

values suggest that there are two excited states in the Zn^{67} nucleus—one at 350 kev, and the other either at 100, or 250 kev above ground. Every case of electron capture leaves the Zn^{67} in the upper state, from which it cascades to ground in two steps. One of the transitions gives rise to the 250 kev gamma-ray, and the other is responsible for the internally converted radiation at 100 kev. The internal conversion coefficient is fairly high, since the transition curves show the 100 kev line to be weaker than the one at higher energy. The relative intensities of electrons and x-rays confirm this. If the line were totally internally converted, the K -excitation would be twice as great as the electron emission, since the K shell would be emptied by capture and conversion in each transition. The observed ratio is 4, which indicates that the conversion coefficient is about 40 percent. All the intensities are consistent with the scheme outlined above.

The question then arises:—how is it possible to have such a large internal conversion factor in an element as light as zinc? It has been quite generally thought by theoretical physicists that internal conversion would play a negligible part in artificial radioactivity, since the equations predict a Z^3 dependence. (Total conversion in a 0-0 transition would be possible, however.) When it first be-

came apparent that Zn^{67} had an anomalously high internal conversion coefficient, Dancoff and Morrison⁴⁴ reexamined the theory, and found that in the energy range near 100 kev for zinc, the factor could be quite high. The 40 percent observed (internal conversion coeff. ~ 0.7) would mean the gamma-rays were due to a quadripole transition. No detailed calculations of this nature had been made previously for light nuclei, as it had seemed certain from an inspection of the formulae that there were no terms entering which could make the ratio appreciable. All details of the picture, both experimental and theoretical, are now self-consistent.

It might be interesting to look for coincidences between the two x-rays ejected almost simultaneously in 1/8 of the disintegrations. (40 percent \times (fluorescent yield)² = 1/8.) An apparatus for this experiment has been constructed, but has not as yet been used. The x-ray spectrum might yield interesting information about the relative lifetimes of x-ray and gamma-ray states. If the K shell were doubly excited, the wave-length of the characteristic radiation would be slightly changed, and this could be detected on a bent crystal spectrograph. No such case of a doubly excited K shell is known.

⁴⁴ Dancoff and Morrison, *Phys. Rev.* **54**, 149 (1938).

Vibrational Analysis for a New CuCl Band System Excited by Active Nitrogen

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The CuCl band spectra in the near ultraviolet, first observed by Strutt and Fowler who used active nitrogen excitation, were photographed and classified. The wave number of any band head in this system may be calculated from the formula

$$\nu = 25,282 + [383(v' + \frac{1}{2}) - 2(v' + \frac{1}{2})^2] - [415(v'' + \frac{1}{2}) - (v'' + \frac{1}{2})^2].$$

This band system has a common lower state with five other systems in the visible, observed in absorption and analyzed by Ritschl.

INDPENDENTLY of Harnack,¹ who photographed the spectrum of copper in a chlorine gas flame, Strutt (now Lord Rayleigh) and Fowler,² working with copper chloride in active nitrogen, observed a set of bands in the near ultraviolet, which Kien³ had not observed at an earlier date in the flame. Eder and Valenta show some of the bands in their Atlas.⁴ Using a

tungsten lamp as source, Ritschl⁵ photographed the absorption spectra of all the copper halides and made a fairly thorough analysis of the CuCl spectrum into five systems, but he failed to record or classify any of the CuCl bands below 4050A previously observed in emission, save one, the 7 2 band of the E system. The possibility of the presence of a sixth system was mentioned previously in a paper by Mulliken,⁶ who excited

¹ A. Harnack, *Zeits. f. Wiss. Phot.* **10**, 281 (1912).

² R. J. Strutt and A. Fowler, *Proc. Roy. Soc.* **A86**, 105 (1912).

³ P. Kien, *Zeits. f. Wiss. Phot.* **6**, 337 (1908).

⁴ Eder and Valenta, *Atlas Typischen Spektren* (Wien, 1928).

⁵ R. Ritschl, *Zeits. f. Physik* **42**, 172 (1927).

⁶ R. S. Mulliken, *Phys. Rev.* **26**, 1 (1925).

all the copper halide spectra by means of active nitrogen, and gave the first analysis for Cu I.

In the process of testing a new tube for exciting spectra from solid materials by bombardment with a jet of active nitrogen produced in a side tube fitted with large graphite electrodes, (Fig. 1) the author photographed the near ultraviolet band spectra emitted by CuCl with a dispersion sufficient for resolution into sequences (16.8 to 24.6Å per mm), but not great enough for a clear demonstration of the isotope effect. With large graphite electrodes, considerably more power can be introduced into the nitrogen discharge than previously with tungsten wire electrodes. The use of a jet for introducing active nitrogen, glowing with a bright yellow hue, into the reaction chamber, causes the formation of a concentrated blue glow above the hot Cu_2Cl_2 , which was projected upon the slit of the spectrograph by means of a quartz lens. A large quartz window for the reaction chamber was supplied by Mr. F. Pearson, Jr., through the kindness of

TABLE I. CuCl *F* band spectra.

v'	v''	I	λ (Å)	ν (cm^{-1})	$O-C$	EDER AND VALENTA	HARNACK	STRUTT AND FOWLER
3	0	0	3789.3	26,383	-8		3788	3785
3	1	1	3848.8	25,975	-3			
2	0	1	3842.1	26,929	0		3839	3835
3	2	1	3909.9	25,569	+2			
2	1	1	3903.8	25,609	+2			
1	0	2	3898.3	25,645	0		3896	3885
3	3	1	3973.5	25,160	+2			
2	2	1	3968.0	25,195	-1			
1	1	1	3961.9	25,233	+1			
0	0	2	3956.9	25,265	-1	3962	3955	3945
2	3	1	4032.9	24,789	+2			
1	2	2	4027.4	24,823	+2			
0	1	3	4022.7	24,852	-1	4007	4020	4010
3	5	1	4106.0	24,348	+1			
2	4	2	4100.6	24,380	0			
1	3	3	4095.1	24,413	+1			
0	2	2	4090.3	24,441	-1	4063	4089	4080
3	6	2	4175.9	23,940	-3			
2	5	2	4169.9	23,975	0			
1	4	4	4165.1	24,005	0			
0	3	3	4159.7	24,033	0	4125	4159	4150

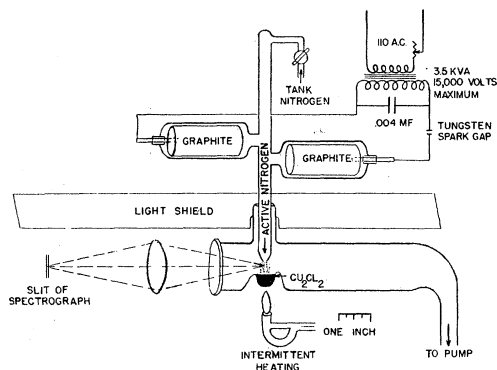


Fig. 1. Experimental arrangement for exciting the CuCl spectrum by means of active nitrogen.

Dean H. G. Gale of this institution. The exposure time was one hour, the plates were Eastman 40.

During a brief visit to Ryerson Laboratory in June of this year, Professor F. A. Jenkins mentioned that he had photographed the absorption spectrum of CuCl recently at Berkeley, and found some new bands in the ultraviolet. He had not published his analysis however, and the following classification of the measured band heads is given for the sake of comparison with his present findings.

Table I contains the wave-length data for this and previous investigations, together with a vibrational quantum analysis, which was effected through the resolution of previously known band groups into sequences. The formula

$$\nu = 25,282 + [383(v' + \frac{1}{2}) - 2(v' + \frac{1}{2})^2] - [415(v'' + \frac{1}{2}) - (v'' + \frac{1}{2})^2]$$

fits the data within the accuracy of measurement. The new band system appears to have a common lower state with the five systems of bands for CuCl analyzed by Ritschl from absorption measurements. The intensity of the new system appears to be appreciably less than that of the visible bands of CuCl observed in emission.

Thanks are due Professor R. S. Mulliken and Dean H. G. Gale of the University of Chicago for encouraging this investigation.