

# Intrinsic Luminescence of KI and RbI at 80°K

J. RAMAMURTI\* AND K. J. TEEGARDEN

*Institute of Optics, University of Rochester, Rochester, New York 14627*

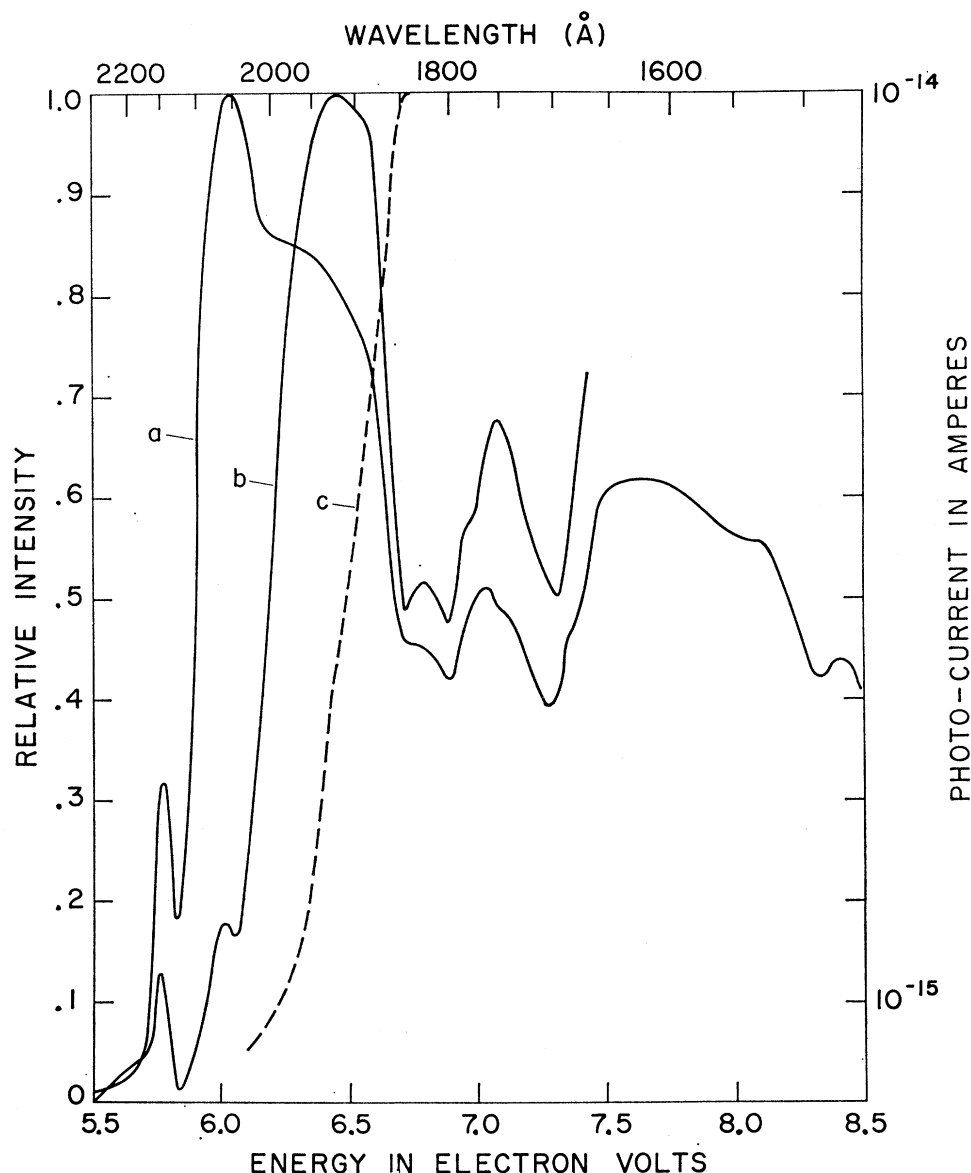
(Received 27 October 1969)

Excitation spectra of intrinsic emission bands of KI and RbI at 80°K are presented. Comparison is made with the photoconductivity spectra.

SINGLE crystals of alkali halides luminesce efficiently when irradiated by photons in the exciton and band-to-band transition regions at low temperatures. In a previous paper,<sup>1</sup> emission and excitation

spectra of this luminescence of KI and RbI at 10°K were reported. In this paper, the excitation spectra of some of the emission bands at 80°K are reported and compared with the photoconductivity spectrum. The

FIG. 1. (a) Excitation spectrum of the 3.32-eV emission band of KI at 80°K. (b) Excitation spectrum of the 4.15-eV emission band of KI at 80°K. In both cases the bandpass of the excitation monochromator was 16.4 Å. (c) Photoconductivity current in a single crystal of KI at 97°K [from Nakai and Teegarden (Ref. 2)].



\* Present address: Radio and Electrical Engineering Division, National Research Council, Ottawa, Canada.

<sup>1</sup> J. Ramamurti and K. J. Teegarden, Phys. Rev. **145**, 698 (1966).

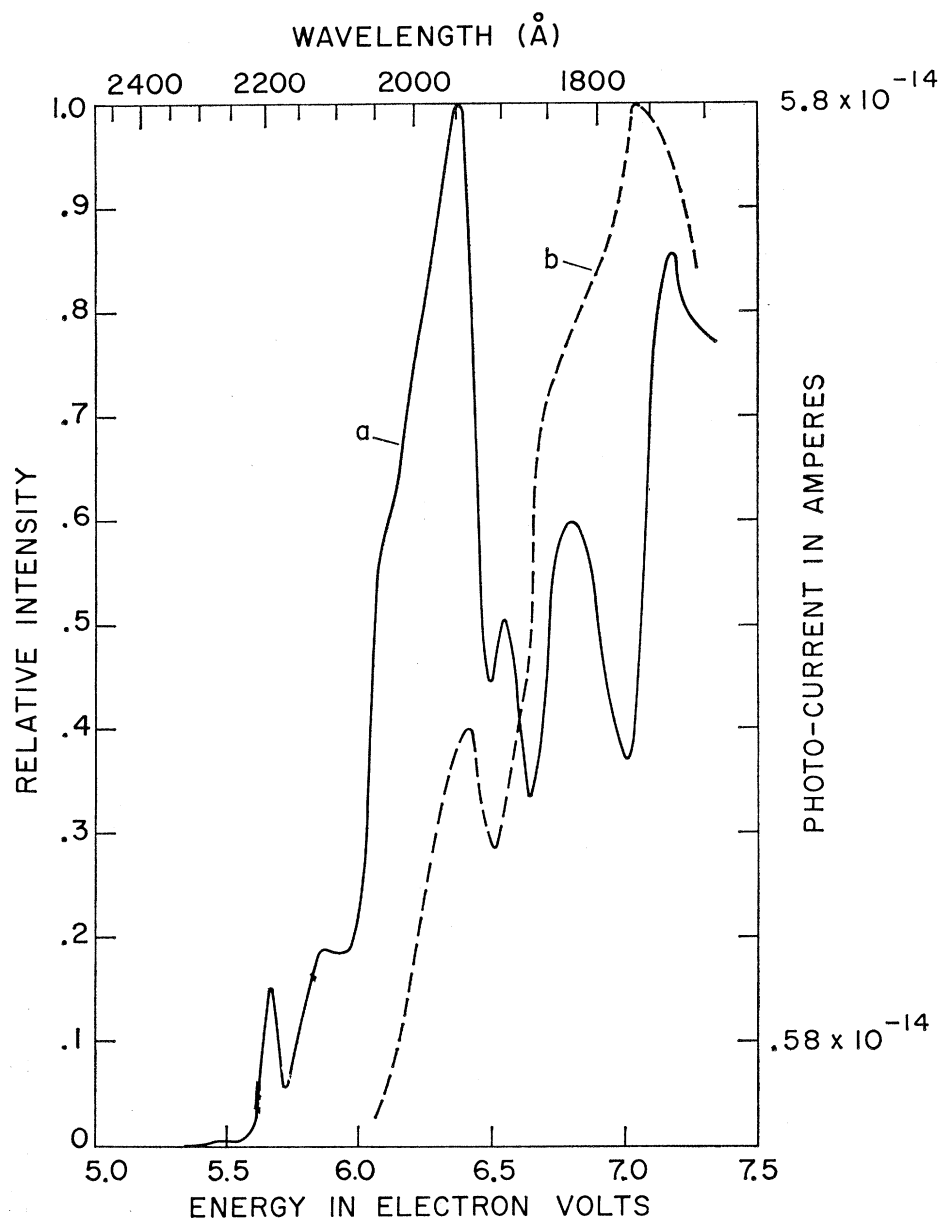


FIG. 2. (a) Excitation spectrum of the 3.88-eV emission band of RbI at 80°K. The excitation band-pass was 16.4 Å. (b) Photoconductivity current in a single crystal of RbI at 80°K [from Huggett and Teegarden (Ref. 3)].

experimental procedure and apparatus used for obtaining these spectra are the same as those described in Ref. 1.

At 80°K, KI has two emission bands at 3.32 and 4.15 eV. Figure 1 shows the excitation spectra of these two bands of KI at 80°K and the photoconductivity spectrum<sup>2</sup> at 97°K. The threshold for the 3.32-eV emission is at 5.83 eV. This value lies at the high-energy side of the first-exciton peak of KI. The threshold for the 4.15-eV emission is at 6.07 eV, which is 0.23 eV below the threshold of photoconductivity. The peak positions of these three curves are at 6.04, 6.45, and

6.75 eV. In the case of RbI, two emission bands are observed at 3.12 and 3.88 eV at 80°K. The excitation spectrum for the 3.12-eV emission could not be measured because its intensity was too low. The excitation spectrum for the 3.88-eV emission and the photoconductivity spectrum<sup>3</sup> are shown in Fig. 2. The 3.88-eV band has a threshold at 6.00 eV and attains its maximum value at 6.37 eV. The photoconductivity starts rising at 6.1 eV and has a peak value at 7.05 eV.

Kabler<sup>4</sup> and Murray and Keller<sup>5</sup> have shown that this

<sup>3</sup> G. R. Huggett and K. J. Teegarden, *Phys. Rev.* **141**, 797 (1966).

<sup>4</sup> M. N. Kabler, *Phys. Rev.* **136**, A1296 (1964).

<sup>5</sup> R. B. Murray and F. J. Keller, *Phys. Rev.* **137**, A942 (1965).

<sup>2</sup> Y. Nakai and K. J. Teegarden, *J. Phys. Chem. Solids* **22**, 327 (1961).

emission is due to recombination of electrons and self-trapped holes.<sup>6</sup> An  $I_2^-$  molecule in excited state, i.e., a self-trapped exciton, is formed from which emission occurs. In KI and RbI, the photoconductive thresholds lie at higher energies than those of emission. In particular, in the case of 3.32-eV emission of KI, the difference in the threshold energies is 0.5 eV. Thus for the low-energy emission band of KI, the formation of free electrons and holes is not necessary, for efficient emission and efficient trapping of excitons must take place. The peak positions of photoconductivity current

occur 0.3 and 0.7 eV above the peak positions of 4.15-eV emission of KI and 3.88-eV emission of RbI in the excitation spectra. But the threshold values for the 4.15-eV emission of KI and 3.88-eV emission of RbI are close to the interband transition energies in these materials. For this reason, it cannot be stated definitely that the formation of free electrons and holes is not necessary for efficient stimulation of high-energy bands in KI and RbI. At 10°K both RbI<sup>7</sup> and KBr<sup>8</sup> show similar effects.

<sup>6</sup> For a detailed discussion, see R. S. Knox and K. J. Teegarden, in *Physics of Color Centers*, edited by W. B. Fowler (Academic Press Inc., New York, 1968).

<sup>7</sup> J. Ramamurti, Ph.D. thesis, University of Rochester, 1966 (unpublished).

<sup>8</sup> J. Ramamurti and K. J. Teegarden (unpublished).

## Diffusion of Tin into Zinc†

J. STANLEY WARFORD\* AND H. B. HUNTINGTON

*Department of Physics and Astronomy, Rensselaer Polytechnic Institute, Troy, New York 12181*

(Received 24 July 1969)

The diffusivity of tin in zinc has been measured from 298 to 400°C. The data are well represented by  $D_{01}=0.13\pm0.03$  cm<sup>2</sup>/sec and  $Q_1=18.4\pm0.2$  kcal/mole;  $D_{011}=0.15\pm0.07$  cm<sup>2</sup>/sec and  $Q_{11}=19.4\pm0.5$  kcal/mole. The general picture for the diffusion of impurities in zinc is briefly reviewed.

THE anisotropic diffusivities of several monovalent, divalent, and trivalent impurities in single-crystal zinc have been measured in this laboratory.<sup>1-4</sup> Recently, a quadrivalent solute, Sn<sup>113</sup>, has been investigated with the following results:  $D_{01}=0.13\pm0.03$  cm<sup>2</sup>/sec and  $Q_1=18.4\pm0.2$  kcal/mole;  $D_{011}=0.15\pm0.07$  cm<sup>2</sup>/sec and  $Q_{11}=19.4\pm0.5$  kcal/mole. A brief report on this investigation follows.

As in the earlier work the method used was the standard sectioning technique. Runs were made at four different temperatures: 400, 358, 328, and 298°C, each with two specimens of different orientation.

The penetration profiles for the higher-temperature runs accurately checked with the Gaussian solution for the thin-film condition, but there was some deviation for the runs at lower temperature for which there appeared to be some upward curvature near the surface.

We believe that the origin of this difficulty lies in the limited solubility of the zinc for the tin which would be more marked at the lower temperatures. Accordingly, the slopes of the deep penetration parts of the profiles were taken to determine the diffusivities. The validity of this approximation was later improved by a more refined procedure. It was found that the associated correction was of the order of 6%.

The results for  $D_{11}$  and  $D_1$  for the four temperatures are shown in Fig. 1. The Arrhenius line, fitted by least squares to the data, corresponds to the parameters given in the first paragraph. Also shown in the same figure are similar lines obtained in earlier investigations for trivalent impurities in zinc and for the self-diffusion of zinc itself, presented for comparison. In Fig. 2(a), the changes in activation energy for all solutes in zinc studied so far are shown as a function of valence difference. While the general correlation is quite evident, there are some notable deviations. In particular, the activation energies for gallium fall about 1.5 kcal/mole below where they might be expected. The same can also be seen from a careful inspection of Fig. 1. The values for the gallium  $D_0$ 's as well are small by a factor of 5. Interestingly enough the correlation of the values of the diffusivities themselves with valence is more

† Supported by contract with the U. S. Atomic Energy Commission.

\* Report covers work done in partial fulfillment of the requirements for the degree of Master of Science at Rensselaer Polytechnic Institute. Present address: Physics Department of the San Diego Campus of the University of California.

<sup>1</sup> J. H. Rosolowski, *Phys. Rev.* **124**, 1818 (1961).

<sup>2</sup> P. B. Ghate, *Phys. Rev.* **131**, 174 (1963).

<sup>3</sup> A. P. Batra and H. B. Huntington, *Phys. Rev.* **145**, 542 (1966).

<sup>4</sup> A. P. Batra and H. B. Huntington, *Phys. Rev.* **154**, 569 (1967).