Mr. E. P. Warekois for orienting all the samples by means of x-ray techniques, Mr. B. Feldman for his assistance with the experiments and Dr. J. W. Meyer for the use of and aid with his *x*-band paramagnetic spectrometer.

Note added in proof.—Evidence of an additional resonance occurring above H_c given by[4] $H_0=[(\omega/\gamma)^2+2H_EH_A]^{\frac{1}{2}}$ at $T=0$ has recently been observed at 35 kMc/sec in MnF. This resonance appears to be extremely sensitive to orientation of the *c* axis with respect to H_0 at this frequency.

Note added in proof.—Similar antiferromagnetic resonance observations have been made on a single crystal of Cr_2O_3 kindly furnished by Dr. E. J. Scott of the Naval Ordnance Laboratory. Resonance data at 35 kMc/sec have been obtained from 77°K up to 325°K ($T\cong 307$°K) to date. The results of these experiments will be presented in the near future.

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Effect of Bleaching on the Optical Band Width of the *F* Center in KCl

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Measurements have been made of the absorption in the *F* region in KCl at 78°K. It has been found that the structure in this region is dependent on the presence of the *M*, *N*, *R*, and *K* bands. The broadening in the presence of small amounts of *M* absorption indicates that it is not simply due to the overlapping of *R*, *M*, and *N* bands but is caused by an additional structure. These measurements support the present interpretation of the work of Van Doorn and Haven; they can explain the difference in the measurements of Pick and Geiger as well as the difference in the half-width observed by Mollwo and more recent data.

Van Doorn and Haven[1] investigated the dichroism of the *F* and *M* bands in additively colored KCl, and suggest that there is a band under the *F* band which arises from the same center which causes the *M* band. Petroff,[2] working with additively colored KCl, indirectly deduced the presence of a band under the *F* band (the *B* band). We assume that bleaching should affect the optical absorption structure of the *F* band, and therefore carried out the following experiments.

Absorption measurements were made on additively colored KCl containing varying concentrations of *F* and *M* bands.[3] All colorations and quenches were performed in the absence of light. The quenches in oil were made as rapidly as possible (15 sec) from coloration temperature (~730°C) to room temperature in order to obtain only *F* centers. All measurements were made at 78°K with a Beckman Model DU spectrophotometer between 1.0 ev and 3.5 ev.[4] *M* and *R* centers were induced by bleaching at room temperature with a tungsten lamp.

The *F* band may be characterized by four wavelengths: the peak, ϵ_M; the half-height to the red, ϵ_r; the half-height to the violet, ϵ_v; and the half-width, $\Delta\epsilon$, the difference between ϵ_v and ϵ_r. The ratios of the *M* band and the *K* band to the *F* band (*M*/*F* and *K*/*F*, respectively) are reported in terms of the maximum absorption at the peaks.

An element of uncertainty occurs due to selection of a base line. When only *F* bands are present, the flatness to the red of the *F* band determines the line and the peak absorption with little doubt. When *M*, *R*, and *N* bands are present, we selected for the base a straight line from the absorption value at 1.1 ev to the lowest value on the violet side of the *F* band. If there is some true absorption at either or both of these points, the half-widths reported here are too small. Our selection, therefore, indicates the minimum $\Delta\epsilon$ to be expected.

The facts are as follows: when a crystal exhibiting mainly an *F* band is bleached, the $\Delta\epsilon$ increases and *M* band arises. Upon further bleaching the *N*, R_1, and R_2 bands appear, the *M* band increases, while the *F* band drops, its peak shifts to the violet, and $\Delta\epsilon$ further increases. From Fig. 1 we see that the increase in $\Delta\epsilon$ is not due to overlap on the red side. Subtraction of the *K* band still leaves a half-width wider than the value for

TABLE I. Summary of data on the *F* center in KCl.

Bleaching[a]	Concentration of *F*[b]	ϵ_{max} (ev)	ϵ_v (ev)	ϵ_r (ev)	$\Delta\epsilon$[c] (ev)	% *M*/*F*	% *K*/*F*
None	3.67×10^{16}	2.303	2.409	2.216	0.193	1.2	4.0
None	4.41×10^{16}	2.304	2.410	2.215	0.195	1.7	3.2
None	4.62×10^{16}	2.300	2.410	2.215	0.195	0.7	3.8
None	4.18×10^{16}	2.304	2.411	2.215	0.196	1.4	3.6
None	3.92×10^{16}	2.304	2.411	2.215	0.196	1.6	4.1
None	4.16×10^{16}	2.308	2.410	2.214	0.196	5.8	4.8
None	4.57×10^{16}	2.308	2.415	2.218	0.197	1.1	3.8
10 min	4.15×10^{16}	2.308	2.413	2.214	0.199	7.8	4.9
5 min	2.78×10^{16}	2.300	2.415	2.210	0.205	29.4	8.1
5 min	3.18×10^{16}	2.304	2.431	2.213	0.218	20.4	8.8
15 min	2.08×10^{16}	2.308	2.439	2.206	0.233	29.2	15.1
30 min	1.87×10^{16}	2.302	2.445	2.210	0.235	23.0	18.4
30 min	2.20×10^{16}	2.310	2.442	2.206	0.236	21.6	16.5
1 hr	1.80×10^{16}	2.310	2.453	2.210	0.243	25.3	20.4
30 min	1.96×10^{16}	2.310	2.454	2.210	0.244	24.3	16.3
3 hr	1.50×10^{16}	2.312	2.457	2.205	0.252	38.6	25.1
X–300°K 3 hr	4.30×10^{16}[d]	2.304	2.410	2.218	0.192	2.2	4.7
X–78°K 3 hr	3.35×10^{16}[d]	2.304	2.409	2.214	0.195	0	4.6

[a] Optical bleaching (tungsten lamp) at room temperature.
[b] Calculated using Smakula's formula ($f=0.81$).
[c] Measured to ±0.001 ev.
[d] Average value. Filtered x-ray (140 kvp).

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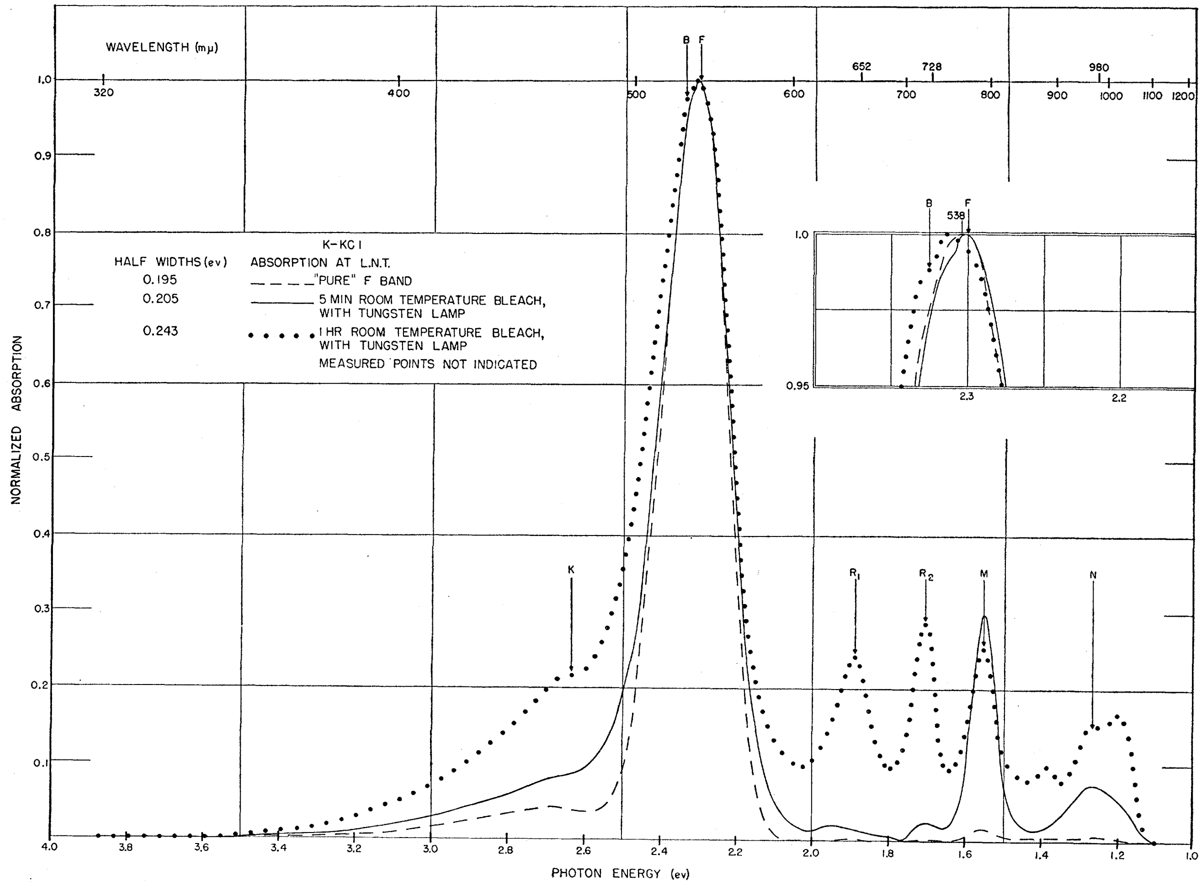

FIG. 1. Effect of bleaching on the absorption of the F structure. Absorption measurements at liquid nitrogen temperature.

the "pure" F band. In the small drawing of Fig. 1, note that the peak of the F band shifts and the B band appears to be somewhat resolved.

Table I shows that $\Delta\epsilon$ and the M/F and K/F ratios increase with increasing bleaching. Notice that a quantitative relationship does not exist between the F band and the M/F and K/F ratios. The table indicates that the concentration of M centers alone does not determine $\Delta\epsilon$. It seems to increase monatomically while M rises and then falls. The x-ray data show that it is not affected greatly for an M/F ratio of 2.2%.

Similar effects are now being studied in KBr.

Undoubtedly there has been confusion in the past, for no one has been careful to distinguish between the pure F and the F composite bands. The distinction resolves some of the contradictory behavior of the F band. For example, a comparison of our data with those of Mollwo[5] indicates that his values for KCl and KBr refer to the composite rather than the "pure" F band. Table I disagrees with values given by Russell and Klick,[6] whose data reflect a theoretical interpretation rather than actual experimental values. The distinction also resolves at least some of the differences between the work of Pick[7] and Geiger.[8] Geiger studies the quantum yield for the composite band while Pick's work refers to the true F center.

To summarize, as the F band is bleached, its half-width increases. This increase is due in part to some overlap of the F band with its side bands, but mainly due to the formation of another band or bands under the F which arise under the same conditions that cause the M band, namely, bleaching the F. This band, Petroff's B band, is probably the same one which gives rise to the dichroism noticed by Van Doorn and Haven.

In future work concerning the F band, we believe a careful distinction must be made as to whether one is treating the F band itself or the F composite bands. We would like to stress that at present there is no reliable information on the temperature variation of the peak and half-width or the shape of the F band.

We would like to thank Dr. H. N. Hersh and Dr. G. A. Noble for their assistance.

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