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Wavelengths of emission lines in the M spectrum of ^{49}In metal in the range 12–265 Å

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Abstract. The wavelengths of the peaks of 13 lines in the M spectrum of ^{49}In are reported. The Mζ emission has been decomposed into its three components whose relative intensities are found to differ greatly from both the ideal values and from the same components in the lighter elements ^{38}Sr at the other end of the series. A number of multiple ionization satellites are identifiable by the behaviour of their relative intensity as a function of exciting voltage.

1. Introduction

Inspection of the tables of x-ray wavelengths of Bearden and Burr (1967) or of Cauchois and Sénemaud (1978) shows that the M spectrum of In has not been reported, though Crisp (1987) has included the wavelength of the Mζ emission in a tabulation of the wavelengths of the Mζ series from ^{38}Sr through ^{50}Sn. In this communication we make good, in part, this omission.

2. Experiment

Spectra in the range 12–265 Å were recorded in a 1 m high vacuum spectrometer whose dispersing element was a concave grating ruled in gold with 2400 grooves per millimetre and 1° blaze. The grating is mounted at an 85.5° angle of incidence, and with entrance and analyser slits set at 45 μm the optical resolution is better than 0.25 Å in the first order over the whole range of the instrument. The spectrometer operates in a scanning mode, usually with channels set fine enough that 10–15 of them span one spectrometer line width, and counts from the detector (an EMI 9642/2B electron multiplier sensitized by evaporation of a 5000 Å layer of CsI onto the first dynode) are collected in real time in a Digital Systems LSI 11/23 computer. Each recorded spectrum consists of a number of summed scans (usually three or four).

Spectra were excited in bulk targets of pure In by electron beam currents of up to 3.0 mA at 3.0–3.5 kV. The targets were cooled with liquid nitrogen and scraped clean under the working vacuum with a tungsten carbide knife. Both the spectrometer and target chamber operated at pressures less than 5×10^{-8} Torr, and by monitoring the relatively intense O–Kα, N–Kα and C–Kα bands at 23.7, 31.2 and 44.5 Å respectively, it was shown that sample contamination was very low; in any case at the 3.0–3.5 kV

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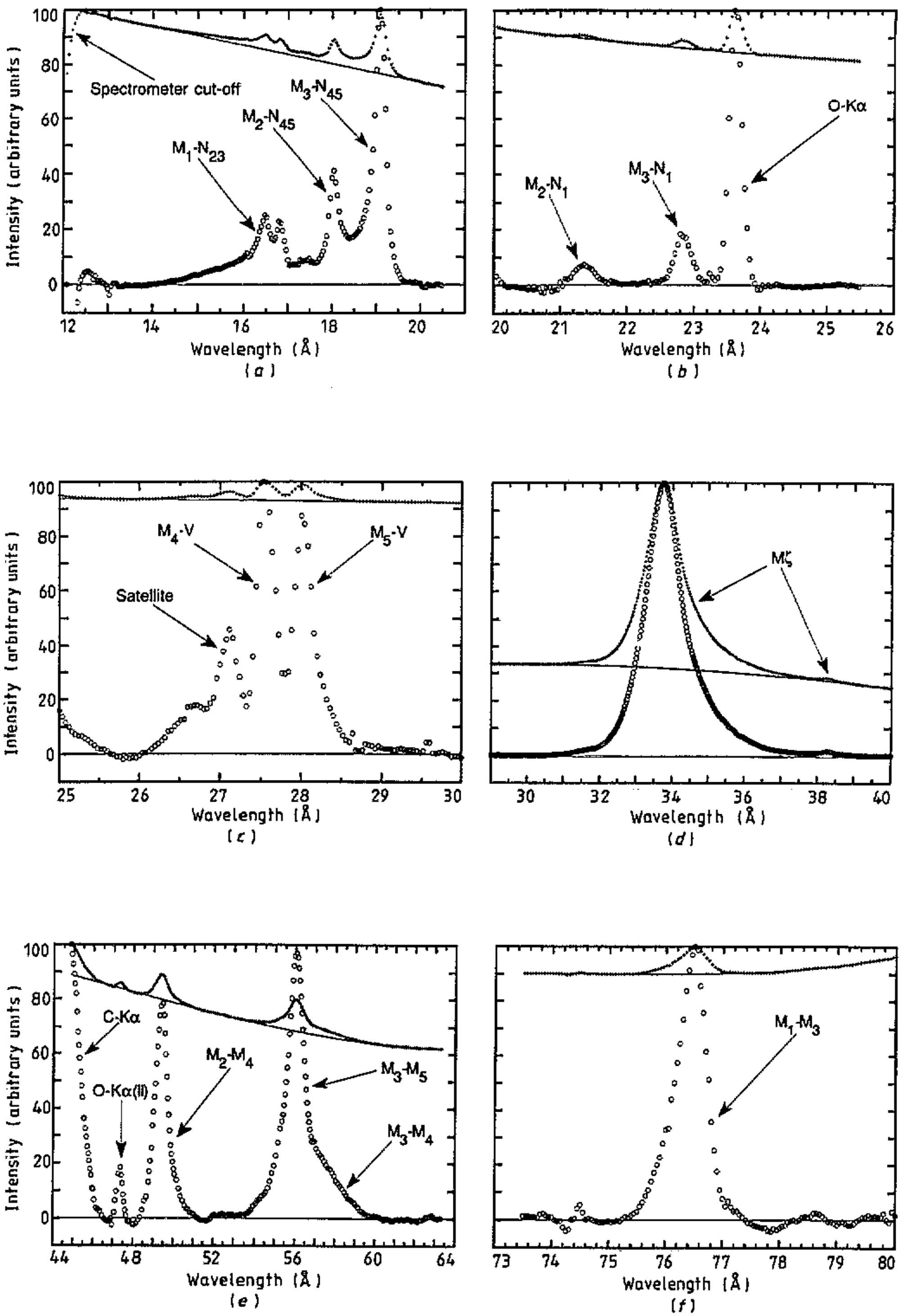

Figure 1. Illustrates the recorded spectra to show background and its removal. Counts at maximum in each case are: (*a*) 250×10^3; (*b*) 10^3; (*c*) 374×10^3; (*d*) 209×10^3; (*e*) 83×10^3; and (*f*) 44×10^3.

exciting voltages used, the mean depth of x-ray production is about 350 Å and hence surface effects can play only a very minor part.

All the spectra are underlain by a background consisting of a continuum diffracted in several orders as well as diffuse scatter and the spectrum to background ratio ($(S-B)/B$) ranged from 2.3 for Mζ to 0.01 for the line M_2–N_1. This background was removed by fitting a linear or a low order polynomial to the background either side of the line or line group. Since the backgrounds are slowly varying, the wavelengths of the line peaks given in table 1 are insensitive to the detailed form of the assumed background. The intensities are low, and only for Mζ and the M_{23}–M_{45} group was it possible to record any useable spectra in the second order with attendant improvement in resolution. Figure 1(a–f) illustrates the general features and nature of the recorded data. Though the O–Kα and C–Kα bands appear relatively intense in figure 1(b) and 1(e), their intensities are low in absolute terms and serve to emphasize the very low intensity of the In M spectra (apart from Mζ).

3. Wavelength values

Wavelengths quoted in table 1 are for the maxima of the fitted peaks of the first order lines. The wavelength values are taken directly from the spectrometer calibration determined in the fashion described by Crisp (1987). The Mζ wavelength quoted is the value from that earlier determination. The calibration introduces an error which varies over the range of the spectrometer and this represents the major portion of the quoted errors since the line peaks are located within ±2 channels and repeatable within this limit on independent runs.

In figure 2 we show a conventional energy diagram for In with energy level values taken from Bearden and Burr (1967), and lines were identified in the first instance by reference to this scheme. The wavelengths for the transitions identified in the present

Table 1. Lines identified in the present study, their measured wavelengths in Å and the corresponding energies in eV with estimated errors.

Line	Wavelength (Å)	Energy (eV)
M1–N3	16.485 ± 0.03	752.11 ± 1.37
M1–N2	16.825 ± 0.03	736.91 ± 1.31
M2–N45	18.040 ± 0.03	687.28 ± 1.14
M3–N45	19.085 ± 0.03	649.65 ± 1.02
M3–N1	21.365 ± 0.03	580.32 ± 0.81
M3–N1	22.854 ± 0.03	542.72 ± 0.71
M4–V	27.550 ± 0.03	450.04 ± 0.49
M5–V	28.025 ± 0.03	442.41 ± 0.47
M45–N23	33.80 ± 0.05	366.82 ± 0.54
M2–M4	49.40 ± 0.06	250.98 ± 0.30
M3–M5	56.05 ± 0.10	221.20 ± 0.39
M3–M4	57.90 ± 0.10	214.14 ± 0.37
M1–M3	76.51 ± 0.06	162.05 ± 0.13

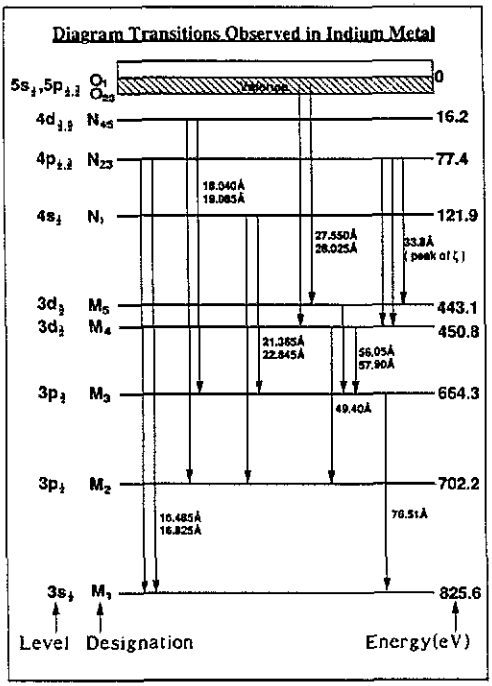

Figure 2. Conventional energy level diagram for In metal with energy level values taken from Bearden and Burr (1967). Transitions observed here and their measured wavelengths are indicated.

work are added in figure 2. Several non-diagram satellite structures were recognizable as multiple ionization satellites by the great reduction in their intensities relative to parent lines as the exciting voltage was lowered to below 1.5 kV (e.g. the structure at 27 Å associated with M_{45}–V). The identification of the double-peaked structure at 16.5 Å as M_1–N_{23} is not certain; the separation of 15.2 eV seems much too large to reflect the N_2–N_3 energy difference. However, a similar large separation of 14.5 eV is found from the components of Mζ (see below) and one is led to accept this as confirmation. There was no indication tht either of these 16.5 Å peaks were satellites. Similarly, there is an asymmetry in the M_1–M_3 line at 76.5 Å suggesting the presence of an unresolved underlying component which cannot be M_1–M_2. The wavelength of the composite peak is given here as M_1–M_3.

For all the shorter wavelength lines below 30 Å the instrumental broadening (0.25 Å) is far from negligible and constitutes a major portion of the observed breadth. Under these conditions and with low intensities and high background it was not possible to extract other than crude estimates of half-widths, hence FWHM values are not quoted.

4. Separation of Mζ components

The Mζ groups arise from transitions between the two pairs of levels M_{45} ($3d_{3/2,5/2}$), and N_{23} ($4p_{1/2,3/2}$). Three dipole transitions are allowed, M_5–N_2 being forbidden by the '*j*-selection' rule as illustrated in figure 3(*a*). In ^{49}In (figure 3(*b*)) these three lines are broad and overlap. By contrast, at the other end of the series, in ^{38}Sr (figure 3(c)), they are sharp and more or less resolved. This trend is illustrated in figure 3(*d*) where the Mζ

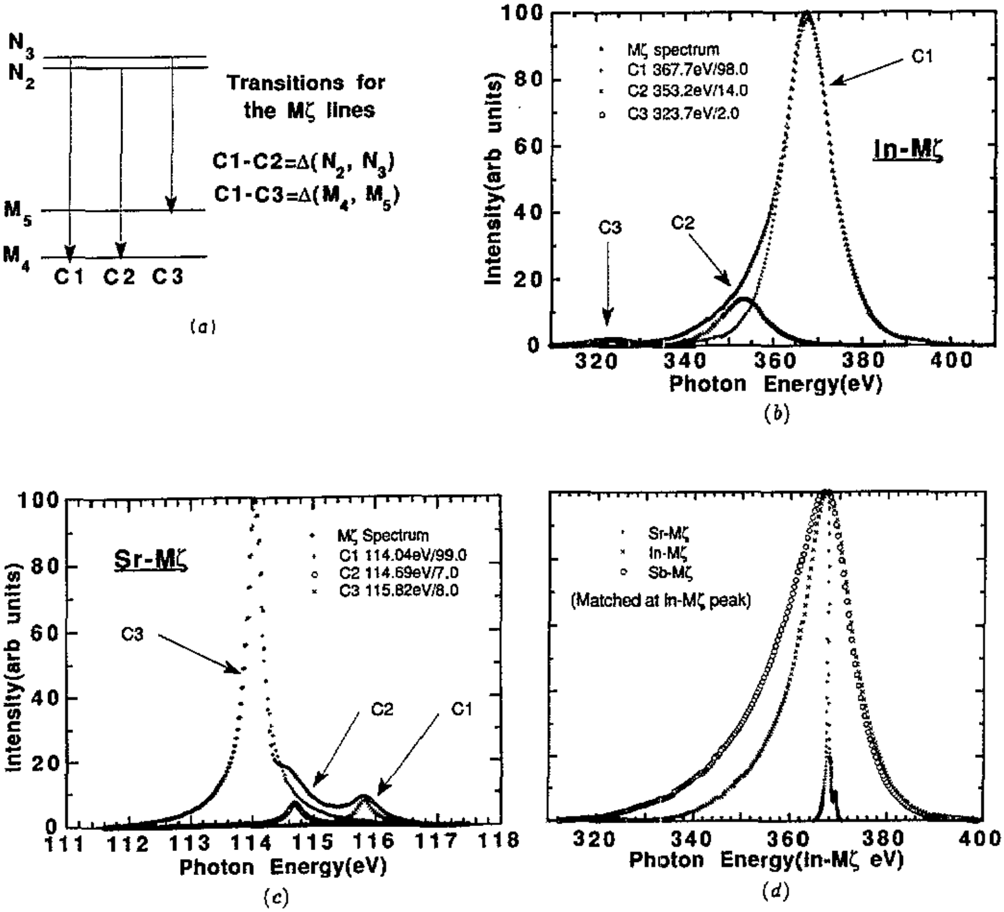

Figure 3. Components of Mζ. (*a*) Mζ transitions and relation of the transition energies to the level separations; (*b*) separation of components of In–Mζ; (*c*) separation of components of Sr–Mζ; (*d*) comparison of Sr–, In– and Sb–Mζ to show the progressive increase in breadths and change in the relative intensity of the components. In (*b*) and (*c*) the energies and relative peak intensities for the three components are indicated. In (d) the Sr and Sb lines have been shifted in energy for plotting so that the three lines are matched at the In–Mζ peak.

lines for ^{38}Sr, ^{49}In and ^{51}Sb are plotted on a common energy scale and matched at the maxima.

In ^{38}Sr the component of lowest energy, C3 (or M_5–N_3), has the greatest intensity. In ^{49}In, however, this is not the case and the component Cl or (M_4–N_3) is the most intense, whereas the ideal ratios for M_5–N_3 : M_4–N_2 : M_4–N_3 are 3 : 1 : 2. The intensities and energies of the components of Mζ across the whole series ^{38}Sr through ^{51}Sb is the subject of a continuing study.

5. Acknowledgments

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