SPLITTING OF ABSORPTION LINES OF OXYGEN CRYSTALS IN A MAGNETIC FIELD

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We investigated the influence of an external magnetic field on the absorption of light by crystalline oxygen at 1.5°K. The narrowness of the absorption lines of the antiferromagnetic α-modification cooled to this temperature [1] makes observations possible at a spectral-instrument dispersion of 2 Å/mm. The magnetic field, of intensity up to 60 kOe, was produced with a superconducting solenoid built at the Ukrainian Physico-technical Institute. The field inhomogeneity in the working volume did not exceed several hundredths of one per-cent. The light was propagated in the direction of the magnetic field.

The absorption bands used to observe the effect of the field were in the visible and near ultraviolet regions of the spectrum. This absorption is completely lacking in free molecules and arises only when the molecules interact. Upon absorbing a photon, the oxygen molecule can go over from the ground $^3\Sigma$ state into one of the lower excited states, $^1\Delta_g$ or $^1\Sigma_g$. If the molecules are bound to one another, as in a crystal, one photon can excite two molecules in the same states. The interaction of the excited molecules leads to a "mixing" of the electronic states whose energy is close to the summary energy of two single excitations, but is not equal to it. Such states will be denoted $\Delta\Delta$ and $\Sigma\Sigma$ if the molecules go over into identical Δ or Σ states, and $\Delta\Sigma$ if they go over into different states. Each of these states corresponds to its own values of the intramolecular-vibration frequencies, on repetitions of which the electron-vibrational series of the investigated spectrum are constructed.

Out of three such series, only one, corresponding to the transition $^3\Sigma \rightarrow \Delta\Delta$, turned out to be sensitive to the influence of an external magnetic field. This influence is manifest only in the electron-vibrational states. The initial band of the series, which is due to the electronic transition, is not altered by the field.

By way of an example, Figs. 1a-d show the absorption band corresponding to the second electron-vibrational quantum of the $^3\Sigma \rightarrow \Delta\Delta$ series (green band of α-oxygen). The spectra on these photographs are marked by horizontal bands of varying degree of blackness, resulting from the different effective thicknesses of the individual blocks of the polycrystal growing from the liquid phase. A whole series of spectra, due to different orientations of the individual blocks relative to the field direction, is obtained for one and the same value of the magnetic field. The line frequencies, as well as the points on Fig. 2, correspond to the same block indicated in Fig. 1d.

When H = 0, the spectra show a group of three lines - one strong, with frequency ν = 18813 cm^{-1}, and two weak ones, with ν = 18810 cm^{-1} and ν = 18807 cm^{-1}.

With increasing field, these lines spit, so that six lines are observed at 60 kOe. It is difficult to trace the fate of each of these lines, especially since the closely-lying lines come in contact after splitting, merge together, spread, and their form becomes distorted. This hinders both the measurement of the spectrum and the interpretation of the results. It can be

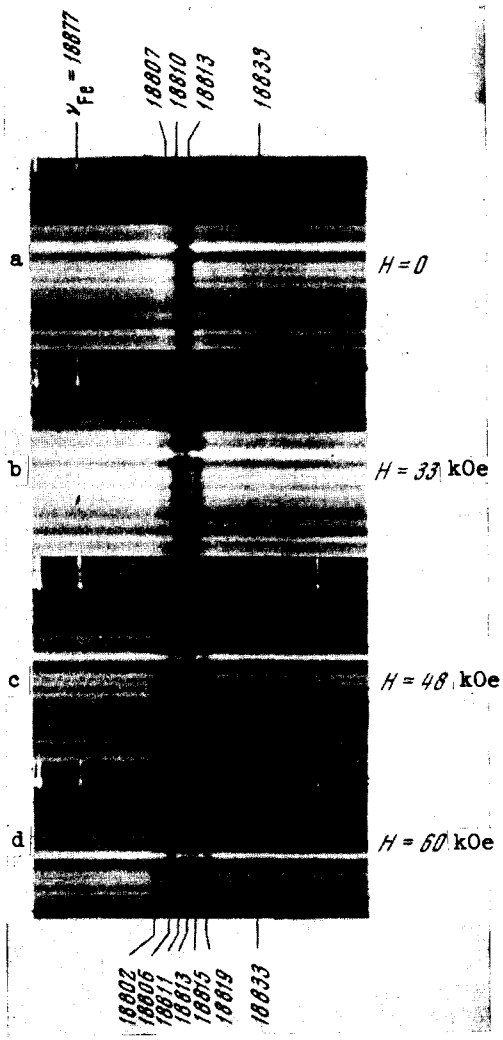

Fig. 1. Splitting of α-oxygen absorption lines in magnetic field.

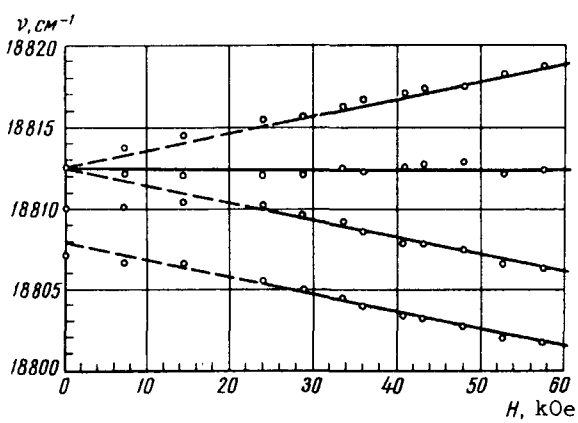

Fig. 2. α-oxygen absorption-line frequency vs. field intensity.

seen, however, that the strong line, ν = 18813 cm^{-1}, is split by the field into three components. The frequency of the central line of this triplet does not depend on the field; the frequencies of the other two are linearly connected with the field, as can be clearly seen at 24 kOe and above.

As seen from Fig. 2, the splitting $\Delta\nu$ is symmetrical with respect to the central component ν_0; at 60 kOe its magnitude is 6 cm^{-1}.

It should be noted that, starting with a field value on the order of 40 kOe, the intensity of the ν_0 line decreases sharply; at the same time, two weak lines appear in its vicinity, ν = 18811 cm^{-1} and ν = 18815 cm^{-1}.

Figure 1d shows also a line with frequency ν = 18802 cm^{-1}. This component is due to the splitting of one of the weak long-wave lines of the initial absorption band, with ν = 18807 cm^{-1}; the remaining components are not seen on the photographs, but were observed in other experiments.

The broadened ν = 18833 cm^{-1} line, one of the satellites of the strong lines, usually attributed to the lattice vibrations, remains insensitive to the influence of the field.

Thus, we have observed in this study the splitting of the absorption lines of molecular -oxygen crystals under the influence of a magnetic field. The magnitude of the splitting $\Delta\nu$ is given by the formula

$$\Delta\nu = e\hbar H/mc,$$

where e and m are the charge and mass of the electron, and c is the velocity of light. The splitting is observed only for lines belonging to electron-vibrational states. It is due to lifting of the degeneracy of the excited states of the crystal under the influence of the magnetic field.

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[1] M. F. Collins, Proc. Phys. Soc. 89, 415 (1966).

TWO-PARTICLE INELASTIC REACTIONS AND MOVING BRANCH POINTS IN ANGULAR-MOMENTUM PLANE

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Two-particle inelastic reactions at high energy (charge exchange, resonance production, etc.) are usually described with the aid of Regge poles in a crossing channel, with appropriate quantum numbers [1]. This approach leads, as it were, to a fair agreement with experiment in the region of small momentum transfers, the only region for which experimental data are presently available. On the other hand, a pure pole analysis is not satisfactory from the theoretical point of view, for it disregards the presence of branching in the angular-momentum plane.

We have previously calculated [2] the contribution of Mandelstam branch points to the asumptotic elastic-scattering amplitude at large momentum transfers. Since the branch points were in this case the singularities farthest to the right in the angular-momentum plane, they were decisive in the determination of the asymptotic behavior of the amplitude. A similar phenomenon takes place in the case of two-particle inelastic processes, too. We consider in this note the contribution of branch points to the asymptotic amplitudes of such reactions, at large momentum transfers $|t| \gg m^2$, but at $|t| \ll s$ (s is the square of the total c.m.s. energy and m is the nucleon mass).

The method described in [3] makes it easy to obtain the branch-point trajectories arising upon exchange in the t-channel of one pole $\beta(t_1)$ with the required quantum numbers and n vacuum poles $\alpha(t_2)(\alpha(0) = 1)$:

$$j_{n+1}(t) = \beta(t_1) + n\alpha(t_2) - n. \tag{1}$$

The "reggeon masses" t_1 and t_2 are determined from the equations

$$\sqrt{t_1}\,\beta'(t_1) = \sqrt{t_2}\,\alpha'(t_2), \quad \sqrt{t_1} + n\sqrt{t_2} = \sqrt{t}. \tag{2}$$

At values of the number $n \gg \sqrt{t/m^2}$ we have

$$\sqrt{t_2} \approx \frac{\sqrt{t}}{n}, \quad \sqrt{t_1} \approx \frac{\sqrt{t}}{n}\,\frac{\alpha'(0)}{\beta'(0)}, \tag{3}$$

and the equations of the trajectories take the form

$$j_{n+1} \approx \beta(0) + \frac{\alpha'(0)\,t}{n}. \tag{4}$$

Thus, the point $j = \beta(0)$ turns out to be a point of branch-point condensation*, just as the point $j = 1$ is a condensation point for Mandelstam branch points. If, for specified quan-