

## LETTER TO THE EDITOR

### Measurement and analysis of the optical excitation function of the 2537 Å mercury line

(Excitation by electrons, 5 — 20 eV).

The renewed measurements of optical excitation functions of mercury lines have now been extended to the ultraviolet lines. The method of measuring and the scheme of an excitation tube were reported in an earlier communication <sup>1)</sup>. Our present excitation tube is fitted with a quartz window. The method of the investigation is passing a nearly parallel beam of electrons of controlled energy (5–20 eV) through mercury vapour of controlled pressure (0.0002–0.002 mm). The light thus produced is measured in a direction perpendicular to the beam by means of a photomultiplier via a monochromator. On this occasion we used a Bausch and Lomb grating monochromator with large aperture.

Most of the excitation functions of visible and ultraviolet mercury lines thus measured show more than one maximum, and hence are of a more complex structure <sup>1)</sup> <sup>2)</sup> than has been reported by the authors of earlier papers. To explain the occurrence of the various maxima in an excitation function, the two following possibilities should be considered <sup>1)</sup> <sup>2)</sup>:

I. The upper level of the line is not only filled by direct excitation from the ground level but also via spontaneous transitions from higher levels (provided that the electrons have sufficient energy to excite these higher levels). If the excitation function of each of these levels has only one maximum, and these maxima lie at different values of the electron energy, the excitation function of the line will represent all these maxima.

II. It is also possible that the excitation probability of one level itself (the "electrical excitation function") shows more than one maximum. The quantum-mechanical collision theory does not exclude this possibility <sup>3)</sup>.

The experimental results to be reported here indicate that with 2537 Å both possibilities are realized.

The measured excitation function of the 2537 Å line ( $6^3P_1 \rightarrow 6^1S_0$ ) is shown in fig. 1. We find maxima at approx. 4.9, 5.5, 7.9, 8.4, 9.1 and 9.6 electronvolts. These abscissa values have an uncertainty of a few tenths of an electronvolt, owing to errors in the corrections applied for contact potential and space charge <sup>1)</sup>. However, by means of special measurements it has been checked that the 3rd, 4th and 5th maximum correspond within 0.1 eV with the 1st, 2nd and 3rd maximum of the excitation function of the 4358 line ( $7^3S_1 \rightarrow 6^3P_1$ ), also plotted in fig. 1. It is plausible therefore to attribute these maxima of 2537 Å not to direct excitation of the  $6^3P_1$  level but to filling of  $6^3P_1$  by transitions from higher levels <sup>4)</sup>, for instance from  $7^3S_1$  with emission of 4358 Å. On the other hand the 1st and 2nd maximum of 2537 Å lie at abscissa values smaller than the height of  $7^3S_1$  or other relevant levels. Consequently these two maxima must be ascribed to direct excitation of  $6^3P_1$  from the ground level  $6^1S_0$ . Excitation from other levels than the ground level is negligible; this is demonstrated by the fact that

the height of each intensity maximum is proportional to the current in the electron beam.

The intensity of 2537 Å is weakened by the absorption in the mercury vapour (vapour pressure 0.0013 mm). However, this does not affect the relative course of the curve. The lines 2535 and 2537 Å were not separated. Consequently the full-drawn curve in fig. 1 will include a contribution of 2535 Å above 9½ eV. This contribution is not weakened by absorption in the vapour. In principle the 2535 Å contribution can be distinguished from 2537 Å by varying the vapour pressure. However, an excitation curve measured at 0.0002 mm showed the same relative shape as at 0.0013 mm, so the 2535 contribution is not of importance.

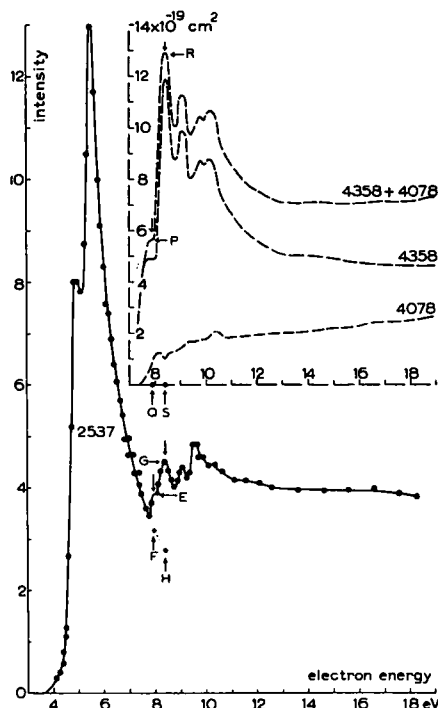


Fig. 1. Optical excitation function of 2537 Å and (for comparison) of 4358 and 4078 Å.

Abscissa: Mean energy of the electrons in the beam. The width of the electron energy distribution at half top height was circa 0.4 eV. This inhomogeneity limits the sharpness and height of the maxima of the measured excitation curves.

Ordinate for 2537 Å: Measured intensity of the spectral line, in arbitrary units, at constant current in the electron beam. This excitation curve (and especially the part between 7 and 10 eV) has been measured repeatedly; the points refer to one of these measurements.

Ordinate for 4358 and 4078 Å: (Approximate) effective cross-section per atom for electron impact causing 4358 or 4078 radiation (in a direction perpendicular to the electron beam, per steradian).

With the help of the level scheme (fig. 2) we can survey which higher levels via radiative transitions can contribute to the population of  $6^3P_1$  and thus to the intensity of 2537 Å. Arranged in order of increasing energy  $6^3P_1$  (4.86 eV) is first followed by

$6^3P_2$  (5.43) and  $6^1P_1$  (6.67), but transitions from these levels to  $6^3P_1$  are forbidden and indeed do not noticeably appear. Next comes  $7^3S_1$  (7.70); about one third <sup>5)</sup> of the atoms brought into this state leave it by spontaneous transition to  $6^3P_1$  with emission of 4358 Å. Only slightly higher we find  $7^1S_0$  (7.89); from here too, spontaneous transitions to  $6^3P_1$  occur, viz. with emission of 4078 Å, but their number is smaller. The latter follows from the recently measured <sup>6)</sup> intensity ratio of 4358 Å to 4078 Å: fig. 1 illustrates that (especially at low electron energies) 4078 is much weaker than 4358. The sum of the curves for 4358 and 4078 Å in fig. 1 accordingly shows chiefly the characteristic maxima of the 4358 curve. Apart from a constant factor, this sum is the

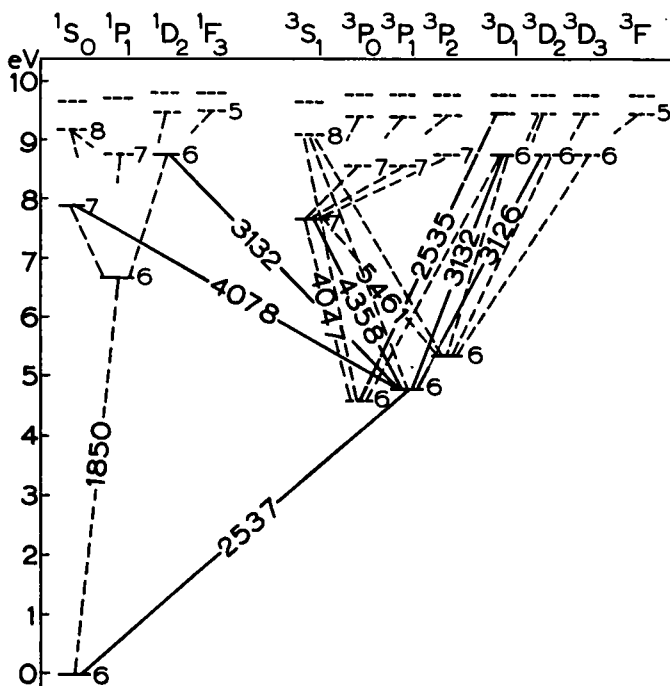


Fig. 2. Energy level scheme of the mercury atom. The levels and transitions in question are indicated by full-drawn lines.

total contribution via  $7^3S_1$  and  $7^1S_0$  delivered to the population of  $6^3P_1$  and thus to the intensity of 2537 Å. For a complete account of the indirect excitation contributing to the 2537 Å intensity, also above  $8\frac{1}{2}$  eV electron, one has to include the contributions of  $6^1D_2$  (8.81) and  $6^3D_{1,2}$  (8.98) and higher levels. We have not yet measured the corresponding excitation functions, viz. those of 3132 and 3126 Å and shorter wavelengths; however, we expect these contributions to have hardly any influence upon the 3rd and 4th maximum of the curve of 2537 Å and no dominant influence upon the 5th maximum, whereas they will contribute noticeably to the further part of the curve i.e. above 9 or 10 eV. The prediction thus obtained about the contribution of indirect excitation to the intensity of 2537 Å – as a function of the electron energy – agrees reasonably with the measured excitation function of 2537 Å (fig. 1, full-drawn curve, above  $7\frac{1}{2}$  eV) diminished by the estimated course of the direct excitation (dotted curve with  $F$  and  $H$ ).

The agreement only concerns the relative course of the excitation probability with the electron energy. It is difficult to measure the absolute excitation function of 2537 Å in consequence of the strong absorption of this wavelength in the mercury vapour in the tube. For the same reason we have not yet measured the intensity ratio of 2537 to 4358 Å. However, it is possible to estimate the ratio without absorption by means of fig. 1. For this we make use of the relationship that the ordinate difference  $GH$  must be equal to the ordinate  $RS$ , provided that both are expressed in photons per second etc. or in collision cross-sections. For the ratio of the intensity of 2537 to that of 4358 Å we thus find 3 : 1 (photons per sec etc.) or 5 : 1 (ergs per sec etc.); these ratios are valid at  $G$  and  $R$ , i.e. at the 4th maximum of the 2537 Å curve. A source of errors in this estimation is the uncertainty in the dotted curve for direct excitation of  $6^3P_1$ , but we can check this curve by means of the condition  $EF : GH = PQ : RS$ . An advantage of the estimation used is that it enables us to determine the emission intensity ratio of two wavelengths without knowledge of the sensitivity of the measuring apparatus as a function of wavelength and in spite of unequal absorption.

The ordinates of 4358 and 4078 Å in fig. 1 are absolute values <sup>6)</sup>. Undoubtedly the absolute values are less reliable than their ratios, the relative values. Nevertheless we will use them for an estimation concerning 2537 Å. According to fig. 1 the effective cross-section per atom, for production of 4358 Å by impinging electrons of 8.4 eV, is  $0.012 \times 10^{-16}$  cm<sup>2</sup> for a radiation direction perpendicular to the electron beam, per steradian. For 2537 Å this cross-section (calculated via the above-mentioned ratio 3 : 1) amounts to  $0.035 \times 10^{-16}$  cm<sup>2</sup>, viz.  $0.013 \times 10^{-16}$  for indirect and  $0.022 \times 10^{-16}$  for direct excitation, both per steradian, at this 4th maximum of 2537 Å. We repeat that the absolute values are less certain than their ratios.

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H. M. JONGERIUS  
W. VAN EGMOND  
J. A. SMIT  
Fysisch Laboratorium der  
Universiteit Utrecht,  
Nederland.

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