recalculated with $F_{se} = -767(77)$ MHz/fm$^2$; $MS_{e\mu} = +1228(15)$ GHz u-calibrated via King plot using $R_{e\mu}$ data of [15]. |
| $_{30}$Zn | IS for Zn I at 307.6 nm, transition $3d^{10}4s^2\,^1S_0 \rightarrow 3d^{10}4s4p\,^3P^1$ [Ca97]; $\delta\langle r^2\rangle$ recalculated with $F_{cal} = -1510(151)$ MHz/fm$^2$ [Ca97], $MS_{e\mu} = +1970(29)$ GHz u-calibrated via King plot using $R_{e\mu}$ data of [15]. |
| $_{36}$Kr | $\delta\langle r^2\rangle$ as given in [Ke94]; $F_{se} = -608(61)$ MHz/fm$^2$, $MS_e = +167(19)$ GHz u determined via King plot using $R_e$ data of [Ma84]. |
| $_{37}$Rb | IS for Rb I at $D_2$-line; $F_{se} = -650(65)$ MHz/fm$^2$, $MS_{se} \approx N = +211$ GHz u [Th81]. |
| $_{38}$Sr | IS for Sr II at 407.9 nm, transition $5\,s^2\,S_{1/2} \rightarrow 5p\,^2P_{3/2}$; IS($^{78,79-98,100}$Sr) [Bu90]; IS($^{77-88}$Sr) [Li92]; IS($^{99}$Sr) [Li91]; $F_{se} = -1582(49)$ MHz/fm$^2$, $MS_{\mu} = +351(44)$ GHz u [Bu90]. |
| $_{39}$Y | Y II at 363 nm ($5s^2\,^1S_0 \rightarrow 4d5p\,^1P_1$); $F_{phen} = -3181$ MHz/fm$^2$, $MS_{phen} = +1789$ GHz u—King plot vs $\delta\langle r^2\rangle$ of neighboring isotones [Ch07]. |
| $_{40}$Zr | IS($^{91-102}$Zr II) at nm 327 nm ($d^2s\,^4F_3 \rightarrow d^2p\,^4F_5$ transition) [Ca02]; $\delta\langle r^2\rangle$ recalculated with $F_{e\mu} = -2190(183)$ MHz/fm$^2$, $MS_e = +737(202)$ GHz u via King plot versus $R_{e\mu}$ data of [8]; IS($^{87-92}$Zr II) at 310 nm ($d^2s\,^4F_{3/2} \rightarrow d^2p\,^4D_{3/2}$ transition) [Fo02], $\delta\langle r^2\rangle$ recalculated with $F_{e\mu}(310$ nm$) = -1762(119)$ MHz/fm$^2$, $MS_{e\mu} = +385(139)$ GHz u via King plot versus $R_{e\mu}$ data of [8]. |
| $_{41}$Nb | IS for Nb II at 291 nm ($5s\,^5F_1 \rightarrow 5p\,^5F_1$ transition); $\delta\langle r^2\rangle$ from [Ch09];, $F_{phen} = -2.43$ GHz/fm$^2$, $MS_{phen} = +718$ GHz u – using King plot versus $\delta\langle r^2\rangle$ of neighbouring isotopic chain of Zr. |
| $_{42}$Mo | IS for Mo II at 293 nm ($4d^45s\,^6D_{1/2} \rightarrow 4d^45p\,^6F_{1/2}$ transition) [Ch09a]; $\delta\langle r^2\rangle$ recalculated with $F_{\mu} = -2.82(2)$ GHz/fm$^2$, $MS_{\mu} = +681(197)$ GHz u from King plot using $R_{\mu}$ of [8]. |
| $_{44}$Ru | IS for Ru I at 437 nm ($4d^65s^2\,^5D_4 \rightarrow 4d^75p\,^3F_4$ transition) [Ki64]; $\delta\langle r^2\rangle$ recalculated with $F_{e\mu} = -4621(581)$ MHz/fm$^2$, $MS_{e\mu} = +2275(766)$ GHz u from King plot versus $R_{e\mu}$ data of [15]. |
| $_{46}$Pd | IS for Pd I at 447.4 nm ($4d^95s\,^1D_2 \rightarrow 4d^95p\,^3P_2$ transition) [Kü93]; $\delta\langle r^2\rangle$ recalculated with $F_{\mu e} = -2775(118)$ MHz/fm$^2$, $MS_{\mu e} = +668(146)$ GHz u-calibrated via King plot versus $\underline{\Lambda}_{\mu e}$[14]. |
| $_{47}$Ag | Ag I at 547.7 nm ($4d^95s^2\,^2D_{5/2} \rightarrow 4d^{10}6p\,^2P_{3/2}$); $\delta\langle r^2\rangle$ as given in [Di89], where $F_{se} = -12070(966)$ MHz/fm$^2$, $MS_{se} = +4446(2700)$ GHz u. |
| $_{48}$Cd | IS for Cd I for at 326.1 nm ($4^{d10}5s^2\,^1S_0 \rightarrow 4d^{10}5s5p\,^3P_1$) using projected values from [14] (see references therein); $\delta\langle r^2\rangle$ recalculated with $F_{se} = +3910(460)$ MHz/fm$^2$, $MS_{se} = +876(230)$ GHz u (see [5] and references therein). |
| $_{49}$In | IS for In II at 451 nm ($5s^25p\,^2P_{3/2} \rightarrow 5s^26s\,^2S_{1/2}$); $F_{cal} = +2.070(10)$ GHz/fm$^2$; $MS_{phen} = -62(73)$ GHz u calibrated using $\delta\langle r^2\rangle$ for neighbouring isotones [Eb87]. |
| $_{50}$Sn | Sn I at 286.3 nm ($5s^25p^2\,^3P_0 \rightarrow 5s^25p6s\,^3P_1$); IS($^{110-125}$Sn) [An86]; IS($^{126-132}$Sn) [Bl05]; IS($^{108,109}$Sn) at 452 nm [Eb87b] calibrated to 286.3 nm; $F_{se} = +3.30(27)$ MHz/fm$^2$ [Ba83]; $MS_{\mu} = -761(200)$ GHz u [Bl05] calibrated using King plot versus $R_{\mu}$ data of [Pi90]. |
| $_{52}$Te | IS for Te II at 214.3 nm ($5p^{43}P_2 \rightarrow 5p^36s^3S_1$) [Ro09], $F_{\mu} = +3.78(48)$ GHz/fm$^2$, $MS_{\mu} = -556(283)$ GHz[16] calibrated via King plot with $R_{\mu}$ data of [4]. |
| $_{54}$Xe | IS for Xe I at $\lambda = 823.2$ nm ($5p^56s\,[3/2]_2 \rightarrow 5p^56p\,[3/2]_2$); $\delta\langle r^2\rangle^{116-146}$Xe (exceptions $^{127,133}$Te) [Bo89]; IS($^{127,133}$Xe) projected values on 823.2 nm (see [14] and references therein); $F_{se} = -2.32(23)$ GHz/fm$^2$, $MS_{se} \approx N = +193(178)$ GHz u [Bo89]. |
| $_{55}$Cs | IS for Cs I at 852.1 nm ($6s\,^2S_{1/2} \rightarrow 6p\,^2P_{3/2}$ transition); IS($^{118-145}$Cs) [Th81b]; IS($^{118,146}$Cs) [Co87]; $F_{se} = -2313(230)$ MHz/fm$^2$, $MS_{se} \approx N = +193$ GHz u [Th81b]. |
| $_{56}$Ba | IS for Ba I – projected values on 553.6 nm ($6s^2\,^1S_0 \rightarrow 6s6p\,^1P_1$ transition) (see [14] and references therein); $\delta\langle r^2\rangle$ recalculated with $F_{se} = -3929(40)$ MHz/fm$^2$, $MS_{se} \approx N = +295$ GHz u [Be79]. |
| $_{57}$La | IS for La II at 538.2 nm ($6s^2\,^1S_0 \rightarrow 5d6p\,^3D_1$); $\delta\langle r^2\rangle$ – recalculated using $F_{se} = -13.15(1.23)$ GHz/fm$^2$, $MS_{se} = -4106$ GHz u – combined data from [Ii03, Fi74]. |
| $_{58}$Ce | IS for Ce II for 331 nm ($5d^2$ J = 7/2 → 5d6p J = 7/2); $F_{se} = +2031(103)$ MHz/fm$^2$, $MS_{se} = -666(504)$ GHz u [Ch03]. |
| $_{60}$Nd | IS for Nd I at 588.8 nm ($6s^2\,^5I_4 \rightarrow 6s6p\,^7K_3$) ; IS ($^{132-143}$Nd) [Le92]; IS($^{142-150}$Nd) [Al87]; $F_{se} = +825$ MHz/fm$^2$, $MS_{se} = +4547(45)$ GHz u [Le92]. |
| $_{62}$Sm | $\delta\langle r^2\rangle$ recalculated using projected values of IS($^{138-154}$Sm) for Sm I on 570.7 nm ($4f^66s^2\,^7F_1 \rightarrow 4f^66s6p\,^7F_0$) (see [14] and references therein), $F_{se} = -4199(389)$ MHz/fm$^2$, $MS_{se} = -295(13)$ GHz u calculated combining OIS data of [En90, Br80]. |

(*continued on next page*)

Table 2 (*continued*)

| | |
|---|---|
| $_{63}$Eu | IS for Eu I; $\delta\langle r^2\rangle$ recalculated using IS($^{137-139}$Eu) [Ba04] and IS($^{154}$Eu) [Zh84] at 576.5 nm ($6s^2\ ^8S_{7/2} \rightarrow 6s6p\ ^6P_{7/2}$) with $F_{se} = -6.55$ GHz/fm$^2$, $MS_{se} \approx N = +285$ GHz u [Ba04]; IS($^{140-153}$ Eu) at 462.7 nm ($4f^7 6s^2\ ^8S_{7/2} \rightarrow 4f^7 6s6p\ ^8P_{7/2}$) with $F_{se} = -5.25$ GHz/fm$^2$; $MS_{se} \approx N = +355$ GHz u [Ah85]; IS($^{155-159}$Eu) at 601.8 nm ($6s^2\ ^8S_{7/2} \rightarrow 6s6p\ ^8P_{9/2}$) with $F_{se} = -6.57$ GHz/fm$^2$, $MS_{se} \approx N = +274$ GHz u [Al90]. |
| $_{64}$Gd | IS of Gd I; $\delta\langle r^2\rangle$ recalculated using IS($^{146-160}$ Gd) projected values on 585.2 nm ($5d6s^2\ ^9D_5 \rightarrow 5d6s6p\ ^9D_5$) – see [14] and references therein; $F_{se} = -7.08$ GHz/fm$^2$, $MS_{se} = +167(139)$ GHz u [Bo87, Al88]; IS($^{145,160}$Gd) at 569.6 nm ($5d6s^2\ ^9D_4 \rightarrow 5d6s6p\ ^9D_5$), $F_{se} = -7.03$ GHz/fm$^2$, $MS_{se} = +162(139)$ GHz u [Ba05, Bo87]. |
| $_{65}$Tb | IS for Tb I at 579.6 nm ($4f^9 6s^2\ ^6H \rightarrow 4f^9 6s6p\ H_{17/2}$); $F_{se} = -7.83$ GHz/fm$^2$, $MS_{se} \approx N = +283.7$ GHz u [Al90b]. |
| $_{66}$Dy | Data for radioactive isotopes are not published; $\delta\langle r^2\rangle$ recalculated using $\lambda$ as given by [5]; IS for Dy I at 421 nm ($D_1$-line) $F_{se} = -7.26$ GHz/fm$^2$, $MS_{se} \approx N = +390$ GHz u[5] (see also the references therein); in this case the uncertainties include statistical and systematic errors. |
| $_{67}$Ho | IS for Ho I at 592.2 nm ($4f^{11}6s^2\ ^4I_{15/2} \rightarrow 4f^{11}6s6p\ (15/2,1)_{15/2}$ transition), $F_{se} = -8.41$ GHz/fm$^2$, $MS_{se} \approx N = +278$ GHz u [Al89]; IS($^{151}$Ho) not published; the $\lambda^{165,151}$ given in [5] was used. |
| $_{68}$Er | IS for Er I – projected values on 582.7 nm ($4f^{12}6s^2\ ^3H_6 \rightarrow [4f^{12}6s6p\ (^3P_1)]_7$) – (see [14] and references therein); $\delta\langle r^2\rangle$ recalculated with $F_{se} = -8.08$ GHz/fm$^2$, $MS_{se} \approx N = +282$ GHz u (preliminary values of [5, Ne84]). |
| $_{69}$Tm | IS for Tm I at 597.13 nm ($4f^{13}6s^2\ ^2F_{7/2} \rightarrow 4f^{13}6s6p_{7/2}$); IS($^{153,154}$Tm) [Ba00]; IS($^{156}$Tm) [Al87]; IS($^{157-172}$Tm) [Al88b] nm; $\delta\langle r^2\rangle$ recalculated with $F_{se} = -10.3$ GHz/fm$^2$, $MS_{se} \approx N = +275$ GHz u [Al88b]. |
| $_{70}$Yb | Yb I; $\delta\langle r^2\rangle$ recalculated using IS($^{152-176}$Yb) projected values on 555.6 nm ($4f^{14}6s^2\ ^1S_0 \rightarrow 4f^{14}6s6p\ ^3P_1$) (see [14] and references therein) with $F_{se} = -11.5$ GHz/fm$^2$, $MS_{se} = +4581(1531)$ GHz u from combined optical, muonic and electronic $K_x$ data analysis of [Cl79]. |
| $_{71}$Lu | IS for Lu I at 451.9 nm ($5d6s^2\ ^2D_3 \rightarrow 5d6s6p\ ^2D_3$) [Ge98]; $\delta\langle r^2\rangle$ recalculated relative 175 Lu with $F_{se} = -11.2$ GHz/fm$^2$, $MS_{se} \approx N = +362$ GHz u from [Ge98] with HM correction as given in [14]. |
| $_{72}$Hf | Hf II; $\delta\langle r^2\rangle^{170-175,176-182}$ recalculated using IS projected values on 301.3 nm ($5d6s^2\ ^2D_{3/2} \rightarrow 5d6s6p\ ^2D_{5/2}$) – (see [14] and references therein) with $F_{se} = -22.1(4)$ GHz/fm$^2$, $MS_{se} = +298(503)$ GHz u using analisys of [Zi94, Le99]; IS ($^{171}$Hf) at 301.3 nm from [Ye00]; $\delta\langle r^2\rangle^{174,175}$ from [Ji97]. |
| $_{74}$W | $\delta\langle r^2\rangle$ mean value of four optical transition of W I; reference transition 543.5 nm ($5d^4 6s^2\ ^5D_1 \rightarrow 5d^4 6s6p\ ^7F_1$); $F_{se} = +19.85$ GHz/fm$^2$, $MS_{se} \approx N = +303(152)$ GHz u [Ji94]. |
| $_{75}$Re | $\lambda^{187,185}$ from [Kr86] additionally corrected for HM. |
| $_{76}$Os | $\lambda^{A'A}$ of [Au87] (see also the references therein) corrected for HM. |
| $_{77}$Ir | IS for Ir I at 351.5 nm ($5d^7 6s^2\ ^4F_9 \rightarrow 5d^7 6s6p\ ^6F_{11/2}$); $\delta\langle r^2\rangle$ from [Ve06]; $F_{se} = -30.94$ GHz/fm$^2$, $MS_{se} \approx N = +468(234)$ GHz u. |
| $_{78}$Pt | IS($^{183-198}$Pt) for Pt I at 265.57 nm ($5d^9 6s\ ^3D_3 \rightarrow 5d^9 6p\ 7_4$) [Hi92], $F_{se} = -20.78$ GHz/fm$^2$, $MS_{se} = +798$ GHz u; IS($^{178-185}$Pt) for Pt I at 306.5 nm ($5d^9 6s\ ^3D_3 - 5d^9 6p\ ^3P_2$), [Bl00, Sa00], $F_{se} = -18.5(10)$ GHz/fm$^2$, $MS_{se} = +764$ GHz u via King plot for stable Pt isotopes using [Ne87]. |
| $_{79}$Au | IS for Au I, projected values on 267.6 nm ($5d^{10}6s\ ^2S_{1/2} \rightarrow 5d^{10}6p\ ^2P_{1/2}$) [14] (see also references therein) for $^{184-189}$Au; $^{183}$Au at 267.6 nm [Kr88]; $F_{cal} = -43.07$ GHz/fm$^2$, $MS_{se} = +799(553)$ GHz u [Wa87, Pa94]. |
| $_{80}$Hg | IS($^{181-204}$Hg) for Hg I projected values on 253.65 nm ($5d^{10}6s^2\ ^3S_0 \rightarrow 5d^{10}6s6p\ ^3P_1$) (see [14] and references therein); IS($^{205,206}$Hg) [Ul86]; $\delta\langle r^2\rangle$ recalculated with $F_{cal} = -55.36$ GHz/fm$^2$ [To85], $MS_{se} \approx N = +648(324)$ GHz u. IS($^{190-207}$Hg) projected values on 535 nm ($6s^2 6p\ ^2P_{3/2} \rightarrow 6s^2 7s\ ^2S_{1/2}$) [14] (see also references therein). |
| $_{81}$Tl | IS($^{188}$Tl) for Tl I at 535 nm ($6s^2 6p\ ^2P_{3/2} - 6s^2 7s\ ^2S_{1/2}$) from [Me92]; $\delta\langle r^2\rangle$ recalculated with $F_{cal} = +18.94$ GHz/fm$^2$ [Me92], $MS_{se} \approx +399(83)$ GHz u; $\delta\langle r^2\rangle^{207,208}$ [La92] recalculated relative $^{205}$Tl using IS ($^{205,207}$Tl) at 535 nm [Ne85]. |
| $_{82}$Pb | IS for Pb I on 283.3 nm ($6s^2 6p^2\ ^3P_0 \rightarrow 6s^2 6p7s\ ^3P_1$); IS ($^{196-214}$Pb) [An86b]; IS ($^{182-189}$Pb) [Wi07, Se09]; IS ($^{190-195}$Pb) projected values on 283.3 nm [14], $F_{e\mu} = +20.26(18)$ GHz/fm$^2$ [An86b], $MS_{cal} = +0.19(25) \cdot N = +110(145)$ GHz u [Ki85]. |
| $_{83}$Bi | IS for Bi I at 306.7 nm ($6s^2 6p^3\ ^4S_{3/2} \rightarrow 6s^2 6p^2 7s\ ^4P_{1/2}$) [Pe00]; $\delta\langle r^2\rangle$ estimated using experimental value of $\delta\langle r^2(\mathrm{Pb})\rangle^{208,206} = -0.119$ fm$^2 \approx \langle r^2(\mathrm{Bi})\rangle^{209,207}$ with an adopted uncertainty of 0.020 fm$^2$; $Fest = -25.4(4.3)$ GHz/fm$^2$ and $MS_{se} \approx N = +536$ GHz u. |
| $_{84}$Po | Po I at $\lambda = 843.38$ nm ($6p^3 7s\ ^5S_2 \rightarrow 6p^3 7p\ ^5P_2$) – even isotopes [Co11]; IS(odd isotopes) [Ko91] projected values on 843.38 nm; $F_{cal} = -12.786$ GHz/fm$^2$; $MS_{cal} = -116$ GHz u [Co10]. |
| $_{86}$Rn | IS for Rn I at 745 nm, $7s[3/2]_2 \rightarrow 7p[5/2]_3$ transition (see Fig. 3 [Bo87b]), $\delta\langle r^2\rangle$ recalculated using $F_{se} = -22.1$ GHz/fm$^2$[5], $MS_{se} \approx N = +221$ GHz u. |
| $_{87}$Fr | IS for Fr I at 717.97 nm, $D_2$-line [Co85]; $\delta\langle r^2\rangle$ recalculated in [Co87] with $F_{se} = -24.10$ GHz/fm$^2$, $MS_{se} \approx N = +229$ GHz u. |
| $_{88}$Ra | IS for Ra I at 482.6 nm, $7s^2\,^1S_0 \rightarrow 7s7p^1\ P_1$ transition; $\delta\langle r^2\rangle$ as given by [Ah88]; $F_{se} = -35.27$ GHz/fm, $MS_{se} \approx N = +341$ GHz u (see [We87, Ah88]). |
| $_{90}$Th | IS for Th II at 583.89 nm ($6d^2 7s\ ^4F_{3/2} \rightarrow 5f6d^2$); $\delta\langle r^2\rangle$ as given by [Kä89] with statistical errors only, $F_{phen} = -81.3(11.2)$ GHz/fm$^2$, calibrated using $\lambda^{232,230} = 0.189(26)$ fm$^2$ (see [Au87] and references therein), $MS_{se} \approx N = +282$ GHz u. |
| $_{92}$U | IS for U I at 591.5 nm ($6d7s^2\ ^5L_0 \rightarrow 6d7s7p\ ^7M_7$) [An92]; $F_{phen} = -33.6(7.4)$ GHz/fm$^2$, calibrated using $\lambda^{238,236} = -0.151(34)$ fm$^2$ (see [Au87] and references therein), $MS_{se} \approx N = +278$ GHz u. |
| $_{94}$Pu | IS for Pu I at 420.64 nm ($f^6 s^2 \rightarrow f^6 sp$) [Ge87]; $\delta\langle r^2\rangle$ recalculated assuming $MS_{se} \approx N = +391$ GHz u, $F = -42.4(3.6)$ GHz/fm$^2$ obtained by one parameter fit to model dependent muonic radii of $^{239,240,242}$Pu of [Zu86] (see also [14]). |
| $_{95}$Am | $\lambda^{243,241} = -0.128(7)$ [Ba98] (see references therein) corrected for HM. |
| $_{96}$Cm | $\lambda^{244,A}$ from [Au87] (see references therein) corrected for HM. |

*References for* Table 2 *(for radii changes from OIS).*


[Ki64] W.H. King, *Isotope shifts in the arc spectrum of ruthenium*, Proc. Roy. Soc. London 280 (1964) 430.

[Fi74] W. Fischer, H. Hühnermann, K. Mandrek, *Isotope shift measurements in the atomic spectrum of lanthanum*, Z. Phys. 269 (1974) 245.

[He74] K. Heilig, A.Steudel, At. Data Nucl. Data Tables 14 (1974) 613.
[Be79] K. Bekk, A. Andle, S. Göring, A. Hansel, G. Nowicki, H. Rebel, G. Schatz, *Laserspectroscopic study of collective properties of neutron deficient Ba nuclei*, Z. Phys. A 291 (1979) 219.
[Cl79] D.L. Clark, M.E. Cage, D.A. Lewis, G.W. Greenlees, *Optical isotope shifts and hyperfine splittings for* Yb, Phys. Rev. 20 (1979) 239.

[Br80] H. Brand, B. Seibert, A. Steudel, *Laser-atomic-beam spectroscopy in Sm: isotope shifts and changes in mean-square charge radii*, Z. Phys. A 296 (1980) 281.
[St80] A. Steudel, U. Triebe and D. Wendtlandt, *Isotope shift in* Ni I *and changes in mean square nuclear charge radii of stable* Ni *isotopes*, Z. Phys. A 296 (1980) 189.

[Wo81] H.D. Wohlfahrt, E.B. Shera, M.V. Hoehn, Y. Yamazaki, R.M. Steffen, *Nuclear charge distributions in* $^{1}f_{7/2}$*-shell nuclei from muonic X-ray measurements*, Phys. Rev. C 23 (1981) 523.
[Th81] C. Thibault, F. Touchard, S. Büttgenbach, R. Klapisch, M. de Saint Simon, H.T. Duong, P. Jaquinot, P. Juncar, S. Liberman, P. Pillet, J. Pinard, J.L. Vialle, A. Pesnelle, G. Hube, *Hyperfine structure and isotope shift of the* $D_2$ *line of* $^{76-98}$Rb *and some their isomers*, Phys. Rev. C 23 (1981) 2720.
[Th81b] C. Thibault, F. Touchard, S. Büttgenbach, R. Klapisch, M. de Saint Simon, H.T. Duong, P. Jaquinot, P. Juncar, S. Liberman, P. Pillet, J. Pinard, J. L. Vialle, A. Pesnelle, G. Huber, *Hyperfine structure and isotope shift of the* $D_2$ *line of* $^{118-145}$Cs *and some their isomers*, Nuclear Phys. A 367 (1981) 1.

[Hu82] G. Huber, F. Touchard, S. Buettgenbach, C. Thibault, R. Klapisch, H.T. Duong, S. Liberman, J. Pinard, J.L. Vialle, P. Juncar, P. Jacquinot, *Spin, magnetic moments and isotope shifts of* $^{21-31}$Na *by high resolution laser spectroscopy of the atomic* $D_1$ *line*, Phys. Rev. C 18 (1978) 2342.
[To82] F. Touchard, P. Guimbal, S. Büttgenbach, R. Klapisch, M. de Saint Simon, C. Thibault, H.T. Duong, P. Juncar, S. Lieberman, J. Pinard, J.L. Vialle, *Isotope shifts and hyperfine structure of* $^{37-48}$K *by laser spectroscopy*, Phys. Lett. B 108 (1982) 169.

[Ba83] P. E.G. Baird, S.A. Blundell, G. Burrows, C. J. Foot, G. Meiselt, D.N. Stacey, G. K. Woodgate, *Laser spectroscopy of the tin isotopes*, J. Phys. B: At. Mol. Phys. 16 (1983) 2485.

[Ma84] G.K. Mallot: Ph.D.Thesis, Univ. Mainz (1984).
[Ne84] R. Neugart, private communication.
[Pa84] C.W.P. Palmer, P.E.G. Baird, S.A. Blundell, J.R. Brandenberger, C.J. Foot, D.N. Stacey, G.W. Woodgate, *Laser spectroscopy of calcium isotopes*, J. Phys. B: At. Mol. Phys. 17 (1984) 2197.
[Zh84] A.N. Zherikhin, O.N. Kompanets, V.S. Letokhov, I.V. Mishin, V.N. Fedoseev, G.D. Alkhasov, A.E. Barzakh, E.E. Berlovich, V.P. Denissov, A.G. Dernatian, V.S. Ivanov, *High-resolution laser photoionization spectroscopy of radioactive europium isotopes*, Zh. Eksp. Teor. Fiz. 86 (1984) 1249.

[Ah85] S.A. Ahmad, W. Klempt, C. Eksröm, R. Neugart, K. Wendt, *Nuclear spins, moments and changes of the mean square radii of* $^{140-153}$Eu, Z. Phys. A 321 (1985) 35.
[Bl85] S.A. Blundell, P.E.G. Baird, C.W.P. Palmer, D.N. Stacey, G.K. Woodgate, D. Zimmermann: A Re-Evaluation of Isotope Shift Constants, Z. Physik A - Atoms and Nuclei 321 (1985) 31.
[Co85] A.Coc, C. Thibault, F. Touchard, H.T. Duong, P. Juncar, S. Liberman, J. Pinard, J. Lerme, J.L. Vialle, S. Büttgenbach, A.C. Mueller, A. Pesnelle and the ISOLDE Collaboration, *Hyperfine structure and isotope shifts of* $^{207-213,220-228}$Fr; *possible evidence of octupole deformation*, Phys. Lett. 163B (1985) 66.
[Ki85] W.H. King, M. Wilson, *Isotope shifts in lead: mass shifts and the odd–even effect*, J. of Phys. G 1l (1985) L43.
[Ne85] R. Neugart, H.H. Stroke, S.A. Ahmad, H.T. Duong. H.L. Ravn, K. Wendt, *Nuclear magnetic moment of* $^{207}$Tl, Phys. Rev. Lett. 55 (1985) 1559.
[To85] G. Torbohm, G. Fricke, A. Rosén, *State dependent volume isotope shifts of low lying states of group IIa and IIb elements*, Phys. Rev. A 31 (1985) 2038.

[An86] M. Anselment, K. Bekk, A. Hanser, H. Hoeffgen, G. Meisel, S. Göring, H. Rebel, G. Schatz, *Charge radii and moments of tin nuclei by laser spectroscopy*, Phys. Rev. C 34 (1986) 1052.
[An86b] M. Anselment, W. Faubel, S. Göring, A. Hansen, G. Meisel, H. Rebel, G. Schatz, *The odd–even staggering of the nuclear charge radii of* Pb *isotopes*, Nuclear Phys. A 451 (1986) 471.
[Kr86] J.-R. Kropp, H.-D. Kronfeldt, A. Lucas, R. Winkler, *Isotope shift and hyperfine-structure analysis in the* Re I *configurations* (5d + 6s) 66p, Physica B + C 138 (1986) 335.
[Ul86] G. Ulm, S.K. Bhattacherjee, P. Dabkewicz, G. Huber, H.-J. Kluge, T. Kühl, H. Lochmann, E.-W. Otten, K. Wendt, A.A. Ahmad, W. Klempt, R. Neugart and the ISOLDE Collaboration, *Isotope shift of* $^{182}$Hg *and update of nuclear moments and charge radii in the isotope range* $^{181}$Hg–$^{206}$Hg, Z. Phys. A 325 (1986) 247.
[Zu86] J.D. Zumbro, R.A. Naumann, M.V. Hoehn W. Reuter, E. B. Shera, C. E. Bemis, Jr., Y. Tanaka, *E2 and E4 deformations in* $^{232}$Th *and* $^{239,240,242}$Pu, Phys. Lett. B 167 (1986) 383.

[Al87] G.D. Alkhazov, A.E. Barzakh,, V.N. Buyanov, V.P. Denisov, V.S. Ivanov, V.S. Letokhov, V.I. Mishin, S.K. Sekatsky, V.N. Fedoseyev, I.Y. Chubukov, *Studies of nuclear charge radii and electromagnetic moments of radioactive* Nd, Sm, Eu, Ho, Tm *isotopes by laser resonance atomic photoionization technique*, Preprint 1309. INP of the Acad. Sci. USSR, Leningrad, 1987.
[Au87] P. Aufmuth, K. Heilig, A. Steudel, *Mean-square nuclear charge radii from optical isotope shifts*, At. Data Nucl. Data Tables 87 (1987) 455.
[Bo87] S. K. Borisov, Yu.P. Gangrsky, C. Hradecny, S.G. Zemlyanoi, B.B. Krynetsky, K.P. Marinova, B.N. Markov, V.A. Mishin, Yu.Ts. Oganessian, O.M. Stel'makh, Hoang Thi Kim Hue, Tran Cong Tam, *Measurements of the charge radii changes of* Nd, Sm *and* Gd *nuclides by resonance laser light*, Sov. Phys. JETP 66 (1987) 882.
[Bo87b] W. Borchers, R. Neugart, E.W. Otten, H.T. Duong, G. Ulm, K. Wendt, *Hyperfine structure and isotope shifts investigations in* $^{202-222}$Rn *for the study of nuclear structure beyond* $Z = 82$, Hyperfine Interact. 34 (1987) 25.
[Co87] A.Coc, C. Thibault, F. Touchard, H.T. Duong, P. Juncar, S. Liberman, J. Pinard, M. Carre, J. Lerme, J. L. Vialle, S. Büttgenbach, A.C. Mueller, A. Pesnelle, *Isotope shift, spin and hyperfine structure of* $^{118,146}$Cs *and some francium isotopes*, Nuclear Phys. A 468 (1987) 1.
[Eb87] J. Eberz, U. Dinger, G. Huber, H. Lochmann, R. Menges, R. Neugart, R. Kirchner, O. Klepper, T.U. Kühl, D. Marx, G. Ulm, K. Wendt, *Spins, moments abd mean square charge radii of* $^{104-127}$In *determined by laser spectroscopy*, Nuclear Phys. A 464 (1987) 9.
[Eb87b] J. Eberz, U. Dinger, G. Huber, H. Lochmann, R. Menges, G. G. Ulm, R. Kirchner, O. Klepper, T.U. Kiihl, D. Marx, *Nuclear spins, moments and charge radii of* $^{108-111}$Sn, Z. Phys. A 326 (1987) 121.
[Ge87] S. Gesternkorn, F. Tomkins, *Evaluation de l'effet spécifique de masse dans le spectre d'arc du plutonium*, Phys. Scr. 36 (1987) 240.
[Ne87] W. Neu, G. Passler, G. Sawatzky, R. Winkler, H.-J. Kluge, *Isotope shift and hyperfine structure of stable platinum isotopes*, Z. Phys. D 7 (1987) 193.
[Wa87] K. Walmeroth, G. Bollen, A. Dohn, P. Egelhof, J. Grüner, F. Lindenlauf, U. Krönert, J. Campos, A. Rodriguez Yunta, M.J.G. Borge, A. Venugopalan, J.L. Wood, R. B. Moor, H.-J. Kluge, *Sudden change in the nuclear charge distribution of very light gold isotopes*, Phys. Rev. Lett. 58 (1987) 1516.
[We87] K. Wendt, S.A. Ahmad, W. Klempt, R. Neugart, E.W. Otten, H.H. Stroke, *On the hyperfine structure and isotope shift of radium*, Z. Phys. D 4 (1987) 227.


(*continued on next page*)

[Ah88] S.A. Ahmad, W. Klempt, R. Neugart, E.W. Otten, P.-G. Reinhard, G. Ulm, K. Wendt, *Mean square charge radii of radium isotopes and octupole deformation in the* $^{220-228}$Ra *region*, Nuclear Phys. A 483 (1988) 224.
[Al88] G.D. Alkhasov, A.E. Barzakh, V.P. Denisov, V.S. Ivanov, I.Y. Chubukov, N.B. Buyanov, V.S. Letokhov, V.I. Mishin, S.K. Sekatskii, V.N. Fedoseev, *Isotopic changes of gadolinium nuclei charge radii and magic nucleus charge radius* $^{146}$Gd, Akad. Nauk USSR, Leningrad Inst. Yad. Fis., preprint No 1417, 20 pages (1988); (in Russian); *Mean square charge radius of the magic nucleus* $^{146}$Gd. Zh. Eksp. Theor. Fiz. 48 (1988) 373.
[Al88b] G.D. Alkhazov, A.E. Barzakh, I.Y. Chubukov, V.P. Denisov, V.S. Ivanov, V.N. Panteleev, V.E. Starodubsky, N.B. Buyanov, M.N. Fedoseyev, V.S. Letokhov, V.I. Mishin, S.K. Sekatskli, *Nuclear electromagnetic moments and charge radii of deformed thulium isotopes with the mass numbers* $A = 157–172$, Nuclear Phys. A 477 (1988) 37.
[Kr88] U. Krönert, S. Becker, G. Bollen, M. Gerber, T. Hilberath, H.-J. Kluge, G. Passler and the ISOLDE Collaboration, *Observation of strongly deformed ground state configuration in*$^{184}$Au *and* $^{183}$Au *by laser spectroscopy*, Z. Phys. A 331 (1988) 521.
[Al89] G.D. Alkhazov, A.E. Barzakh, I.Y. Chubukov, V.P. Denisov, V.S. Ivanov, N.B. Buyanov, *Nuclear deformation of holmium isotopes*, Nuclear Phys. A 504 (1989) 549.
[Bo89] W. Borchers, E. Arnold, W. Neu, R. Neugart, K. Wendt, G. Ulm and ISOLDE Collaboration, *Xenon isotopes far from stability studied by collisional ionization laser spectroscopy*, Phys. Lett. B 216 (1989) 7.
[Di89] U. Dinger, J. Eberz, G. Huber, R. Menges, R. Kirchner, O. Klepper, T. Kühl, D. Marx, *Nuclear moments and change in the charge radii of neutron-deficient silver isotopes*, Nuclear Phys. A 503 (1989) 331.
[Kä89] W. Kälber, J. Ring, W. Faubel. S. Göring, G. Meisel, H. Rebel, R.C. Thompson, *Nuclear radii of thorium isotopes from laser spectroscopy*, Z. Physics A334, (1989) 103.
[Ot89] E.W. Otten, *Nuclear radii and moments of unstable isotopes*. in Treatise on heavy-ion science, D.A. Bromley, Editor. 1989. p. 517–638.

[Al90] G.D. Alkhazov, A.E. Barzakh, V.A. Bolshakov, V.P. Denisov, V.S. Ivanov, Y.Y. Sergeyev, I.Y. Chubukov, V.I. Tikhonov, V.S. Letokhov, V.I. Mishin, S.K. Sekatsky, V.N. Fedoseyev, *Odd–even staggering in nuclear charge radii of neutron-rich europium isotopes*, Z. Phys. A 337 (1990) 257.
[Al90b] G.D. Alkhazov, A.E. Barzakh, V.P. Denisov, V.S. Ivanov, I.Y. Chubukov, V.S. Letokhov, V.I. Mishin, S.K. Sekatsky, V.N. Fedoseyev, *Electromagnetic moments and nuclear charge radii for neutron-deficient Tb isotopes and the deformation jump near* $Z = 64$, $N = 90$, Z. Phys. A 337 (1990) 367.
[Bu90] F. Buchinger, E.B. Ramsay, E. Arnold, W. Neu, R. Neugart, K. Wendt, R.E. Silverans, P. Lievens, L. Vermeeren, D. Berdichevsky, R. Fleming, D.W.L. Sprung, G. Ulm, *Systematics of nuclear ground state properties in* $^{78-100}$Sr *by laser spectroscopy*, Phys. Rev. C 41 (1990) 2883.
[En90] J.G. Englandt, I.S. Grant, J.A.R. Griffith, D.E. Evans, D.A. Eastham, G.W.A. Newton, P.M. Walker, *Isotope shifts and hyperfine splittings in* $^{144-151}$Sm I, J. Phys. G 16 (1990) 105
[Pi90] C. Piller, C. Gugler, R. Jacot-Guillarmod, L.A. Schaller, L. Schellenberg, H. Schneuwly, G. Fricke. T. Hennemamm, J. Herzberz, *Nuclear charge radii of the tin isotopes from muonic atoms*, Phys. Rev. C 42 (1990) 182.

[Ko91] D. Kowalewska, K. Bekk, S. Göring, A. Hanser, W. Kälber, G. Meisel, H. Rebel, *Isotope shifts and hyperfine structure in polonium isotopes by atomic-beam laser spectroscopy*, Phys. Rev. A 44 (1991) R1442.
[Li91] P. Lievens, R.E. Silverans, L. Vermeeren, W. Borchers, W. Neu, R. Neugart, K. Wendt, F. Buchinger, E. Arnold and ISOLDE. Collaboration, *Nuclear ground state properties of* $^{99}$Sr *by collinear laser spectroscopy with non-optical detection*, Phys. Lett. B 256 (1991)141.

[An92] A. Anastasov, Yu.P. Gangrsky, K.P. Marinova, B.N. Markov and S.G. Zemlyanoi, *Nuclear charge radii changes of uranium and hafnium isotopes determined by laser spectroscopy*, Hyperfine Interact. 74 (1992) 31.
[Hi92] T. Hilberath, S. Becker, G. Bollen, H.-J. Kluge, U. Krönert, G. Passler, J. Rikovska, R. Wyss and ISOLDE Collaboration, *Ground-state properties of neutron-deficient platinum isotopes*, Z. Phys. A 342 (1992) 1.
[La92] W. Lauth, H. Backe, M. Dahlinger, I. Klaft, P. Schwamb, G. Schwickert, N. Trautmann, U. Othmer, *Resonance ionization spectroscopy in a buffer gas cell with radioactive decay detection, demonstrated using* $^{208}$Tl, Phys. Rev. Lett. 68 (1992) 1675.
[Le92] V.S. Letokhov, V.I. Mishin, S.K. Sekatsky, V.N. Fedoseyev, G.D. Alkhazov, A.E. Barzakh, V.P. Denisov, V.E. Starodubsky, *Laser spectroscopic studies of nuclei with neutron number* $N < 82$ (Eu, Sm *and* Nd *isotopes*), J. Phys. G 18 (1992) 1177.
[Li92] P. Lievens, L. Vermeeren, R.E. Silverans, E. Arnold, R. Neugart, K. Wendt, F. Buchinger, *Spin, moments, and mean square nuclear charge radius of* $^{77-88}$Sr, Phys. Rev. C 46 (1992) 797.
[Må92] A.-M. Mårtensson-Pendrill, A. Ynnerman, H. Warston, L. Vermeeren, R.E. Silverans, A. Klein, R. Neugart, C. Schulz, P. Lievens, *Isotope shifts and nuclear-charge radii in singly ionized* $^{40-48}$Ca, Phys. Rev. A 45 (1992) 4675.
[Me92] R. Menges, U. Dinger, N. Boos, G. Huber, S. Schröder, S. Dutta, R. Kirchner, O. Klepper, T. Kühl, D. Marx, G.D. Sprouse, *Nuclear moments and the change in the mean square charge radius of neutron deficient thallium isotopes*, Z. Phys. A 341 (1992) 475.
[Ve92] L. Vermeeren, R.E. Silverans, P. Lievens, A. Klein, R. Neugart, C. Schulz, F. Buchinger, *Ultrasensitive radioactive detection of collinear-laser optical pumping: Measurement of the nuclear charge radius of* $^{50}$Ca, Phys. Rev. Lett. 68 (1992) 1679.

[Kü93] E. Kümmel, M. Baumann, C.S. Kischkel, *Hyperfine structure and isotope shift in the*4d$^9$5s*configuration of Pd I*, Z. Phys. D 25 (1993) 161.

[Ji94] W.G. Jin, M. Wakasugi, T.T. Inamura, T. Murayama, T. Wakui, H. Katsuragawa, T. Ariga, T. Ishizuka, M. Koizumi, I. Sugai, *Isotope shifts and hyperfine structure in* LuI *and* WI, Phys. Rev. A 49 (1994) 762.
[Ke94] M. Keim, E. Arnold, W. Borchers, U. Georg, A. Klein, R. Neugart, L. Vermeeren, R.E. Silverans, P. Lievens, *Laser-spectroscopy measurements of* $^{72-96}$Kr *spins, moments and charge radii*, Nuclear Phys. A 586 (1994) 219.
[Pa94] G. Passler, J. Rikovska, E. Arnold, H.-J. Kluge, L. Monz, R. Neugart, H. Ravn, K. Wendt and ISOLDE Collaboration, *Quadrupole moments and nuclear shape of neutron-deficient gold isotopes*, Nuclear Phys. A580 (1994) 173.
[Zi94] D. Zimmermann, P. Baumann, D. Kuszner, A. Werner, *Isotope shift and hyperfine structure in atomic spectrum of hafnium by laser spectroscopy*, Phys. Rev. A 50 (1994) 1112.

[Kl96] A. Klein, B.A. Brown, U. Georg, M. Keim, P. Lievens, R. Neugart, M. Neuroth, R.E. Silverans, L. Vermeeren, and ISOLDE Collaboration, *Moments and mean square charge radii of short-lived argon isotopes*, Nuclear Phys. A 607 (1996) 1.
[Ve96] L.Vermeeren, P. Lievens, R.E. Silverans, U. Georg, M. Keim, A. Klein, R. Neugart, M. Neuroth, F. Buchinger, and ISOLDE Collaboration, *The mean square nuclear charge radius of* $^{39}$Ca, J. Phys. G 22 (1996) 1517.

[Be97] D. M. Bentony, E.C.A. Cochrane, J.A.R Griffith, *Optical isotope shifts in the iron atom*, J. Phys. B: At. Mol. Opt. Phys. 30 (1997) 5359
[Ca97] P. Campbell, J. Billowes I. S. Grant, *The specific mass shift of the zinc atomic ground state*, J. Phys. B: At. Mol. Opt. Phys. 30 (1997) 2351.
[Ji97] W. G. Jin, M. Wakasugi, M. G. Hies, T. T. Inamura, T. Murayama, T. Ariga, A. Yamashita, T. Wakui, H. Katsuragawa, T. Ishizuka, J. Z. Ruan, I. Sugai, *Nuclear moments and charge radius of* $^{175}$Hf *from optical measurement of hyperfine structure*, Phys. Rev. C 55 (1997) 1545.

[Ba98] H. Backe, M. Hies, H. Kunz, W. Lauth, O. Curtze, P. Schwamb, M. Sewtz, W. Theobald, R. Zahn, K. Eberhardt, N. Trautmann, D. Habs, R. Repnow, B. Fricke, *Isotope Shift Measurements for Superdeformed Fission Isomeric States*, Phys. Rev. Lett. 80 (1998) 920.
[Ge98] U. Georg, W. Borchers, M. Keim, A. Klein, P. Lievens, R. Neugart, M. Neuroth, P.M. Rao, C. Schulz and ISOLDE Collaboration, *Laser spectroscopy investigation of the nuclear moments and radii of lutetium isotopes*, Eur. Phys. J. A 3 (1998) 225.

(*continued on next page*)

[Le99] J. M. G. Levins, D. M. Benton, J. Billowes, P. Campbell, T. G. Cooper, P. Dendooven, D. E. Evans, D. H. Forest, I. S. Grant, J. A. R. Griffith, J. Huikari, A. Jokinen, K. Peräjärvi, G. Tungate, G. Yeandle, J. Äystö, *First On-Line Laser Spectroscopy of Radioisotopes of a Refractory Element*, Phys. Rev. Lett. 82 (1999) 2476.

[Ba00] A. E. Barzakh, I. Ya. Chubukov, D. V. Fedorov, V. N. Panteleev, M. D. Seliverstov, Yu. M. Volkov, *Mean square charge radii of the neutron-deficient rare-earth isotopes in the region of the nuclear shell* $N = 82$ *measured by the laser ion source spectroscopy technique*, Phys. Rev. C 61 (2000) 034304.

[Bl00] F. Le Blanc, The COMPLIS experiment on neutron-deficient Au, Pt *and* Ir *isotopes*, Hyperfine Interact. 127 (2000) 71.

[Pe00] M.R. Pearson, P. Campbell, K. Leerungnavarat, J. Billowes, I.S. Grant, M. Keim, J. Kilgallon, I.D. Moore, R. Neugart, M. Neuroth, S. Wilbert and ISOLDE Collaboration, *Nuclear moments and charge radii of bismuth isotopes*, J. Phys. G 26 (2000) 1829.

[Sa00] J. Sauvage, N. Boos, L. Cabaret, J.E. Crawford, H.T. Duong, J. Genevey, M. Girod, G. Huber, F. Ibrahim, M. Krieg, F.L. Blanc, J.K.P. Lee, J. Libert, D. Lunney, J. Obert, J. Oms, S. Péru, J. Pinard, J.C. Putaux, B. Roussière, V. Sebastian, D. Verney, S. Zemlyanoi, J. Arianer, N. Barré, M. Ducourtieux, D. Forkel-Wirth, G.L. Scornet, J. Lettry, C. Richard-Serre, C. Véron. COMPLIS experiments: Collaboration for spectroscopy, *Measurements using a Pulsed Laser Ion Source*, Hyperfine Interact. 129 (2000) 303.

[Ye00] G. Yeandle, J. Billowes, P. Campbell, E.C.A. Cochrane, P. Dendooven, D.E. Evans, J.A.R. Griffith, J. Huikari, A. Jokinen, I.D. Moore, A. Nieminen, K. Peräjärvi, G. Tungate, J. Äystö, *Nuclear moments and charge radii of the* $^{171}$Hf *ground state and isomer*, J. Phys. G 26 (2000) 839.

[Ca02] P. Campbell, H.L. Thayer, J. Billowes, P. Dendooven, K.T. Flanagan, D.H. Forest, J.A.R. Griffith, J. Huikari, A. Jokinen, R. Moore, A. Nieminen, G. Tungate, S. Zemlyanoi, J. Äystö, *Laser Spectroscopy of Cooled Zirconium Fission Fragments*, Phys. Rev. Lett. 89 (2002) 082501.

[Fo02] D.H. Forest, J. Billowes, P. Campbell, P. Dendooven, K.T. Flanagan, J.A.R. Griffith, J. Huikari, A. Jokinen, R. Moore, A. Nieminen, H.L. Thayer, G. Tungate, S. Zemlyanoi, J. Äystö, *Laser spectroscopy of neutron deficient zirconium isotopes*, J. Phys. G 28 (2002) L63.

[Ch03] B. Cheal, M. Avgoulea, J. Billowes, P. Campbell, K.T. Flanagan, D.H. Forest, M. D. Gardner, J. Huikari, B.A. Marsh, A. Nieminen, H.L. Thayer, G. Tungate, J. Äystö, *Collinear laser spectroscopy of neutron-rich cerium isotopes near the* $N = 88$ *shape transition*, J. Phys. G 29 (2003) 2479.

[Ii03] H. Iimura, M. Koizumi, M. Miyabe, M. Oba, T. Shibata, N. Shinohara, Y. Ishida, T. Horiguchi, H. A. Schuessler, *Nuclear moments and isotope shifts of* $^{135}$La, $^{137}$La, *and* $^{138}$La *by collinear laser spectroscopy*, Phys. Rev. C 68 (2003) 054328.

[Ba04] A.E. Barzakh, D.V. Fedorov, A.M. Ionan, V.S. Ivanov, F.V. Moroz, K.A. Mezilev, S.Yu. Orlov, V.N. Panteleev, Yu.M. Volkov, *Changes in the mean square charge radii of neutron-deficient europium isotopes measured by the laser ion source resonance ionization spectroscopy*, Eur. Phys. J. A 22 (2004) 69.

[Dr04] G.W.F. Drake, *Helium. Relativity and QFD*, Nuclear Phys. A 737 (2004) 25.

[Ew04] G. Ewald, W. Nörtershäuser, A. Dax, S. Götte, R. Kirchner, H.-J. Kluge, T. Kühl, R. Sanchez, A. Wojtaszek, B.A. Bushaw, G.W.F. Drake, Z.-C. Yan, C. Zimmerman, *Nuclear Charge Radii of* $^{8,9}$Li *Determined by Laser Spectroscopy*, Phys. Rev. Lett. 93 (2004) 113002.

[Ga04] Yu.P. Gangrsky, K.P. Marinova, S.G. Zemlyanoi, I.D. Moore, J. Billowes, P. Campbell, K.T. Flanagan, D.H. Forest, J.A.R. Griffith, J. Huikari, R. Moore, A. Nieminen, H. Thayer, G. Tungate, J. Äystö, *Nuclear charge radii of neutron deficient titanium isotopes* $^{44}$Ti *and* $^{45}$Ti, J.Phys. G 30 (2004) 1089.

[Mu04] P. Mueller, I. A. Sulai, *A.C.C. Villari*, J.A. Alcántara-Nuñez, R. Alves-Condé, K. Bailey, *G.W. F. Drake*, M. Dubois, C. Eléon, G. Gaubert, R. J. Holt, R.V. F. Janssens, N. Lecesne, Z.-T. Lu,T. P. O'Connor, M.-G. Saint-Laurent, J.-C. Thomas, L.-B. Wang, *Nuclear Charge Radius of* $^{8}$He, Phys. Rev. Lett. 99 (2004) 252501.

[Wa04] L.-B. Wang, P. Mueller, K. Bailey, G.W.F. Drake, J.P. Greene, D. Henderson, R.J. Holt, R.V.F. Janssens, C.L. Jiang, Z.-T. Lu, T.P. O'Connor, R.C. Pardo, K.E. Rehm, J.P. Schiffer, X.D. Tang, *Laser spectyroscopic Determination of the* $^{6}$He *Nuclear Charge Radius*, Phys. Rev. Lett. 93 (2004) 142501.

[Ba05] A. E. Barzakh, D. V. Fedorov, A. M. Ionan, V. S. Ivanov, F. V. Moroz, K. A. Mezilev, S. Yu. Orlov, V. N. Panteleev, Yu. M. Volkov, *Laser spectroscopic studies of* $^{145}$Gd, $^{145}$Gdm, *and* $^{143}$Gd$^{m}$, Phys. Rev. C 72 (2005) 017301.

[Bl05] F. Le Blanc, L. Cabaret, E. Cottereau, J. E. Crawford, S. Essabaa, J. Genevey, R. Horn, G. Huber, J. Lassen, J. K. P. Lee, G. Le Scornet, J. Lettry, J. Obert, J. Oms, A. Ouchrif, J. Pinard, H. Ravn, B. Roussiere, J. Sauvage, D. Verney, *Charge-radius change and nuclear moments in the heavy tin isotopes from laser spectroscopy: Charge radius of* $^{132}$Sn, Phys. Rev Lett C 72 (2005) 034305.

[Ve06] D. Verney, L. Cabaret, J.E. Crawford, H.T. Duong, B. Fricke, J. Genevey, G. Huber, F. Ibrahim, M. Krieg, F. Le Blanc, J.K.P. Lee, G. Le Scornet, D. Lunney, J. Obert, J. Oms, J. Pinard, J.C. Puteaux, K. Rashid, B. Roussière, J. Sauvage, V. Sebastian and the ISOLDE Collaboration, *Deformation change in light iridium nuclei from laser spectroscopy*, Eur. Phys. J. A 30 (2006) 489.

[Sá06] R. Sánchez, W. Nörtershäuser, A. Dax, G. Ewald, S. Götte, R. Kirchner, H.-J. Kluge, T. Kühl, A. Wojtaszek, B.A. Bushaw, G.W. F. Drake, Zong-Chao Yan, C. Zimmermann, D. Albers, J. Behr, P. Bricault, J. Dilling, M. Dombsky, J. Lassen,C. D. P. Levy, M. R. Pearson, E. J. Prime, V. Ryjkov, *Nuclear charge radius of* $^{11}$Li, Hyperfine Interact. 171 (2006) 181.

[Sá06b] R. Sánchez, W. Nörtershäuser, G. Ewald, D. Albers, J. Behr, P. Bricault, B. A. Bushaw, A. Dax, J. Dilling, M. Dombsky, G.W. F. Drake, S. Götte, R. Kirchner, H.-J. Kluge, Th. Kühl, J. Lassen, C. D. P. Levy, M. R. Pearson, E. J. Prime, V. Ryjkov, A. Wojtaszek, Z.-C. Yan, C. Zimmermann, *Nuclear Charge Radii of* $^{9-11}$Li: *The Influence of Halo Neutron*, Phys. Rev. Lett. 96 (2006) 033002.

[Ch07] B. Cheal, M. D. Gardner, M. Avgoulea, J. Billowes, M. L. Bissell, P. Campbell, T. Eronen, K. T. Flanagan, D. H. Forest, J. Huikari, A. Jokinen, B. A. Marsh, I. D. Moore, A. Nieminen, H. Penttilä, S. Rinta-Antila, B. Tordoff, G. Tungate, J. Äystö, *The shape transition in the neutron-rich yttrium isotopes and isomers*, Phys. Rev. Lett B 645 (2007) 133.

[Li07] J. Libert, B. Roussière, J. Sauvage, *Signs of dynamical effects for* Cd, Sn, Te, Xe, Ba *and* Sm *nuclear charge radii*, Nuclear Phys. A 786 (2007) 47.

[Mu07] P. Mueller, I. A. Sulai, A. C. C. Villari, J. A. Alcántara-Núñez, R. Alves Condé, K. Bailey, G.W. F. Drake, M. Dubois, C. Eléon, G. Gaubert, R. J. Holt, R.V. F. Janssens, N. Lecesne, Z.-T. Lu,1 T. P. O'Connor, M.-G. Saint-Laurent, J.-C. Thomas, L.-B. Wang, *Nuclear Charge Radius of* $^{8}$He. Phys. Rev. Lett. 99 (2007) 252501.

[Wi07] H. de Witte, A. N. Andreyev, N. Barré, M. Bender, T. E. Cocolios, S. Dean, D. Fedorov, V. N. Fedoseyev, L. M. Fraile, S. Franchoo, V. Hellemans, P. H. Heenen, K. Heyde, G. Huber, M. Huyse, H. Jeppessen, U. Köster, P. Kunz, S. R. Lesher, B. A. Marsh, I. Mukha, B. Roussière, J. Sauvage, M. Seliverstov,
I. Stefanescu, E. Tengborn, K. Van de Vel, J. Van de Walle, P. Van Duppen, Yu. Volko,. *Nuclear Charge Radii of Neutron-Deficient Lead Isotopes Beyond* $N = 104$ *Midshell Investigated by In-Source Laser Spectroscopy*. Phys. Rev. Lett. 98 (2007) 112502.

[Bl08] K. Blaum, W. Geithner, J. Lassen, P. Lievens, K. Marinova, R. Neugart, *Nuclear moments and charge radii of argon isotopes between the neutron-shell closures* $N = 20$ *and* $N = 2$. Nuclear Phys. A 799 (2008) 30.

[Ge08] W. Geithner, T. Neff, G. Audi, K. Blaum, P. Delahaye, H. Feldmeier, S. George, C. Guénaut, F. Herfurth, A. Herlert, S. Kappertz, M. Keim, A. Kellerbauer, H.-J. Kluge, M. Kowalska, P. Lievens, D. Lunney, K. Marinova, R. Neugart, L. Schweikhard, S. Wilbert, C. Yazidjian, *Masses and Charge Radii of* $^{17-22}$Ne *and the Two-Proton-Halo Candidate* $^{17}$Ne, Phys. Rev Lett 101 (2008) 252502.

[Pu08] M. Puchalski, K. Pachucki, *Relativistic, QED, and finite nuclear mass corrections for low-lying states of Li and Be+*, Phys. Rev. A 78 (2008) 052511.

[Ya08] Z.-C. Yan, W. Nörtershäuser, G. W. F. Drake, *High Precision Atomic Theory for* Li *and* Be+: *QED Shifts and Isotope Shifts*, Phys. Rev. Lett. 100 (2008) 243002.

[Ch09] B. Cheal, K. Baczynska, J. Biliowes, P. Campbell, F.C. Charlwood, T. Eronen, D.H. Forest, T. Kessler, I.D. Moore, M. Reponen, S. Rothe, M. Riiffer, A. Saastamoinen, G. Tungate, J. Äystö, *Laser Spectroscopy of Niobium Fission Fragments: First Use of optical Pumping in an Ion Beam Cooler-Buncher*, Phys. Rev. Lett. 102 (2009) 222501.

[Ch09a] F.C. Charlwood, K. Baczynska, J. Billowes, P. Campbell, B. Cheal, T. Eronen, D.H. Forest, A. Jokinen, T. Kessler, I.D. Moore, H. Penttilä, R. Powis, M. Rüffer, A. Saastamoinen, G. Tungate, J. Äystö, *Nuclear charge radii of molybdenum fission fragments*, Phys. Lett. B 674 (2009) 23.


(*continued on next page*)

[Nö09] W. Nörtershäuser, D. Tiedemann, M. Záková, Z. Andjelkovic, K. Blaum, M. L. Bissell, R. Cazan, G.W.F. Drake, Ch. Geppert, M. Kowalska, J. Krämer, A. Krieger, R. Neugart, R. Sánchez, F. Schmidt-Kaler, Z.-C. Yan, D.T. Yordanov, C. Zimmermann, *Nuclear Charge Radii of* $^{7,9,10}$Be *and the One-Neutron Halo Nucleus* $^{11}$Be, Phys. Rev. Lett. 102 (2009) 062503.

[Ro09] B. Roussière, (2009) — private communication

[Se09] M. D. Seliverstov, A. N. Andreyev, N. Barré, A. E. Barzakh, S. Dean, H. De Witte, D.V. Fedorov, V.N. Fedoseyev, L.M. Fraile, S. Franchoo, J. Genevey, G. Huber, M. Huyse, U. Koester, P. Kunz, S.R. Lesher, B.A. Marsh, I. Mukha, B. Roussiere, J. Sauvage, I. Stefanescu, K. Van de Vel, P. Van Duppen, Yu.M. Volkov, *Charge radii and magnetic moments of odd-A* $^{183-189}$Pb *isotopes*, Eur. Phys. J. A 41 (2009) 315.

[Ch10] F.C. Charlwood, J. Billowes, P. Campbell, B. Cheal, T. Eronen, D.H. Forest, S. Fritzsche, M. Honmaf, A. Jokinen, I.D. Moore, H. Penttil, R. Powis, A. Saastamoinen, G. Tungate, J. Aysto, *Ground state properties of manganese isotopes across the* $N = 28$ *shell closure*, Phys. Lett. B 690 (2010) 346.

[Pa10] C.G. Parthey, A. Matveev, J. Alnis, R. Pohl, Th. Udem, U.D. Jentschura, N. Kolachevsky, T. W. Hänsch, *Precision Measurement of the Hydrogen-Deuterium 1S-2S Isotope Shift*, Phys. Rev. Lett. 104 (2010) 233001.

[Žá10] M. Žáková, Z. Andjelkovic, M.L. Bissell, K. Blaum, G.W.F. Drake, Ch. Geppert, M. Kowalska, J. Krämer, A. Krieger, M. Lochmann, T. Neff, R. Neugart, W. Nörtershöuser, R. Sánchez, F. Schmidt-Kaler, D. Tiedemann, Z.-C. Yan, D.T. Yordanov, C. Zimmermann, *Isotope shift measurements in the* $2s_{1/2} \rightarrow 2p_{3/2}$ *transition of* $\mathrm{Be}+$ *and extraction of the nuclear charge radii for* $^{7,10,11}$Be, J. Phys. G 37 (2010) 055107.

[Av11] M. Avgoulea, Yu.P. Gangrsky, K.P. Marinova, S.G. Zemlyanoi, S. Fritzsche, D. Iablonskyi, C. Barbieri, E.C. Simpson, P.D. Stevenson, J. Billowes, P. Campbell, B. Cheal, B. Tordoff, M.L. Bissell, D.H. Forest, M.D. Gardner, G. Tungate, J. Huikari, A. Nieminen, H. Penttilä, J. Äystö, *Nuclear charge radii and electromagnetic moments of radioactive scandium isotopes and isomers*, J. Phys. G 38 (2011) 025104.

[Co11] T.E. Cocolios, W. Dexters, M.D. Seliverstov, A.N. Andreyev, S. Antalic, A.E. Barzakh, B. Bastin, J. Büscher, I.G. Darby, D.V. Fedorov, V.N. Fedosseyev, K.T. Flanagan, S. Franchoo, S. Fritzsche, G. Huber, M. Huyse, M. Keupers, U. Köster, Yu. Kudryavtsev, E. Mané, B.A. Marsh, P.L. Molkanov, R.D. Page, A.M. Sjoedin, I. Stefan, J. Van de Walle, P. Van Duppen, M. Venhart, S.G. Zemlyanoy, M. Bender, P.-H. Heenen, *Early onset of ground-state deformation in the neutron-deficient polonium isotope*, Phys. Rev. Lett. 106 (2011) 052503.

[Ma11] K. Marinova, W. Geithner, M. Kowalska, K. Blaum, S. Kappertz, M. Keim, S. Kloos, G. Kotrotsios, P. Lievens, R. Neugart, H. Simon, S. Wilbert, *Charge radii of neon isotopes over sd-shell*, Phys. Rev. C 84 (2011) 034313.

[Nö11] W. Nörtershäuser, R. Sánchez, G. Ewald, A. Dax, J. Behr, P. Bricault, B. A. Bushaw, J. Dilling, M. Dombsky, G. W. F. Drake, S. Götte, H.-J. Kluge, Th. Kühl, J. Lassen, C. D. P. Levy, K. Pachucki, M. Pearson, M. Puchalski, A. Wojtaszek, Z.-C. Yan, C. Zimmermann, *Isotope-shift measurements of stable and short-lived lithium isotopes for nuclear-charge-radii determination*, Phys. Rev. A 83 (2011) 012516.