INTRODUCTION

Atomic data for energy levels and radiative rates (A-values) are required for the modelling of fusion plasmas for a range of elements and their ions. Laboratory measurements for a few energy levels are generally available, but the corresponding data for the A-values are very limited. Therefore, we have recently reported such data for a few Br-like ions, namely with 38 ≤ Z ≤ 42 [1] and W XL [2]. Here we extend the work for 8 other ions with 43 ≤ Z ≤ 50, or specifically Te IX, Ru X, Rh XI, Pd XII, Ag XIII, Cd XIV, In XV, and Sn XVI.

CALCULATIONS

We have adopted the General-purpose Relativistic Atomic Structure Package (GRASP) code and have calculated A-values for the electric dipole (E1), electric quadrupole (E2), magnetic dipole (M1), and magnetic quadrupole (M2) transitions. Extensive CI (configuration interaction) among 39 configurations is included, i.e.

\[ 4s^34p^5, 4s^44p^4d/4f, 4s^4p^6, 4p^4d/4f, 4s^4p^5d/4f, 4s^4p^2d^2/4f/4d/4f, 4s^4p^2d^2, 4s^4p^3d, 4s^4p^3d^2, 4s^4p^4d^2, 4s^4p^4d^3, 4s^4p^3d^4, 4s^4p^4d^4, 4s^4p^5d, 4s^4p^4d^5, 4p^4d^3, 4d^3s^4s^2p^4d/4f, 4d^4s^4p^4d, 4s^4p^4d^5, 4p^4d^5, 4p^4d^5f, \text{and 3d}^4s^4p^5f. \]

These configurations generate 3990 levels in total and have been carefully chosen, because of their interacting energy ranges. Other configurations, such as \( 3p^3d^34s^4p^5, 3p^3d^34s^4p^5d^4 \) and \( 3p^3d^3s^4s^4p^5f \), have also been tested, but excluded from the calculations because they generate levels at much higher energy ranges, and hence their impact on the lower energy levels is insignificant. This has been confirmed by performing considerably larger calculations with the Flexible Atomic Code (FAC), which involve 12,137 levels. The additional 8147 levels have arisen from the inclusion of the \( 4p^6 \) 61, \( 4s^4p^5 \) 61, \( 4s^4p^5 \) 61, \( 4p^4d^2 \) 71, \( 4s^4p^5 \) 71, \( 4s^4p^5 \) 71, \( 3p^3d^34s^4p^5 \), \( 3p^3d^34s^4p^5d^4/4f, 4s^4p^5 \) 52, and \( 4s^4p^5 \) 52 configurations.

RESULTS

Energies, A-values and lifetimes (τ) have been determined for 3990 levels for all 8 Br-like ions. Since experimental energies are available only for the levels of the \( 4s^4p^5 \) and \( 4s^4p^5 \) configurations, we compare our results in Tables 1–3 for Ru X, Rh XI and Pd XII. In general, our energies with the GRASP code are higher than the measurements by up to 4%, and those obtained with FAC show even (slightly) larger discrepancies. This indicates that the additional CI included in FAC is of no advantage as far as the levels of the \( 4s^4p^5 \) configuration are concerned. However, it may be possible to improve upon the accuracy of our calculated energies by including a significantly larger CI (i.e. thousands of configurations generating over a million levels).

Wavelengths (λ) in \( \sim 10 \) Å range for 13 transitions of Sn XVI between the levels of the \( 4s^4p^4d \) and \( 4s^4p^4p \) configurations have been measured by D’Arcy et al. [3] who also reported the f-values. Agreement with our calculations with GRASP is within 3% for the wavelengths but differences for the f-values are up to 50% for a few. However, all measured lines are weak, i.e. \( f \leq 0.1 \), for which differing amount of CI produce variable results.

CONCLUSIONS

1. Based on limited comparisons with available measurements and our calculations with two independent atomic codes (GRASP and FAC), and with differing amount of CI, our energy levels are assessed to be accurate to better than 4%, although scope remains for improvements.

2. Corresponding available results for f-values are limited to only 13 transitions of Sn XVI for which differences with our calculations are up to 50% for a few. However, all such transitions are weak and therefore it is difficult to assess their accuracy based on such limited comparisons.

3. Presented results are preliminary and their detailed analysis is still in progress.

REFERENCES

1. KM Aggarwal and FP Keenan, Phys. Scr. 89 (2014) 125404

2. KM Aggarwal and FP Keenan, ADNDT 100 (2014) 1399