$1s2s2s$ and $1s2p2p$ transitions is good. However, the important correspondence is the energy difference of 11 eV between peaks in both the calculated and the observed cases; this energy difference is independent of the values taken for the binding energy, contact-potential difference, and the Fermi energy. Absence of the $1s2s2p$ and $1s2p2s$ peak may be due to the nature of its distribution, a small transition probability, poor resolution capability of the analyzing conditions, or any combination of the above. The relative amplitudes of the $1s2s2s$ and $1s2p2p$ peaks may be explainable in terms of two different transition probabilities.

Our results indicate that Auger transitions can be very sensitive to electronic band structure and can be valuable for determining band information when x-ray techniques are not completely suitable; however, $N(E)$ data corresponding to $f(\epsilon)$ Auger peaks would be more informative than $dN(E)/dE$ data. A background-nulling technique[18] should be useful in obtaining worthwhile $N(E)$ data.

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Photoelectric Emission of RbCl in the Extreme Ultraviolet

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The spectral photoelectric yield of RbCl has been determined in the photon energy range 10 to 40 eV by using synchrotron radiation as a continuous light source. Comparison of the absorption spectrum with the spectral yield measured with and without retarding potential reveals that the general features of the spectral yield are attributable to electron-electron scattering and the absorption spectrum. The yield exceeds unity in the region 21.0 to 25.0 eV, and the electron affinity is estimated to be 0.50 ± 0.05 eV.

The quantum yield of RbCl was measured by Metzger[1] up to 21 eV. According to his results, the electron affinity χ was estimated to be 0.40 eV, assuming that the minimum of the spectral yield at 17.2 eV should be observed at $2(E_g + \chi)$, where E_g is the band-gap energy. The photoelectric emission did not closely correspond with the absorption spectra. He concluded that the magnitude of the quantum efficiencies at photon energies greater than the minimum at $2E_g$ implies multiple processes to be dominant. Recent experiments on the photoemission of alkali ha-

lides[2,3] showed that the study of photoelectric emission offers valuable information on electron-electron scattering effects of excited electrons[4] and relaxation processes of excitons with a core-state hole.

The absorption spectra of RbCl in the photon energy range 10 to 30 eV were recently obtained by Saito et al.[5] at room and liquid-nitrogen temperatures by using the synchrotron radiation of the Institute for Nuclear Study, Tokyo, as a light source. In the absorption spectrum, five sharp exciton bands were found at room temperature. The first band and the third one (D and F in Fig. 1) were ascribed to the excitons associated with the lowest s-like conduction band at Γ point. Other bands E, G, and H were attributed to the transitions from the Rb^+ $4p^6$ to the $4p^5 4d$ configurations.

The photoelectric yield and the kinetic-energy distribution of photoelectrons of RbCl in the photon energy range 10 to 40 eV are reported on in the present work.

The continuous spectrum of synchrotron radiation of the Institute for Nuclear Study synchrotron in Tokyo operated at 900 MeV was used as a light source. A 50-cm monochromator of the Seya-Namioka type equipped with a gold-coated replica grating of 1200 lines/mm was used. The wavelength resolution of the monochromator was about 3 Å when both the entrance and the exit slits were 200 μm in width. A spherical concave mirror with a 6-m radius was placed in front of the entrance slit at an angle of incidence of 75°. The samples were thick films prepared in situ by evaporation of reagent-quality powder onto a nonmagnetic stainless-steel plate mounted on the center of a stainless-steel cylindrical collector. All the measurements reported here were made at normal incidence. The sample chamber was made of stainless steel and evacuated down to pressures of 3×10^{-7} Torr. For the yield measurements a collector voltage of +25 V was applied, and photocurrents ranged from 10^{-13} to 10^{-10} A. In order to study the energy distribution of photoelectrons, spectra of the photoelectric yield were also obtained by applying various retarding potentials to the collector. The photon flux behind the exit slit was measured by means of a double ionization-chamber technique, which was essentially the same as that described by Samson.[6] In the photon energy range higher than 24.6 eV where the first ionization potential of helium lies, the ionization chamber was filled with helium gas. As the first ionization potential

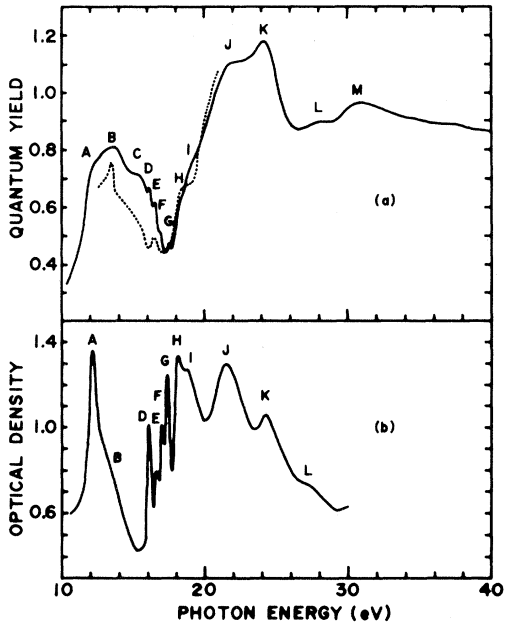

FIG. 1. The photoelectric yield and the absorption spectra of RbCl. (a) The photoelectric-yield spectrum. The solid line indicates the present work and the dotted line represents Metzger's findings. (b) The absorption spectrum.

of argon lies at 15.8 eV, argon gas was used in the photon energy range 15.8 to 24.6 eV. In the photon energy range below 15.8 eV, the photon flux was determined by the output current of a sodium salicylate–coated photomultiplier normalized to the value determined by using the argon chamber at the ionization limit of argon gas. The spectrum of the photon flux showed an intensity distribution with a maximum at 18.4 eV. The values of the photon flux at 10.0, 18.4, and 40.0 eV were estimated at 3.5×10^7, 9.3×10^7, and 1.2×10^7 photons/sec, respectively. Further details of the experimental procedure will be described elsewhere.[7]

The spectral dependence of the quantum yield of RbCl is shown in Fig. 1, together with the absorption spectrum of the same substance obtained by Saito et al.[5] The quantum yield is defined here as the yield per incident photon. As Fig. 1 and Table I show, photon energies of the maxima of the yield spectrum correspond well to those of the absorption spectrum and those of the electron energy-loss spectrum measured by Creuzburg.[8] It is remarkable that all the maxima which have been assigned to the exciton absorption bands associated with Rb^+ $4p$ core states, namely D, E, F, G, and H in Fig. 1, appear in the yield spectrum. This result differs

Table I. Photon energies of the maxima of photoelectric yield, absorption, and energy-loss spectra of RbCl.

Designation of the maxima	Photoelectric emission (present work) (eV)	Absorption[a] (eV)	Energy loss[b] (eV)
A	12.2	12.15	12.9
B	13.7	13.5	13.9
C	15.3	...	...
D	16.1	16.09	16.1
E	16.6	16.62	...
F	17.0	16.99	...
G	17.5	17.42	17.4
H	18.2	18.17	18.4
I	19.0	18.70	19.0
J	21.8	21.6	22.3
K	24.1	24.3	25.0
L	28.0	27.2	27.5
M	31.0	...	...

[a]Ref. 5. [b]Ref. 8.

considerably from that reported previously by Metzger.[1]

The general features of the yield spectrum, however, do not in the least resemble those of the absorption spectrum and so, in this respect, there is good agreement with Metzger's result. The yield spectrum generally consists of two broad regions of high yield, namely, 12 to 16 eV and 20 to 25 eV, and two distinct minima are found at 17.4 and 26.5 eV. In the photon energy range 21.0 to 25.0 eV, the quantum yield exceeds unity, and the maximum yield at 24 eV is as high as 1.17.

Figure 2 shows the spectral yield of photoelectrons with retarding potential V_c as a parameter.

High yield at a photon energy range lower than $E_g + E_x = 15.6$ eV, where a photoelectron has not enough energy to excite another electron from the valence band, can be explained mainly by the low probability of electron-electron scattering, and possibly also by ionization of impurity- or F-center-trapped electrons. E_x is the photon energy of the first exciton band.

The yield decreases rapidly above 15.6 eV and reaches the minimum at $2(E_g + \chi) = 17.4$ eV. In the photon energy range 15.6 to 17.4 eV, an emitted electron has enough energy to excite another electron across the gap but the probability of retaining at least one of the scattered electrons above the vacuum level remains low. The value of an electron affinity of 0.50 ± 0.05 eV, determined by the photon energy of the yield minimum[9] and the band gap E_g of 8.20 eV, is in fair agreement with Metzger's result, 0.40 eV.

It is probable that the core exciton decays through an Auger transition so that an energetic electron is consequently emitted from the valence band. The penetration depth of incident

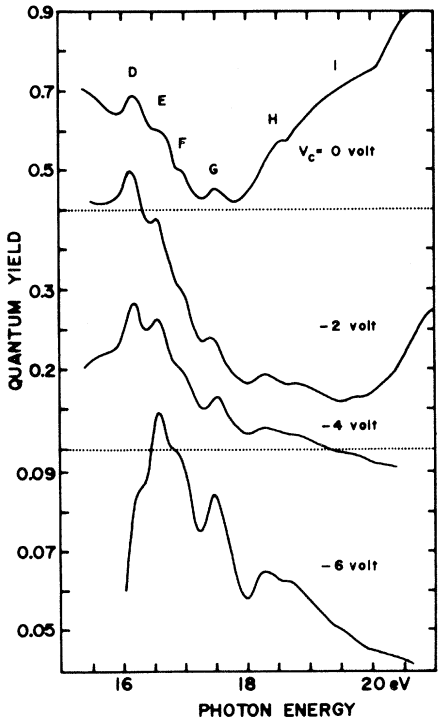

FIG. 2. The photoelectric yields of RbCl obtained with various retarding potentials.

light is small at the exciton band, where the optical density is relatively high. Therefore the Auger electrons can reach the surface of the crystal without inelastic scattering, and escape from the crystal with high kinetic energies. Thus, yield maxima at the photon energies of exciton bands, D, E, F, G, and H in Figs. 1 and 2, can be explained by Auger processes and short escape distances. The yield maxima at the photon energies of exciton bands remain under -6 V retardation, indicating the existence of photoelectrons with kinetic energies higher than 6 eV. A possible Auger transition resulting in such energetic photoelectrons is the one accompanying recombination of the core exciton. In the case of the first exciton band, D at 16.09 eV, the kinetic energy of the photoelectron emitted in this way is estimated to be 7.4 eV.

At the photon energies just exceeding $2(E_g+\chi)$, both the scattered electrons have, or at least one of them will have, sufficient energy to escape from the crystal; the yield minimum at $2(E_g+\chi)$ can therefore be assigned to the onset of high yield. The yield exceeds unity in the photon energy range 21.0 to 25.0 eV and this fact means that more than one photoelectron is emitted for one incident photon. The retarded-yield spectrum in the photon energy range exceeding 17.4 eV decreases remarkably with the increase of the retarding potential, and shows that distribution of low-energy electrons is dominant in this photon energy range. These experimental facts, as well as shifts of the photon energy of the yield minimum due to the difference of halogen ions in rubidium halides,[9] support the above conclusions regarding the yield minimum.

For the photon energies exceeding 14.7 eV, photoelectrons which do not suffer electron-electron scattering can escape from the crystal with kinetic energies of higher than 6 eV if one assumes that the electrons come from the top of the valence band. Therefore, when a retarding potential of -6 V is applied, the yield spectrum must have a peak extending from 14.7 eV to 17.4 eV to make a gross feature of the spectrum. The maximum of the peak is reasonably supposed to lie at 16.1 eV. This supposition is supported by the experimental facts that peak D decreases much more than peak E and the background of exciton bands forms a peak with the maximum at 16.5 eV. A steep slope of the spectrum at the photon energy lower than 16.5 eV is considered to be due to rapid increase of optical density and, therefore, rapid decrease of escape distance against photon energy.

The yield minimum by another scattering process, in which an excited $Rb^+ 4p$ electron excites a valence electron across the gap, may occur at $E_c+E_g+2\chi=26.0$ eV. E_c, assumed to be 16.8 eV, is a gap between the core level $Rb^+ 4p$ with $j=\frac{3}{2}$ and the bottom of a conduction band, whereas the observed photon energy of the second minimum is 26.5 eV. The yield minimum by double scattering at $3(E_g+\chi)=26.1$ eV may also contribute partly to form this minimum.

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