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LETTER TO THE EDITOR

Comments on the Be I $2s^2\ {}^1S$–$2s2p\ {}^1P$ transition probability

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Abstract. We report an accurate re-measurement of the oscillator strength of the Be I $2s^2\ {}^1S$–$2s2p\ {}^1P$ resonance line (2348·6 Å). Our new result, $f = 1{\cdot}34 \pm 0{\cdot}05$ is based on beam-foil experiments at several ion energies and detailed studies of cascade effects.

The oscillator strength for the Be I $2s^2\ {}^1S$–$2s2p\ {}^1P$ resonance line (2348·6 Å) has recently been the subject of several theoretical investigations. Calculations that neglect configuration interactions yield typical f values of $f = 1{\cdot}8$ (dipole length approximation) and $f = 0{\cdot}95$ (dipole velocity approximation). As shown by eg Crossley (1969), the situation improves when the interaction between the $2s^2\ {}^1S$ and $2p^2\ {}^1S$ configurations in the ground state is included in the calculations. Oscillator strengths close to 1·20 are obtained in this way.

Using the many-body perturbation procedure, Kelly (1964) obtained $f = 1{\cdot}25$. The same value was also reported by Nicolaides *et al* (1973) who used the non-closed shell many electron theory (NCMET) of Sinanoğlu (1969). Significantly higher f values, 1·40–1·42, are given by the CI calculations of A W Weiss (1970 unpublished, see Smith and Wiese 1971) and Burke *et al* (1972). On the basis of model-potential calculations Victor and Laughlin (1973) conclude that $f = 1{\cdot}37$. In a critical survey of the previous work, Hibbert (1973) emphasizes the significance of so-called all-external correlations (eg between $2s2p\ {}^1P$ and $3p3d\ {}^1P$) which were neglected in the treatment of Nicolaides *et al* (1973). By including such correlations, Hibbert finds $f = 1{\cdot}41$ for the Be I resonance transition. Using CI with very elaborate wavefunctions (over 50 configurations for the excited ${}^1P$ state) Sims and Whitten (1973) obtain $f = 1{\cdot}34$.

A number of experimental studies with the beam-foil technique have been made for this transition. Bergström *et al* (1969) and Andersen *et al* (1969) thus determined the Be I $2s2p\ {}^1P$ lifetime to $\tau = 2{\cdot}05 \pm 0{\cdot}06$ ns ($f = 1{\cdot}21$) and $\tau = 2{\cdot}3 \pm 0{\cdot}1$ ns ($f = 1{\cdot}08$) respectively. These experiments are reasonably reliable, but the error limits are too optimistic—certain systematic errors of the beam-foil technique had not been explored in 1969. In a more recent beam-foil experiment Hontzeas *et al* (1972) found

$$\tau = 1{\cdot}80 \pm 0{\cdot}15\ \text{ns}\ (f = 1{\cdot}38).$$

In this letter we report the results of a methodical beam-foil study of the $2s2p\ {}^1P$ lifetime. Beryllium ions were accelerated to 180, 200 and 280 keV in the Stockholm 400 kV accelerator (Lundin *et al* 1973) and directed through a 6·5 μg cm^{-2} (± 10%) carbon foil. The light was analysed with a Heath 35 cm EUE 700 monochromator,

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equipped with a Peltier-cooled EMI 6256 photomultiplier. Five independent, reproducible decay curves were recorded at each ion energy. The decays were followed over distances corresponding to times longer than 35 ns after the excitation. Figure 1 shows one of the decay curves. The beam current was kept constant (within 2–4 %) in all measurements. We further normalized the counting rate at each point to a preset number of photons counted close to the foil, by means of a fibre optics light guide, connected to another EMI phototube. By this technique, changes in the foil character which might affect the light emission are compensated for. The accelerator energy was calibrated using the $^{19}F(p, \alpha\gamma)^{16}O$ resonance at 340 keV. The small energy loss in the foil was easy to account for, because the foil thicknesses were accurately known. By measuring at different ion energies we reduced the errors due to velocity uncertainty to less than 2 %.

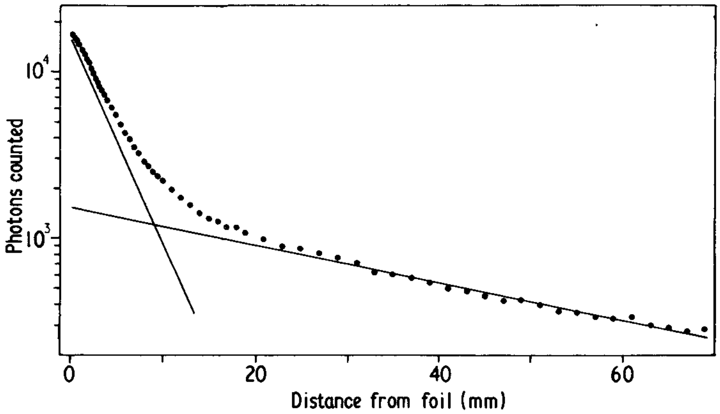

Figure. 1. Intensity decay of the 2348 Å Be I line ($2s^2\ ^1S$–$2s2p\ ^1P$) measured at 180 keV ion energy. For simplicity we show a decomposition into two exponentials, which here yields the lifetimes $\tau_1 = 1{\cdot}83$ ns ($2s2p\ ^1P$) and $\tau_2 = 20$ ns (weighted average of the cascading ^1S and ^1D states), ie in reasonable agreement with the more sophisticated analyses discussed in the text.

Cascade effects are one of the main limitations of beam-foil lifetime experiments. In the present case we expect the $2s2p\ ^1P$ level to be repopulated by transitions from $2sns\ ^1S$ and $2pnd\ ^1D$ ($n \geqslant 3$) configurations, all of which fortunately have lifetimes above 10 ns (and thus markedly longer than the $2s2p\ ^1P$ decay time). The $2s2p\ ^1P$–$2s3s\ ^1S$ line (8254 Å) lies outside our experimental range, while transitions from higher ^1S states were extremely weak in our spectra and they are therefore not expected to influence the final result. Transition from ^1D levels were much more intense, allowing direct measurements of the $2s3d\ ^1D$ ($\tau = 11{\cdot}6 \pm 1{\cdot}0$ ns) and $2s4d\ ^1D$ ($\tau = 18{\cdot}4 \pm 1{\cdot}5$ ns). These results are in excellent agreement with the calculations of Victor and Laughlin (1973). Our decay curves for these ^1D terms contained only a single exponential, showing that indirect cascading into $2s2p\ ^1P$ (eg from higher $2snp\ ^1P$ and $2snf\ ^1F$ levels) can be neglected in analysing the $2s2p\ ^1P$ decay curve. However, the latter also showed components corresponding to lifetimes longer than 20 ns. Constrained fits were therefore attempted, using the experimental $2s3d\ ^1D$ and $2s4d\ ^1D$ lifetimes (quoted above) and the theoretical (Victor and Laughlin 1973) $2s3s\ ^1S$ (20·6 ns), $2s5d\ ^1D$ (33·7 ns) and $2s6d\ ^1D$ (53·4 ns) lifetimes as corrections. However, the inclusion of these detailed cascades had only an insignificant effect on the primary lifetime. Figure 1 also shows that a comparatively naive two-exponential fit leads to satisfactory results in this case. As a final check numerical differentiations of the primary 2s2p ^{1}P decay curves were made, by means of a moving seven point least squares fit to a cubic-quartic polynomial, which reduced the cascade contributions from 10% to 0·5%, leaving a single-exponential decay curve for over two decades.

After all these corrections we obtain a 2s2p ^{1}P lifetime of $1{\cdot}85 \pm 0{\cdot}07$ ns, corresponding to an oscillator strength of $1{\cdot}34 \pm 0{\cdot}05$. We thus confirm the result of Hontzeas *et al* (1972). Thanks to a wider energy range and better statistics the experimental uncertainty has been reduced. The final result includes a velocity uncertainty, a small statistical error (~ 1%) as well as an estimated systematic error, due to decay curve decompositions. Our result is in particularly good agreement with the theoretical values of Victor and Laughlin (1973) and Sims and Whitten (1973). The latter authors note that neglect of $1s^2$ core correlations may yield f values that are too high by 5–10%. As well as confirming this interpretation our experimental value also seems to indicate the importance of all-external correlations for Be I.

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