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ABSTRACT

Energy levels, radiative rates, oscillator strengths, line strengths, and lifetimes have been calculated for transitions in B-like to F-like Xe ions, Xe L - XLVI. For the calculations, a fully relativistic GRASP code has been adopted, and results are reported for all electric dipole (E1), electric quadrupole (E2), magnetic dipole (M1), and magnetic quadrupole (M2) transitions among the lowest 125, 236, 272, 226, and 113 levels of Xe L, Xe XLIX, Xe XLVIII, Xe XLVII, and Xe XLVI, respectively, belonging to the $n \leq 3$ configurations.

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INTRODUCTION

High Z elements of the fourth and fifth periods are being increasingly used as injected impurities for diagnosing tokamak fusion plasmas. For example, diagnostic experiments involving several Kr (XXXII-XXVIII) ions and ions from fifth period elements are in progress at the JET-EFDA facility, because spectral line intensity ratios (particularly in the XUV region) may be useful in diagnosing alpha particles produced in a burning DT plasma. However, to reliably model these experiments accurate atomic data are required, and one must depend on theoretical results as measured values are (generally) not available. Therefore, in view of the forthcoming ITER project, atomic data (namely energy levels, oscillator strengths or radiative decay rates, collision strengths, etc.) are required for many ions in order to estimate the power loss from the impurities. With this in view, in a recent paper [1] we reported energy levels, lifetimes, and radiative rates for four types of transitions, namely electric dipole (E1), electric quadrupole (E2), magnetic dipole (M1), and magnetic quadrupole (M2) for five Kr ions (Kr XXXII - Kr XXVIII). In this paper we report similar results for the corresponding five Xe ions (Xe L - Xe XLVI), which will facilitate interpolation to any fifth period element. Additionally, collision strengths and excitation rates have also been published [2] for transitions in B-like Kr XXXII and similar calculations are in progress for F-like Kr XXVIII.

In a recent review, Saloman [3] has listed measured energy levels for many ions of xenon, but unfortunately there is a paucity of data for Xe L - Xe XLVI. The situation on the theoretical front is slightly better as some calculations are available for all five ions of the present interest, but only for a limited number of levels/transitions as discussed below in section 2. Therefore, in this work we report the above parameters for a comparatively larger number of levels/transitions. The methodology adopted is the same as for the Kr ions [1].

ENERGY LEVELS

For our calculations, we have adopted the GRASP (*General purpose Relativistic Atomic Structure Package*) code, which was originally developed as GRASP0 by Grant et al. [4] and has been further updated by Dr. P. H. Norrington. This is a fully relativistic code, and is based on the jj coupling scheme. Moreover, further relativistic corrections arising from the Breit interaction and QED effects have also been included. Additionally, we have used the option of *extended average level* (EAL), in which a weighted (proportional to $2j+1$) trace of the Hamiltonian matrix is minimized. This produces a compromise set of orbitals describing closely lying states with moderate accuracy. However, a calculation performed with the AL (*average level*) option yields results in close agreement (within 0.01 Ryd) for *all* levels and all ions. Furthermore, in order to assess the accuracy of our results, calculations have also been performed from the *Flexible Atomic Code* (FAC) of Gu [5], which is available at the website: `http://kipac-tree.stanford.edu/fac`.

Calculations for B-like Xe L have previously been performed by Zhang and Sampson [6], who adopted the earlier version of GRASP. However, they included only 15 levels among the $2s^2 2p$, $2s 2p^2$, and $2p^3$ configurations. In a later paper, Zhang and Sampson [7] extended their work to include all the 125 levels of the $2s^2 2p$, $2s 2p^2$, $2p^3$, $2s^2 3\ell$, $2s 2p 3\ell$, and $2p^2 3\ell$ configurations of all B-like ions with $8 \leq Z \leq 92$, but for brevity did not report results for Xe L. In the present paper we also include the same 125 levels, consistent with our earlier work on B-like Kr XXXII [1].

In Table 1a we list our calculated energy levels of Xe L, obtained from the GRASP code *with* and *without* the inclusion of Breit and QED effects. Also listed in this table are the corresponding energies obtained from the FAC code. For a majority of levels, our Breit and QED corrected energies are lower than the corresponding Coulomb energies by up to ~ 2 Ryd (see particularly levels 110 and higher), or equivalently up to 1.6% - see, for example, level 9. Furthermore, inclusion of the Breit and QED corrections has resulted in a slightly different level orderings in a few instances, such as for levels 6/7, 24/25, and 39/40. Energy levels obtained from the FAC code with the same 125 level calculations (FAC1) agree with our GRASP results within 0.1 Ryd. Generally, the level orderings are also the same between the two calculations.

Xenon is a heavy element with nuclear charge $Z = 54$, and hence *relativistic effects* should be comparatively more important than the *configuration interaction* (CI). Nevertheless, in order to assess the effect of additional CI, we have performed a larger calculation including 528 levels of the $2s^2 2p$, $2s 2p^2$, $2p^3$, $2s^2 3\ell$, $2s 2p 3\ell$, $2p^2 3\ell$, $2s 3\ell^2$, $2p 3\ell^2$, $2s^2 4\ell$, and $2p^2 4\ell$ configurations. This calculation has been performed with FAC and is referred to as FAC2. All the additional 403 levels belonging to the higher configurations lie *above* the lowest 125 levels listed in Table 1a. For this reason, energy levels from the FAC1 and FAC2 calculations agree within 0.05 Ryd for all levels, and hence we can state with confidence that for the energy levels of Table 1a, the effect of additional CI is negligible.

However, we would like to note here that for many levels the mixing of eigenvectors from different levels is very strong. Examples of such strong mixing are levels $(2p^3)$ $^2D^o_{3/2}$, $^4S^o_{3/2}$, and $^2P^o_{3/2}$ (8, 12, and 15), $(2s 2p 3p)$ $^4S_{3/2}$ and $^4P_{3/2}$ (27 and 45), and $(2s 2p 3d)$ $^4F^o_{7/2}$, $^4D^o_{7/2}$, and $^2F^o_{7/2}$ (37, 63, and 73), as can be seen from Table 1b, where we list the dominant mixing coefficients for all the levels. Therefore, for a few levels the identification is not unique and scope remains for redesignations. In fact, for highly mixed levels the LSJ designations provided in Table 1a are not fully appropriate and the jj coupling scheme, as adopted in the calculations, is more suitable. Therefore, in Table 1b we have also provided the corresponding jj designations to facilitate the level/configuration identifications.

Earlier results for C-like Xe XLIX have been reported by Zhang and Sampson [8], [9], who performed relativistic calculations for a series of C-like ions ($9 \leq Z \leq 54$), and included 236 levels among the $2s^2 2p^2$, $2s2p^3$, $2p^4$, $2s^2 2p3\ell$, $2s2p^2 3\ell$, and $2p^3 3\ell$ configurations. They adopted the earlier version of the GRASP code with the option of AL (average level) which yields results comparable to the EAL option as already stated. However, they did not report energy levels, although these can be inferred from their tabulations of the oscillator strengths for the E1 transitions. In the present work we also include the same 236 levels of Xe XLIX.

In Table 2a we list our calculated energy levels for Xe XLIX, obtained from the GRASP code *with* and *without* the inclusion of Breit and QED effects. Also listed in this table are the corresponding energies obtained from the FAC code. Our Breit and QED corrected energies are lower than the corresponding Coulomb energies by up to 2.2 Ryd for many levels (see, for example, levels higher than 200), or equivalently up to 2.5%, particularly for the lowest 20 levels. Furthermore, inclusion of the Breit and QED corrections has resulted in a slightly different level orderings in a few instances, such as for levels 12/13, 52/53, and 81/82/83. Energy levels obtained from the FAC code with the same 236 level calculations (FAC1), agree very well with our GRASP results, although there are differences of up to 0.3 Ryd, particularly for levels 111, 132, and 154. The level orderings are also (nearly) the same.

In order to assess the effect of additional CI on the energy levels, we have performed a larger calculation including 564 levels. This calculation has been performed with FAC and is referred to as FAC2. The additional 328 levels belong to the $2s^2 2p4\ell$, $2s2p^2 4\ell$, and $2p^3 4\ell$ configurations, but all of these levels lie *above* the lowest 236 levels listed in Table 2a. For this reason, as for Xe L, energy levels from FAC1 and FAC2 agree within 0.03 Ryd for all levels, and hence confirm the accuracy of the energy levels listed in Table 2a.

As in the case of Xe L, for Xe XLIX the mixing of eigenvectors from different levels is also very strong for some levels. Examples of such strong mixing are levels $(2s2p^3)$ $^5S^o_2$, $^3D^o_2$, and $^3P^o_2$ (4, 8, and 16), $2s2p^2 3s$ $^5P_1$, $2s^2 2p3p$ $^3S_1$, and $2s^2 2p3p$ $^3P_1$ (25, 27, and 42), and $(2s2p^2 3s)$ $^3D^o_2$ and $^3P^o_2$ (49 and 122), as can be seen from Table 2b in which we list the dominant mixing coefficients for all the levels. Therefore, for a few levels the identification is not unique and scope remains for redesignations. In fact, for highly mixed levels the LSJ designations provided in Table 2a are not fully appropriate and the jj coupling scheme, as adopted in the calculations, is more suitable. Therefore, in Table 2b we have also provided the corresponding jj designations to facilitate the level/configuration identifications.

Earlier results for N-like Xe XLVIII have been reported by Zhang and Sampson [10], who performed relativistic calculations, but only for the lowest 15 levels of the $2s^2 2p^3$, $2s2p^4$, and $2p^5$ configurations. In the present work we include 272 levels belonging to the $2s^2 2p^3$, $2s2p^4$, $2p^5$, $2s^2 2p^2 3\ell$, $2s2p^3 3\ell$, and $2p^4 3\ell$ configurations of Xe XLVIII.

In Table 3a we list our calculated energy levels, obtained from the GRASP code *with* and *without* the inclusion of Breit and QED effects. Also listed in this table are the corresponding energies obtained from the FAC code. Our Breit and QED corrected energies are lower than the corresponding Coulomb energies by up to 2 Ryd ($\leq 0.4\%$) for a majority of levels - see, for example, levels 129 and higher. For the lowest 15 levels, differences between the two sets of energies are only up to ~ 1 Ryd, but correspond to $\leq 2.5\%$, particularly for the $2s^2 2p^3$ $^2D^o_{5/2}$ level (3). Furthermore, inclusion of the Breit and QED corrections has resulted in a slightly different level orderings in a few instances, such as for levels 39/40, 61/62, and 85/86. Energy levels obtained from the FAC code with the same 272 level calculations (FAC1) agree with our GRASP results within 0.1 Ryd ($\leq 0.1\%$) for a majority of levels, but the discrepancy is slightly higher (up to 0.2 Ryd) for a few levels, such as: 61, 106, 204, and 236.

In order to assess the effect of additional CI on the energy levels, we have performed a larger calculation including 668 levels. This has been performed with FAC and is referred to as FAC2. The additional 396 levels belong to the $2s^2 2p^2 4\ell$, $2s2p^3 4\ell$, and $2p^4 4\ell$ configurations, but (almost) all of these levels lie above the lowest 272 levels listed in Table 3a. For this reason, as for Xe XLIX and Xe L, the energy levels from the FAC1 and FAC2 calculations agree within 0.03 Ryd for all levels, and hence confirm the accuracy of the results listed in Table 3a.

As in the cases of Xe L and Xe XLIX, for Xe XLVIII the mixing of eigenvectors from different levels is very strong for some levels. Examples of such strong mixing are levels $(2p^3)$ $^2D^o_{3/2}$ and $^2P^o_{3/2}$ (1 and 8), $(2s2p^4)$ $^2S_{1/2}$, $^2P_{1/2}$, and $^4P_{1/2}$ (6, 11, and 14), and $(2s^2 2p^2 3p)$ $^4P^o_{3/2}$ and $^2P^o_{3/2}$ (18 and 95), as can be seen from Table 3b where we list the dominant mixing coefficients for all the levels. Therefore, for a few levels the identification is not unique and scope remains for redesignations. In fact, for highly mixed levels the LSJ designations provided in Table 3a are not fully appropriate and the jj coupling scheme, as adopted in the calculations, is more suitable. Therefore, in Table 3b we have also provided the corresponding jj designations to facilitate the level/configuration identifications.

XE XLVII

Results for O-like Xe XLVII have been reported by Zhang and Sampson [11], who performed relativistic calculations, but only for the lowest 10 levels of the $2s^2 2p^4$, $2s2p^5$, and $2p^6$ configurations. In the present work we include 226 levels belonging to the $2s^2 2p^4$, $2s2p^5$, $2p^6$, $2s2p^4 3\ell$, $2p^5 3\ell$, and $2s^2 2p^3 3\ell$ configurations of Xe XLVII.

In Table 4a we list our calculated energy levels, obtained from the GRASP code *with* and *without* the inclusion of Breit and QED effects. Also listed in this table are the corresponding energies obtained from the FAC code. Our Breit and QED corrected energies are lower than the corresponding Coulomb energies by up to 1.6 Ryd ($\leq 0.4\%$) for many levels - see, for example, levels 57, 140, and 226. However, for the lowest 10 levels, differences between the two sets of energies are only up to 0.7 Ryd, corresponding to $\leq 1.7\%$, particularly for the $2s^2 2p^4\ ^1D_2$ level (4). Similarly, for the $2s^2 2p^4\ ^1S_0$ level (2) the net effect of Breit and QED corrections is significant (8%) and positive, as also noted earlier for Kr XXIX. Furthermore, inclusion of the Breit and QED corrections has resulted in a slightly different level orderings in a few instances, such as for levels 15/16, 21/22, and 52/53. Energy levels obtained from the FAC code with the same 226 level calculations (FAC1), agree with our GRASP results within 0.2 Ryd for all levels. However, differences for two levels, namely 133 and 134, i.e. $2s2p^4 3p\ ^5D_2^o$ and $2s^2 2p^3 3d\ ^5F_2^o$, are higher (~ 0.6 Ryd), which is clearly due to their different identifications in the two independent calculations.

In order to assess the effect of additional CI on the energy levels, we have performed a larger calculation including 554 levels. This has been performed with FAC and is referred to as FAC2. The additional 328 levels belong to the $2s^2 2p^3 4\ell$, $2s2p^4 4\ell$, and $2p^5 4\ell$ configurations, but (almost) all of these levels lie above the lowest 226 levels listed in Table 4a. For this reason, as for Xe L - XLVIII, the energy levels from the FAC1 and FAC2 calculations agree within 0.03 Ryd for all levels. This excellent agreement between the two calculations with differing amount of CI confirms the accuracy of the energy levels listed in Table 4a.

However, as in the above cases for other Xe ions, the identification of all levels is not unambiguous because many of them are highly mixed, such as $2s^2 2p^3 3s\ ^3D_2^o$, $2s^2 2p^3 3p\ ^1F_3$, $2s^2 2p^3 3s\ ^5S_1^o$, and $2s^2 2p^3 3p$ $^3D_2$ (11, 16, 27, and 40), as seen from the mixing coefficients in Table 4b. In case of such mixed levels, the LSJ identifications can easily be swapped. Therefore, in Table 4b we also provide the corresponding jj coupling designation for the levels, which may be comparatively more appropriate and reliable.

XE XLVI

To our knowledge, the only calculations for F-like Xe XLVI are those reported by Sampson et al. [12], who adopted their Dirac-Fock-Slater (DFS) code. They performed calculations mainly for oscillator strengths for

E1 transitions and collision strengths for transitions among the lowest three levels of the $2s^22p^5$ and $2s2p^6$ configurations, and from these to 110 excited levels of the $2s^22p^43\ell$, $2s2p^53\ell$, and $2s2p^53\ell$ configurations. However, they did not report energy levels, although these can be inferred from their tabulations of the oscillator strengths for the E1 transitions. In the present work we also include the same 113 levels of Xe XLVI.

In Table 5a we list our calculated energy levels, obtained from the GRASP code *with* and *without* the inclusion of Breit and QED effects. Also listed in this table are the corresponding energies obtained from the FAC code. Our Breit and QED corrected energies are lower than the corresponding Coulomb energies by up to 1.3 Ryd ($\leq 0.3\%$) for a majority of levels - see, for example, levels 38, 75, and 105. However, for the lowest 3 levels, differences between the two sets of energies are higher by up to 0.32 Ryd, and correspond to $\leq 1.3\%$. Furthermore, these corrections have resulted in a slightly different level orderings in a few instances, such as for levels 37/38, 48/49, and 74/75. Energy levels obtained from the FAC code with the same 113 level calculations (FAC1), agree with our GRASP results within 0.1 Ryd for all levels.

In order to assess the effect of additional CI on the energy levels, we have performed a larger calculation including 279 levels with FAC, which is referred to as FAC2. The additional 166 levels belong to the $2s^22p^44\ell$, $2s2p^54\ell$, and $2p^64\ell$ configurations, but all of these levels lie *above* the lowest 113 levels listed in Table 5a. For this reason, as with Xe L - XLVII, energy levels from the FAC1 and FAC2 calculations agree within 0.03 Ryd for all levels, and hence confirm the accuracy of the results listed in Table 5a.

As for other xenon ions the identification of some levels of Xe XLVI is also ambiguous, because some are highly mixed, such as levels 13, 22, and 35, as seen from the mixing coefficients in Table 5b. In case of such mixed levels, the LSJ identifications can easily be swapped. Therefore, in Table 5b we also provide the corresponding jj coupling designation for the levels, which may be comparatively more appropriate and reliable.

RADIATIVE RATES

The absorption oscillator strength (f_{ij}) and radiative rate A_{ji} (in s^{-1}) for a transition $i \rightarrow j$ are related by the following expression:

$$f_{ij} = \frac{mc}{8\pi^2 e^2}\lambda_{ji}^2\frac{\omega_j}{\omega_i}A_{ji} = 1.49 \times 10^{-16}\lambda_{ji}^2(\omega_j/\omega_i)A_{ji} \tag{1}$$

where m and e are the electron mass and charge, respectively, c is the velocity of light, λ_{ji} is the transition energy/wavelength in Å, and ω_i and ω_j are the statistical weights of the lower i and upper j levels, respectively. Similarly, the oscillator strength f_{ij} (dimensionless) and the line strength S (in atomic unit, 1 a.u. =

6.460×10^{-36} cm^2 esu^2) are related by the following standard equations:

For the electric dipole (E1) transitions:

$$A_{ji} = \frac{2.0261 \times 10^{18}}{\omega_j \lambda_{ji}^3} S^{E1} \quad \text{and} \quad f_{ij} = \frac{303.75}{\lambda_{ji}\omega_i} S^{E1}, \tag{2}$$

for the magnetic dipole (M1) transitions:

$$A_{ji} = \frac{2.6974 \times 10^{13}}{\omega_j \lambda_{ji}^3} S^{M1} \quad \text{and} \quad f_{ij} = \frac{4.044 \times 10^{-3}}{\lambda_{ji}\omega_i} S^{M1}, \tag{3}$$

for the electric quadrupole (E2) transitions:

$$A_{ji} = \frac{1.1199 \times 10^{18}}{\omega_j \lambda_{ji}^5} S^{E2} \quad \text{and} \quad f_{ij} = \frac{167.89}{\lambda_{ji}^3 \omega_i} S^{E2}, \tag{4}$$

and for the magnetic quadrupole (M2) transitions:

$$A_{ji} = \frac{1.4910 \times 10^{13}}{\omega_j \lambda_{ji}^5} S^{M2} \quad \text{and} \quad f_{ij} = \frac{2.236 \times 10^{-3}}{\lambda_{ji}^3 \omega_i} S^{M2}. \tag{5}$$

We present and discuss below our results of radiative rates for each ion, and make accuracy assessment of these based on a variety of comparisons.

XE L

In Table 6a we present our wavelengths (λ), length forms of oscillator strengths (f_L), radiative rates (A_L), and line strengths (S) from the GRASP calculations, for 2739 E1 and 3290 M2 transitions among all 125 levels of Xe L. The corresponding results for 3254 E2 and 2679 M1 transitions are given in Table 6b. The indices adopted for the lower and upper levels of a transition are already given in Table 1a. In calculating these parameters, we have used our adjusted theoretical energy splittings, corresponding to the Breit and QED corrected energies.

Since the E1 transitions are comparatively more important, we confine our comparison and discussion to these transitions alone. Furthermore, the corresponding values from FAC are not included in Tables 6a,b because the results obtained are similar to those from the GRASP calculations for a majority of transitions - for examples, see Table A.

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In our GRASP calculations, the two forms of oscillator strengths (f_L and f_V) agree within 20% for a majority of strong transitions (f $\geq$ 0.01). However, there are differences of over 20% for 24 transitions ($\sim$ 1%) for which the two forms differ by up to a maximum factor of 2.5. Examples of such transitions are: 52-64 (f = 0.0318), 76-92 (f = 0.0175), and 85-99 (f = 0.0368). However, differences between the two forms for weaker transitions ($f < 0.01$) are often larger and up to several orders of magnitude. The two forms differ by over three orders of magnitude for 35 transitions, but all of these are very weak. Examples of such transitions are: 18-106 (f = 2.1×10^{-11}), 23-110 (f = 1.4×10^{-12}), and 47-102 (f = 5.3×10^{-12}). Such large differences between the two forms arise because the weaker transitions are more sensitive to cancellations effect among the mixing coefficients, and/or the inclusion of insufficient CI. Therefore, their accuracy is always doubtful, as also recently discussed in detail by Hibbert [13]. Nevertheless, all of these transitions are non-resonant and have very small f- values. Therefore, the larger differences between the two forms for some weaker transitions do not affect the overall accuracy of the results. Furthermore, although comparisons between the length and velocity forms have been made to obtain some estimate of the accuracy of the f-values, a good agreement between the two does not necessarily confirm the accuracy as discussed in detail by Hibbert [14] and demonstrated through various examples by Aggarwal et al. [15].

In Table A we compare the f_L- values for some transitions from our GRASP and FAC calculations with the earlier work of Zhang and Sampson [6]. For most of these (and many other) transitions there are no discrepancies among the three sets of independent calculations. Additionally, as expected, the contribution of additional CI included in the larger FAC2 calculations with 528 levels is negligible for a majority of transitions. In fact, all strong transitions agree within 20%. However, there are 31 (1%) transitions which differ by up to a factor of 1.65, but their f- values are invariably small ($\sim 10^{-4}$ or less). Similarly, there is no discrepancy between the f- values from the GRASP and FAC calculations for a majority of strong transitions, although 23 differ by up to an order of magnitude, and the 3-68 transition shows f- values differing by a factor of 300. Such large differences are generally due to a mismatch in level orderings as can be better understood by a closer examination of our results from GRASP and those of Zhang and Sampson. As shown in Table A, differences between the two sets of f- values are up to five orders of magnitude for some transitions, such as: 2-8 and 2-15, 6-8 and 6-15, and 8-10 and 10-15. This is clearly because our identification and those of Zhang and Sampson are different for levels 8 and 15, i.e. $(2p^3)$ $^2D^o_{3/2}$ and $^2P^o_{3/2}$, which are highly mixed as shown in Table 1b and discussed earlier in section 2.1. If the f- values for these pairing transitions are swapped then there is no discrepancy. In conclusion, we may state that there is no (major) discrepancy for the radiative rates among different calculations, and the results listed in Tables 6a,b are generally accurate to within 20%. Finally, the addition of further CI, than those included in our 125 level calculations, does not improve the accuracy of the A- values.

In Table 7a we present our wavelengths (λ), length forms of oscillator strengths (f_L), radiative rates (A_L), and line strengths (S) from the GRASP calculations, for 8636 E1 and 10795 M2 transitions among all 236 levels of Xe XLIX. The corresponding results for 10698 E2 and 8527 M1 transitions are given in Table 7b. The indices adopted for the lower and upper levels of a transition are already given in Table 2a. In calculating these parameters, we have used our adjusted theoretical energy splittings, corresponding to the Breit and QED corrected energies.

Since the E1 transitions are comparatively more important, we confine our comparison and discussion to these transitions alone. Furthermore, the corresponding values from FAC are not included in Tables 7a,b because the results obtained are similar to those from the GRASP calculations for a majority of transitions - for examples, see Table B.

In our GRASP calculations, the two forms of oscillator strengths (f_L and f_V) agree within 20% for a majority of strong transitions ($f \geq 0.01$). However, there are differences of over 20% for 72 transitions ($\sim$ 1%), but less than a factor of two. Examples of such transitions are: 22-23 (f = 0.0154), 50-65 (f = 0.0187), and 155-192 (f = 0.0157), and for one transition (228-236, f = 0.0446) the ratio f_L/f_V is 9. Differences between the two forms for weaker transitions ($f < 0.01$) are often larger and up to several orders of magnitude. The two forms differ by over three orders of magnitude for 136 transitions ($\sim$ 3%), but all of them are very weak. Examples of such transitions are: 23-155 (f = 1.1×10^{-13}), 36-186 (f = 9.8×10^{-8}), and 41-217 (f = 2.1×10^{-13}). The reason for such large differences has already been explained in section 3.1.

In Table B we compare the f_L- values for some transitions from our GRASP and FAC calculations with the earlier work of Zhang and Sampson [8]. For these (and many other) transitions there are no discrepancies between the present GRASP and FAC calculations, particularly for the strong transitions, although there are differences of up to an order of magnitude for 39 transitions. Examples of such transitions are: 6-145, 9-90, 9-180, 13-118, and 13-119. Similarly, the contribution of additional CI included in the larger FAC2 calculations with 564 levels is negligible for a majority of transitions, because only 93 of them differ by over 20% and a majority of these have f $\leq 10^{-4}$. Only seven transitions (3-61, 3-63, 6-63, 13-118, 13-119, 61-176, and 118-217) among these have f $\geq$ 0.01, and particularly noteworthy are only two, namely 3-61 (f = 0.291) and 13-119 (f = 0.747). Finally, the earlier reported f- values of Zhang and Sampson are also comparable with our present calculations from GRASP as well as FAC, although for some random *weak* transitions, such as 5-7, differences may be up to a factor of three. In general, based on the comparison shown in Table B and the one discussed above between the length and velocity forms, we may state that the radiative rates listed in Tables 7a,b are generally accurate to within 20%, and the addition of further CI does not improve their accuracy.

In Table 8a we present our wavelengths (λ), length forms of oscillator strengths (f_L), radiative rates (A_L), and line strengths (S) from the GRASP calculations, for 12156 E1 and 15380 M2 transitions among all 272 levels of Xe XLVIII. The corresponding results for 15301 E2 and 12031 M1 transitions are given in Table 8b. The indices adopted for the lower and upper levels of a transition are already given in Table 3a. In calculating these parameters, we have used our adjusted theoretical energy splittings, corresponding to the Breit and QED corrected energies.

Since the E1 transitions are comparatively more important, we confine our comparison and discussion to these transitions alone. Furthermore, the corresponding values from FAC are not included in Tables 8a,b because the results obtained are similar to those from the GRASP calculations for a majority of transitions - for examples, see Table C.

In our GRASP calculations, the two forms of oscillator strengths (f_L and f_V) agree within 20% for a majority of strong transitions ($f \geq 0.01$). However, differences are over 20% for 79 transitions ($< 1\%$), but less than a factor of 1.8. Examples of such transitions are: 22-26 (f = 0.0196), 94-110 (f = 0.0106), and 233-243 (f = 0.0202), and for one transition (252-267, f = 0.0219) the ratio f_L/f_V is 6. Differences between the two forms for weaker transitions ($f < 0.01$) are often larger and up to several orders of magnitude. For 222 transitions ($\sim 1\%$), the ratio f_L/f_V is larger than 10^3. Examples of such transitions are: 38-251 (f = 5.0×10^{-14}), 81-101 (f = 3.7×10^{-6}), and 153-162 (f = 9.4×10^{-13}). The reason for such large differences has already been explained in section 3.1.

In Table C we compare the f_L- values for some transitions from our GRASP and FAC calculations with the earlier work of Zhang and Sampson [10]. Generally, and particularly for the strong transitions, there are no discrepancies between our calculations from GRASP and those of Zhang and Sampson. However, we note that the $(2s^2 2p^3)$ $^2D^o_{3/2}$ and $^2P^o_{3/2}$ levels (1 and 8) in our calculations have been identified in the reverse order of the Zhang and Sampson calculations, and therefore their results corresponding to these two levels have to be swapped for comparisons. These two levels (along with some more such as 7 and 12) are highly mixed, as already discussed in section 2.3 and seen in Table 3b. Similarly, for a majority of strong transitions there is no discrepancy between the GRASP and FAC calculations, but differences are up to an order of magnitude for 91. Particularly noteworthy are the two transitions, namely 13-255 (f = 0.152) and 15-266 (f = 1.504), for which differences are larger. This is certainly due to a mismatch between the level identification, as the two calculations from FAC, i.e. FAC1 and FAC2, agree within a factor of two for almost all transitions, including the weaker ones. This also shows, as for transitions in Xe L and Xe XLIX, that the contribution of additional CI included in the larger FAC2 calculations with 668 levels is negligible for a majority of transitions. To conclude, we may state that the radiative rates listed in Tables 8a,b are generally accurate to better than 20%.

In Table 9a we present our wavelengths (λ), length forms of oscillator strengths (f_L), radiative rates (A_L), and line strengths (S) from the GRASP calculations, for 7827 E1 and 9817 M2 transitions among all 226 levels of Xe XLVII. The corresponding results for 9729 E2 and 7730 M1 transitions are given in Table 9b. The indices adopted for the lower and upper levels of a transition are already given in Table 4a. In calculating these parameters, we have used our adjusted theoretical energy splittings, corresponding to the Breit and QED corrected energies.

Since the E1 transitions are comparatively more important, we confine our comparison and discussion to these transitions alone. Furthermore, the corresponding values from FAC are not included in Tables 9a,b because the results obtained are similar to those from the GRASP calculations for a majority of transitions - for examples, see Table D.

In our GRASP calculations, the two forms of oscillator strengths (f_L and f_V) agree within 20% for a majority of strong transitions (f $\geq$ 0.01). However, differences are over 20% for 56 transitions ($<$ 1%), but less than a factor of two. Examples of such transitions are: 30-35 (f = 0.0247), 81-91 (f = 0.0125), and 84-91 (f = 0.0115). Differences between the two forms for weaker transitions ($f < 0.01$) are often larger and are up to several orders of magnitude. Furthermore, for 138 transitions, the ratio f_L/f_V is larger than 10^3. Examples of such transitions are: 11-215 (f = 1.5×10^{-14}), 47-212 (f = 1.0×10^{-13}), and 76-96 (f = 2.3×10^{-12}). The reason for such large differences has already been explained in section 3.1.

In Table D we compare the f_L- values from our GRASP and FAC calculations with the earlier work of Zhang and Sampson [11]. In general, the agreement between the two calculations from GRASP and MCDF is highly satisfactory. Similarly, for a majority of strong transitions there is no discrepancy between the GRASP and FAC calculations, although 70 transitions differ by up to an order of magnitude. Some of these differences are due to a mismatch in level identifications, as there is no discrepancy between the two calculations from FAC, i.e. FAC1 and FAC2, for all strong transitions, and only three *weak* transitions, namely 3-225 (f = 3.2×10^{-4}), 5-221 (f = 5.8×10^{-6}), and 222-223 (f = 5.7×10^{-3}), differ by up to an order of magnitude. Therefore, the contribution of additional CI included in the larger FAC2 calculations with 554 levels is negligible for a majority of transitions, and the radiative rates listed in Tables 9a,b are generally accurate to better than 20%, particularly for the strong ones.

XE XLVI

In Table 10a we present our wavelengths (λ), length forms of oscillator strengths (f_L), radiative rates (A_L), and line strengths (S) from the GRASP calculations, for 2191 E1 and 2659 M2 transitions among all 113

levels of Xe XLVI. The corresponding results for 2622 E2 and 2135 M1 transitions are given in Table 10b. The indices adopted for the lower and upper levels of a transition are already given in Table 5a. In calculating these parameters, we have used our adjusted theoretical energy splittings, corresponding to the Breit and QED corrected energies.

Since the E1 transitions are comparatively more important, we confine our comparison and discussion to these transitions alone. Furthermore, the corresponding values from FAC are not included in Tables 10a,b because the results obtained are similar to those from the GRASP calculations for a majority of transitions - for examples, see Table E.

In our GRASP calculations, the two forms of oscillator strengths (f_L and f_V) agree within 20% for a majority of strong transitions ($f \geq 0.01$). However, differences are over 20% for 17 transitions ($< 1\%$), but less than a factor of 1.6. Examples of such transitions are: 5-8 (f = 0.0310), 29-32 (f = 0.0311), and 90-95 (f = 0.0135). Differences between the two forms for weaker transitions ($f < 0.01$) are often larger and are up to several orders of magnitude. Particularly for 29 transitions, the ratio f_L/f_V is larger than 10^3. Examples of such transitions are: 16-33 (f = 5.1×10^{-11}), 29-107 (f = 1.0×10^{-12}) and 55-112 (f = 8.3×10^{-6}). The reason for such large differences has already been explained in section 3.1. Furthermore, all of these transitions are non-resonant and their small f- values should not significantly affect modelling applications.

In Table E we compare the f_L- values for some transitions from our GRASP and FAC calculations with the earlier calculations of Sampson et al. [12]. For transitions in Xe XLVI, including the weaker ones such as 2-15,17,21, there is no discrepancy between the present calculations and those of Sampson et al. Similarly, the agreement between our GRASP and FAC calculations is highly satisfactory for a majority of (strong) transitions, although differences are particularly large for three, i.e. 3-55, 29-55, and 55-72. The contribution of additional CI included in the larger FAC2 calculations with 279 levels is also negligible, as the only transition for which the f- values differ from FAC1 is 3-30 (f = 1.2×10^{-8}). Therefore, we may confidently state that all calculations from different structure codes agree for transitions in Xe XLVI, and the radiative rates listed in Tables 10a,b are accurate to within 20%, particularly for the stronger transitions.

LIFETIMES

The lifetime τ for a level j is defined as follows:

$$\tau_j = \frac{1}{\sum_i A_{ji}}. \tag{6}$$

Since this is a measurable parameter, it provides a check on the accuracy of calculations. However, to our knowledge no measurements of lifetimes are yet available in the literature. Nevertheless, in the last

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columns of Tables 1a-5a we list lifetimes for all the excited levels of Xe L - XLVI, which may be useful for comparisons with future calculations and/or measurements. Finally, these lifetimes *include* the contributions from all four types of transitions, i.e. E1, E2, M1, and M2.

CONCLUSIONS

In this paper we have reported energy levels, and radiative rates for E1, E2, M1, and M2 transitions among the lowest 125, 236, 272, 226, and 113 levels of Xe L, Xe XLIX, Xe XLVIII, Xe XLVII, and Xe XLVI, respectively. Two independent calculations have been performed, adopting the GRASP and FAC codes. A comparison made between the two sets of energy levels, as well as with the other available theoretical results, shows a satisfactory agreement in general. The energy levels from the GRASP and FAC calculations are almost in complete agreement, both in magnitude and orderings. However, the level orderings of earlier calculations are slightly different, in a few instances. This is mainly because it is not always feasible to identify the levels unambiguously due to their strong mixing. We have taken all care to identify the levels based on the strength of their eigenvectors, but a possibility of their redesignations cannot be ruled out.

Comparisons have also been made, especially for the radiative rates for E1 transitions. In general, the accuracy of the listed A- values is assessed to be $\sim 20\%$, especially for the strong transitions with $f \geq 0.01$. Furthermore, inclusion of additional CI in the determination of energy levels as well as the radiative rates does not improve the accuracy further, as the results obtained are nearly the same for a majority of levels/transitions as reported in this paper. However, as expected for a heavy element Xe, the contribution of relativistic effects is significant for energy levels (and subsequently the radiative rates) of all ions.

Finally, the lifetimes for all levels are also reported, although no comparisons with measured values are possible, because of a paucity of data. However, future measurement of lifetimes for a few levels will be helpful for an accuracy assessment of our calculations.

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TABLES

Explanation of Tables

Table 1a. Energy levels of Xe L (in Ryd) and their lifetimes (τ).

Index	Level Index
Configuration	The configuration to which the level belongs
Level	The LSJ designation of the level with its spin, parity and J value
GRASP^a	Present energies from the GRASP [?] code *without* Breit and QED corrections
GRASP^b	Present energies from the GRASP [?] code *with* Breit and QED corrections
FAC^c	Present energies from the FAC [5] code for 125 level calculations
FAC^d	Present energies from the FAC [5] code for 528 level calculations
τ(s)	Lifetimes (in s)
a±b	$\equiv a \times 10^{\pm b}$

Table 1b. Level designations of Xe L and their mixing coefficients in LSJ and jj coupling.

Index	Level Index
Configuration	The configuration to which the level belongs
LSJ	The LSJ designation of the level with its spin, parity and J value
jj	The jj designation of the configuration
Mixing coefficients	The mixing coefficients in both jj and LSJ coupling
a	The number at the end or inside the bracket is 2J
b	s+ $\equiv$ s$_{1/2}$, p− $\equiv$ p$_{1/2}$, p+ $\equiv$ p$_{3/2}$, d− $\equiv$ d$_{3/2}$ and d+ $\equiv$ d$_{5/2}$
c	The number after $\pm$ is the power of the corresponding configuration. For example, the jj configuration of level 5 is: 2s$_{1/2}$ 2p$_{1/2}$ 2p$_{3/2}$
d	Mixing coefficient of the level (in bracket)

Table 2a. Energy levels of Xe XLIX (in Ryd) and their lifetimes (τ).

Index	Level Index
Configuration	The configuration to which the level belongs
Level	The LSJ designation of the level with its spin, parity and J value
GRASP^a	Present energies from the GRASP [?] code *without* Breit and QED corrections
GRASP^b	Present energies from the GRASP [?] code *with* Breit and QED corrections
FAC^c	Present energies from the FAC [5] code for 236 level calculations
FAC^d	Present energies from the FAC [5] code for 564 level calculations
τ(s)	Lifetimes (in s)
a±b	$\equiv a \times 10^{\pm b}$

Table 2b. Level designations of Xe XLIX and their mixing coefficients in LSJ and jj coupling.

Index	Level Index
Configuration	The configuration to which the level belongs
LSJ	The LSJ designation of the level with its spin, parity and J value
jj	The jj designation of the configuration
Mixing coefficients	The mixing coefficients in both jj and LSJ coupling
[a]	The number at the end or inside the bracket is 2J
[b]	s+ $\equiv$ s$_{1/2}$, p$-$ $\equiv$ p$_{1/2}$, p+ $\equiv$ p$_{3/2}$, d$-$ $\equiv$ d$_{3/2}$ and d+ $\equiv$ d$_{5/2}$
[c]	The number after $\pm$ is the power of the corresponding configuration. For example, the jj configuration of level 9 is: $2s_{1/2} \, 2p_{1/2} \, 2p_{3/2}^2$
[d]	Mixing coefficient of the level (in bracket)

Table 3a. Energy levels of Xe XLVIII (in Ryd) and their lifetimes (τ).

Index	Level Index
Configuration	The configuration to which the level belongs
Level	The LSJ designation of the level with its spin, parity and J value
GRASP^a	Present energies from the GRASP [?] code *without* Breit and QED corrections
GRASP^b	Present energies from the GRASP [?] code *with* Breit and QED corrections
FAC^c	Present energies from the FAC [5] code for 272 level calculations
FAC^d	Present energies from the FAC [5] code for 668 level calculations
τ(s)	Lifetimes (in s)
a±b	$\equiv a \times 10^{\pm b}$

Table 3b. Level designations of Xe XLVIII and their mixing coefficients in LSJ and jj coupling.

Index	Level Index
Configuration	The configuration to which the level belongs
LSJ	The LSJ designation of the level with its spin, parity and J value
jj	The jj designation of the configuration
Mixing coefficients	The mixing coefficients in both jj and LSJ coupling
^{a}	The number at the end or inside the bracket is 2J
^{b}	s+ $\equiv$ s$_{1/2}$, p$-$ $\equiv$ p$_{1/2}$, p+ $\equiv$ p$_{3/2}$, d$-$ $\equiv$ d$_{3/2}$ and d+ $\equiv$ d$_{5/2}$
^{c}	The number after $\pm$ is the power of the corresponding configuration. For example, the jj configuration of level 9 is: 2s$_{1/2}$ 2p$_{1/2}$ 2p$_{3/2}^3$
^{d}	Mixing coefficient of the level (in bracket)

Table 4a. Energy levels of Xe XLVII (in Ryd) and their lifetimes (τ).

Index	Level Index
Configuration	The configuration to which the level belongs
Level	The LSJ designation of the level with its spin, parity and J value
GRASP^a	Present energies from the GRASP [?] code *without* Breit and QED corrections
GRASP^b	Present energies from the GRASP [?] code *with* Breit and QED corrections
FAC^c	Present energies from the FAC [5] code for 226 level calculations
FAC^d	Present energies from the FAC [5] code for 554 level calculations
τ(s)	Lifetimes (in s)
a±b	$\equiv a \times 10^{\pm b}$

Table 4b. Level designations of Xe XLVII and their mixing coefficients in LSJ and jj coupling.

Index	Level Index
Configuration	The configuration to which the level belongs
LSJ	The LSJ designation of the level with its spin, parity and J value
jj	The jj designation of the configuration
Mixing coefficients	The mixing coefficients in both jj and LSJ coupling
a	The number at the end or inside the bracket is 2J
b	s+ $\equiv$ s$_{1/2}$, p$-$ $\equiv$ p$_{1/2}$, p+ $\equiv$ p$_{3/2}$, d$-$ $\equiv$ d$_{3/2}$ and d+ $\equiv$ d$_{5/2}$
c	The number after $\pm$ is the power of the corresponding configuration. For example, the jj configuration of level 27 is: $(2s^2)\, 2p_{1/2}\, 2p^2_{3/2}\, 3s_{1/2}$
d	Mixing coefficient of the level (in bracket)

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Table 5a. Energy levels of Xe XLVI (in Ryd) and their lifetimes (τ).

Index	Level Index
Configuration	The configuration to which the level belongs
Level	The LSJ designation of the level with its spin, parity and J value
GRASP[a]	Present energies from the GRASP [?] code *without* Breit and QED corrections
GRASP[b]	Present energies from the GRASP [?] code *with* Breit and QED corrections
FAC[c]	Present energies from the FAC [5] code for 113 level calculations
FAC[d]	Present energies from the FAC [5] code for 279 level calculations
τ(s)	Lifetimes (in s)
a±b	$\equiv$ a$\times 10^{\pm b}$

Table 5b. Level designations of Xe XLVI and their mixing coefficients in LSJ and jj coupling.

Index	Level Index
Configuration	The configuration to which the level belongs
LSJ	The LSJ designation of the level with its spin, parity and J value
jj	The jj designation of the configuration
Mixing coefficients	The mixing coefficients in both jj and LSJ coupling
a	The number at the end or inside the bracket is 2J
b	s+ $\equiv$ s$_{1/2}$, p$-$ $\equiv$ p$_{1/2}$, p+ $\equiv$ p$_{3/2}$, d$-$ $\equiv$ d$_{3/2}$ and d+ $\equiv$ d$_{5/2}$
c	The number after ± is the power of the corresponding configuration. For example, the jj configuration of level 25 is: $(2s^2)\, 2p_{1/2}\, 2p_{3/2}^3\, 3s_{1/2}$
d	Mixing coefficient of the level (in bracket)

Table 6a. Transition energies/wavelengths (λ_{ij} in Å), radiative rates (A_{ji} in s^{-1}), oscillator strengths (f_{ij}, dimensionless), and line strengths (S, in atomic units) for electric dipole (E1) and magnetic quadrupole (M2) transitions in Xe L.

i and j	The lower (i) and upper (j) levels of a transition as defined in Table 1a.
λ_{ij}	Transition energy/wavelength (in Å)
A_{ji}	Radiative transition probability (in s^{-1})
f_{ij}	Absorption oscillator strength (dimensionless)
S	Line strength in atomic unit (a.u.), 1 a.u. = 6.460$\times 10^{-36}$ cm^2 esu^2
a±b	$\equiv a \times 10^{\pm b}$

Table 6b. Transition energies/wavelengths (λ_{ij} in Å), radiative rates (A_{ji} in s^{-1}), oscillator strengths (f_{ij}, dimensionless), and line strengths (S, in atomic units) for electric quadrupole (E2) and magnetic dipole (M1) transitions in Xe L.

i and j The lower (i) and upper (j) levels of a transition as defined in Table 1a.

λ_{ij} Transition energy/wavelength (in Å)

A_{ji} Radiative transition probability (in s^{-1})

f_{ij} Absorption oscillator strength (dimensionless)

S   Line strength in atomic unit (a.u.), 1 a.u. = 6.460×10^{-36} cm^2 esu^2

$a \pm b$ $\equiv a \times 10^{\pm b}$

Table 7a. Transition energies/wavelengths (λ_{ij} in Å), radiative rates (A_{ji} in s^{-1}), oscillator strengths (f_{ij}, dimensionless), and line strengths (S, in atomic units) for electric dipole (E1) and magnetic quadrupole (M2) transitions in Xe XLIX.

    i and j The lower (i) and upper (j) levels of a transition as defined in Table 2a.

    λ_{ij} Transition energy/wavelength (in Å)

    A_{ji} Radiative transition probability (in s^{-1})

    f_{ij} Absorption oscillator strength (dimensionless)

    S   Line strength in atomic unit (a.u.), 1 a.u. = 6.460×10^{-36} cm^2 esu^2

    $a \pm b$ $\equiv a \times 10^{\pm b}$

Table 7b. Transition energies/wavelengths (λ_{ij} in Å), radiative rates (A_{ji} in s^{-1}), oscillator strengths (f_{ij}, dimensionless), and line strengths (S, in atomic units) for electric quadrupole (E2) and magnetic dipole (M1) transitions in Xe XLIX.

    i and j The lower (i) and upper (j) levels of a transition as defined in Table 2a.

    λ_{ij} Transition energy/wavelength (in Å)

    A_{ji} Radiative transition probability (in s^{-1})

    f_{ij} Absorption oscillator strength (dimensionless)

    S   Line strength in atomic unit (a.u.), 1 a.u. = 6.460×10^{-36} cm^2 esu^2

    $a \pm b$ $\equiv a \times 10^{\pm b}$

Table 8a. Transition energies/wavelengths (λ_{ij} in Å), radiative rates (A_{ji} in s^{-1}), oscillator strengths (f_{ij}, dimensionless), and line strengths (S, in atomic units) for electric dipole (E1) and magnetic quadrupole (M2) transitions in Xe XLVIII.

    i and j The lower (i) and upper (j) levels of a transition as defined in Table 3a.

    λ_{ij} Transition energy/wavelength (in Å)

    A_{ji} Radiative transition probability (in s^{-1})

    f_{ij} Absorption oscillator strength (dimensionless)

    S   Line strength in atomic unit (a.u.), 1 a.u. = 6.460×10^{-36} cm^2 esu^2

    $a \pm b$ $\equiv a \times 10^{\pm b}$

Table 8b. Transition energies/wavelengths (λ_{ij} in Å), radiative rates (A_{ji} in s^{-1}), oscillator strengths (f_{ij}, dimensionless), and line strengths (S, in atomic units) for electric quadrupole (E2) and magnetic dipole (M1) transitions in Xe XLVIII.

i and j The lower (i) and upper (j) levels of a transition as defined in Table 3a.

λ_{ij} Transition energy/wavelength (in Å)

A_{ji} Radiative transition probability (in s^{-1})

f_{ij} Absorption oscillator strength (dimensionless)

S   Line strength in atomic unit (a.u.), 1 a.u. = 6.460$\times10^{-36}$ cm^2 esu^2

$a\pm b$ $\equiv a \times 10^{\pm b}$

λ_{ij} Transition energy/wavelength (in Å)

A_{ji} Radiative transition probability (in s^{-1})

f_{ij} Absorption oscillator strength (dimensionless)

S   Line strength in atomic unit (a.u.), 1 a.u. = 6.460$\times10^{-36}$ cm^2 esu^2

$a\pm b$ $\equiv a \times 10^{\pm b}$

Table 9a. Transition energies/wavelengths (λ_{ij} in Å), radiative rates (A_{ji} in s^{-1}), oscillator strengths (f_{ij}, dimensionless), and line strengths (S, in atomic units) for electric dipole (E1) and magnetic quadrupole (M2) transitions in Xe XLVII.

i and j	The lower (i) and upper (j) levels of a transition as defined in Table 4a.
λ_{ij}	Transition energy/wavelength (in Å)
A_{ji}	Radiative transition probability (in s^{-1})
f_{ij}	Absorption oscillator strength (dimensionless)
S	Line strength in atomic unit (a.u.), 1 a.u. = 6.460×10^{-36} cm^2 esu^2
$a{\pm}b$	$\equiv a \times 10^{\pm b}$

Table 9b. Transition energies/wavelengths (λ_{ij} in Å), radiative rates (A_{ji} in s^{-1}), oscillator strengths (f_{ij}, dimensionless), and line strengths (S, in atomic units) for electric quadrupole (E2) and magnetic dipole (M1) transitions in Xe XLVII.

i and j	The lower (i) and upper (j) levels of a transition as defined in Table 4a.
λ_{ij}	Transition energy/wavelength (in Å)
A_{ji}	Radiative transition probability (in s^{-1})
f_{ij}	Absorption oscillator strength (dimensionless)
S	Line strength in atomic unit (a.u.), 1 a.u. = 6.460×10^{-36} cm^2 esu^2
$a{\pm}b$	$\equiv a \times 10^{\pm b}$

Table 10a. Transition energies/wavelengths (λ_{ij} in Å), radiative rates (A_{ji} in s^{-1}), oscillator strengths (f_{ij}, dimensionless), and line strengths (S, in atomic units) for electric dipole (E1) and magnetic quadrupole (M2) transitions in Xe XLVI.

i and j	The lower (i) and upper (j) levels of a transition as defined in Table 5a.
λ_{ij}	Transition energy/wavelength (in Å)
A_{ji}	Radiative transition probability (in s^{-1})
f_{ij}	Absorption oscillator strength (dimensionless)
S	Line strength in atomic unit (a.u.), 1 a.u. = 6.460×10^{-36} cm^2 esu^2
$a{\pm}b$	$\equiv a \times 10^{\pm b}$

Table 10b. Transition energies/wavelengths (λ_{ij} in Å), radiative rates (A_{ji} in s^{-1}), oscillator strengths (f_{ij}, dimensionless), and line strengths (S, in atomic units) for electric quadrupole (E2) and magnetic dipole (M1) transitions in Xe XLVI.

i and j The lower (i) and upper (j) levels of a transition as defined in Table 5a.

λ_{ij} Transition energy/wavelength (in Å)

A_{ji} Radiative transition probability (in s^{-1})

f_{ij} Absorption oscillator strength (dimensionless)

S   Line strength in atomic unit (a.u.), 1 a.u. = 6.460×10^{-36} cm^2 esu^2

$a \pm b$ $\equiv a \times 10^{\pm b}$