The importance of He-like ions in high temperature plasmas is well established and accurate data are required for various atomic processes involving the helium sequence. In this review we discuss and assess the accuracy of the latest data for electron impact excitation that have been calculated in the past four or five years. Prior to these calculations, the available data were mainly in the Coulomb-Born (CB) approximation or the distorted-wave (DW) approximation without resonances (which recent work has shown to be important). An assessment of the earlier data is given by Gallagher and Pradhan\(^{(1)}\) in their compilation of all available electron scattering data. The recent calculations are summarized in Table 1.

The recommended cross sections and rate coefficients are: (A) Kingston and Tayal\(^{(2)}\) for C V, O VII and Mg XI, (B) Pradhan\(^{(3)}\) for Ca XIX, Fe XXV, Se XXXIII, Mo XLI. For other highly charged ions and \(n > 3\) transitions, the data by Sampson et al.\(^{(4)}\) may be employed although its accuracy is 30% for strong transitions (e.g., \(1^{1}S_{0} - 2^{1}P_{1}\), \(1^{1}S_{0} - 2^{3}P_{1}\)) and may be 50% for weaker transitions (e.g., \(1^{1}S_{0} - 2^{3}S_{1}\), \(2^{3}S_{1} - 3^{3}S_{1}\)). The calculations (A) are the most elaborate ones to be carried out for He-like ions. They involve an eleven-state eigenfunction expansion for the target states and the solution of close-coupling (CC) equations using the RMATRIX method. Autoionizing resonances occurring within the \(n = 2\) complex and between the \(n = 2\) and the \(n = 3\) complexes are fully accounted for. Fine structure effects are not considered but those should not be significant for \(Z < 15\). For highly charged ions, the data of Pradhan\(^{(3)}\) incorporate the effects due to (i) fine structure, (ii) autoionization, and (iii) dielectronic recombination. These calculations, (B), are carried out first, in the CC approximation (using the IMPACT code) for the test case of Fe XXV and compared with the DW calculations with the same target function expansion. The CC and the DW results for Fe XXV are found to agree to within 5% even for low \(l\) waves (e.g., \(l = 0\)). The DW approximation is thereupon employed to calculate the collision strengths for the high \(Z\) ions mentioned above. Resonance effects are accounted for using detailed calculations for resonance structures and quantum defect theory. The effect of dielectronic recombination due to radiative decay of resonances converging onto the various \(n = 2\) and \(n = 3\) states is considered through a modified Galitsis formulation for the resonance averaged collision strengths (Ref. 3, 1983b).

In the earlier calculations by Pradhan et al.,\(^{(5)}\) the autoionization effect was overestimated for the ions with \(Z > 10\). For example, the effective collision strength for the transition \(1^{1}S_{0} - 2^{3}S_{1}\) in Mg XI is approximately twice that calculated by Kingston and Tayal.\(^{(2)}\) The calculations of Steenman-Clark and Faucher,\(^{(6)}\) on the other hand, significantly underestimate the effect of resonances. These authors contend that for highly charged ions the radiative decay of resonances dominates and largely wipes out the autoionization enhancement of the cross sections. However, the results of Steenman-Clark and Faucher are about 60% smaller than the considerably more accurate calculations of Kingston and Tayal for the transition \(1^{1}S_{0} - 2^{3}S_{1}\) in O VII, where the radiation damping of the resonances is not significant (except in the small energy region just below the \(2^{1}P\) threshold). Thus the difference in the calculations of Steenman-Clark and Faucher on the one hand, and Kingston and Tayal and Pradhan on the other, appears to be mainly due to incomplete consideration of the autoionization effect itself by the former authors. Recently, Faucher\(^{(7)}\) has recalculated the contributions of autoionization versus radiative decay to the excitation rate coefficients of Fe XXV, but reaches the same conclusion as earlier (Ref. 6). Faucher's method is not the same as that of Pradhan (Ref. 3); the relevant papers may
<table>
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<th>Ions</th>
<th>Author(s)</th>
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<tr>
<td>Be III, C V, O VII, Ne IX, Si XIII, Ca XIX, Fe XXV</td>
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<td>1981</td>
<td>5 DW, LS</td>
<td>All transitions between 1'S, 2'1S, 2'3S, 2'3P, 2'1P</td>
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<tr>
<td>C V, O VII, Mg XI, Ca XIX, Fe XXV</td>
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<td>Ω,γ</td>
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<tr>
<td>O VII, Mg XI, Ca XIX, Fe XXV</td>
<td>Steenman-Clark and Faucher(6)</td>
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<td>5 DW, IC</td>
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<tr>
<td>Ca XIX, Fe XXV, Se XXXIII, Mo XLI</td>
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<td>9 (CC,DW), IC</td>
<td>All transitions between 1'S0, 2'3S1, 2'3P0, 2'3F0, 2'3P1, 2'3P2, 2'1P1, 3'3S1, 3'3P0, 3'3P0, 3'3P1, 3'3P2, 3'1P1</td>
<td>Ω,γ</td>
<td>R</td>
</tr>
<tr>
<td>8 ≤ Z ≤ 74</td>
<td>Sampson et al.(4)</td>
<td>1978, 1980, 1983</td>
<td>CB, with exchange and IC</td>
<td>Transitions up to levels with n ≤ 5</td>
<td>Ω,γ</td>
<td>C,ν(f)</td>
</tr>
</tbody>
</table>

(a) nDW - n state distorted wave, nCC - n state close coupling, LS - LS coupling approximation for the target states, IC - intermediate-coupling approximation for the target states (with fine structure).

(b) Ω - collision strengths, γ - Maxwellian averaged Ω's, ν - rate coefficients.

(c) Accuracy ratings are (Ref. 1): A - <10%, B - <20%, C - <30%, D - <50.

(d) Ω for Be III, C V and O VII, and D for higher Z ions.

(e) ν for the transition 1'S0-2'3S1 and C for other transitions.

(f) D for forbidden transitions and C for others.
be consulted for the details. Pradhan finds that the resonance enhancement in the $^1S-^3S$ transition is 90% for all ions in the sequence, with approximately 10–20% reduction due to radiation damping in ions with $20 \leq Z \leq 42$ (i.e., −10% for Fe XXV and −20% for Mo XLI).

The extensive calculations by Sampson and co-workers\(^4\) have been carried out in the Coulomb-Born approximation with exchange and intermediate coupling. Until systematic computations have been completed for the entire sequence, their data are useful and should be considered complementary to the more accurate CC and DW calculations, which have been done only for a few ions and a limited number of transitions.

REFERENCES

1. J.W. Gallagher and A.K. Pradhan, JILA Information Center Report (1985); see also review in these proceedings.


