In this case, the relativistic electrons are created *in situ*, that is, at any place within the quasar where the radiation is generated. This makes it likely that the relativistic electrons (and positrons) are secondary products of high-energy protons. The total energy output is now solely determined by the creation rate of the relativistic electrons and positrons. A magnetic or radiation field, or both, may only influence the spectral distribution of the radiation.

These two alternatives were also obtained by Hoyle, Burbidge and Sargent (*3*), who used the observed spectral characteristics of the quasar radiation in their analysis.

The lifetime τ_e of individual electrons is proportional to $1/\gamma_e$ and is connected with the mean values τ and γ by

$$\tau_e = \gamma\tau/\gamma_e \tag{6}$$

If we combine this equation with Eq. 5 then it follows that within the cosmological hypothesis the individual lifetimes are smaller than R/c for all electrons whose energy is high enough to contribute to the nonthermal radiation ($\gamma_e > 30$). The reason is that the actual lifetime must be still smaller than the lifetime due to Compton radiation alone, which itself is smaller than R/c for all sufficiently large values of γ_e.

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16 August 1966

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Crystal Structure of Kernite, $Na_2B_4O_6(OH)_2 \cdot 3H_2O$

Abstract. *Kernite, $Na_2B_4O_6(OH)_2 \cdot 3H_2O$, contains parallel infinite chains of the borate polyanion $[B_4O_6(OH)_2]_n^{2n-}$. The chains are composed of six-membered rings containing one boron-oxygen triangle and two boron-oxygen tetrahedra. The rings are linked through commonly shared boron-oxygen tetrahedra.*

The mineral kernite is a member of the borate group $Na_2O \cdot 2B_2O_3 \cdot nH_2O$ where $n = 0$, 1, 2, 4, 5, and 10. Of this group, only the structure of the decahydrate (borax) is known (*1*). The borax polyanion consists of two boron-oxygen triangles and two boron-oxygen tetrahedra which share corner oxygens. By analogy to other hydrated borate systems, it was thought that the lower hydrates would be formed by polymerization of the borax anion into chains or other three-dimensional arrangements, with the removal of H_2O (*2*). In addition, Christ and Garrels (*3*) suggested that in kernite the borax polyanion had itself been altered. The structure of kernite ($n = 4$) has now been solved, and the result substantiates these ideas.

The structure was solved with the use of approximately 1800 x-ray diffraction intensities. A General Electric XRD-6, equipped with a scintillation counter and $CuK\alpha$ radiation monochromatized by a balanced pair of Ni and Co filters, was used for these measurements. The symbolic-addition method of Karle and Karle (*4*) yielded directly the phases of 225 of the largest normalized structure factors. I computed a three-dimensional Fourier map using the phases so determined and the normalized structure factors which revealed 14 of the 17 nonhydrogen atoms in the asymmetric unit. Refinement proceeded with least-squares techniques and a difference electron-density map for the location of the three missing atoms. The present residual factor is 0.10 for all reflections. The relevant crystallographic data for kernite and a list of atomic coordinates at the present stage of refinement are shown in Table 1. An anisotropic temperature-factor refinement is in preparation.

The average distances between B and O in the polyanion are 1.37 Å in the triangles and 1.48 Å in the tetrahedra. The Na^+ ions are surrounded by six oxygens in an irregular manner. The Na^+-coordination polyhedra share some edges and corners to form a three-dimensional network around the anions. The average Na–O distance is 2.41 Å.

The borate polyanion in kernite consists of six-membered boron-oxygen rings which share tetrahedral boron atoms. These form infinite chains which extend in the *b* direction, two in each unit cell. Because of the manner in which the rings share boron atoms the plane of each successive ring is approximately 90° to the plane of the preceding ring. Since the shared boron atoms are adjacent in each ring, the chain forms a spiral in the direction of the *b*-axis. From a projection of the polyanion viewed down the *a*-axis (Fig. 1) all the oxygen atoms take part in bonding between boron atoms, except for the

Table 1. Atomic coordinates for kernite $Na_2B_4O_6(OH)_2 \cdot 3H_2O$. Monoclinic $P2_1/c$: $a = 7.0172 \pm 0.0006$; $b = 9.1582 \pm 0.0006$; $c = 15.6774 \pm .0015$ Å; $\beta = 108.861° \pm .002°$; cell volume = 953.4 Å^3; $z = 4$; density = 1.93 (calc.), [(obs.) 1.91 g cm^{-3}].

Atom	Coordinates (in fractions of cell edges)		
	x	*y*	*z*
Na_1	0.319	0.465	0.311
Na_2	.186	.367	.072
O_1	.511	.025	.397
O_2	.440	.099	.241
O_3	.768	.205	.269
O_4	.465	.351	.209
O_5	.792	.448	.215
O_6 (OH)	.064	.290	.240
O_7 (OH)	.585	.295	.011
O_8 (H_2O)	.774	.034	.067
O_9	.565	.272	.362
O_{10} (H_2O)	.037	.062	.414
O_{11} (H_2O)	.167	.117	.077
B_1	.552	.167	.421
B_2	.552	.232	.269
B_3	.572	.481	.200
B_4	.866	.315	.243

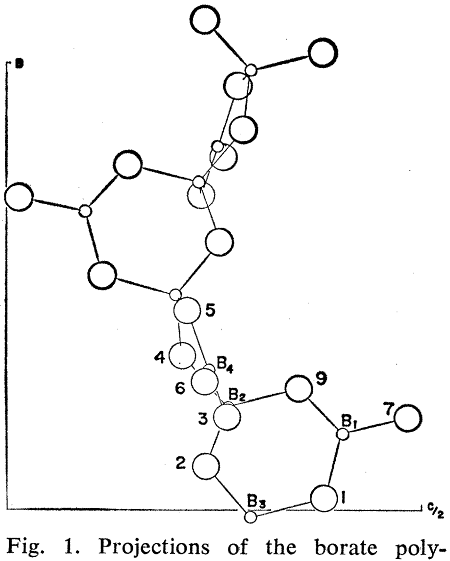

Fig. 1. Projections of the borate polyanion $[B_4O_6(OH)_2]_n^{2n-}$ viewed along the *a*-axis. The small circles are boron atoms; the large circles are oxygen atoms, except for the circles at Nos. 6 and 7 which are hydroxyl groups. The numbering conforms to Table 1.

OH⁻ attached to the triangle borons (Nos. 1 and 4). This structure explains very nicely the fibrous nature of the excellent cleavages (100) and (001), since the bonds holding neighboring chains together are much weaker than the bonds in the chains.

The oplyanion in kernite can be formed from that of borax as indicated by the equation (*3*):

$$n[B_4O_5(OH)_4]^{2-} = nH_2O + [B_4O_6(OH)_2]_n^{2n-}$$

This transformation is not a simple dehydration of the sort that occurs, for example, in the inyoite-colemanite transformation since a boron-oxygen bond must also be broken (*5*). The breaking of the bond would require considerably more energy than simple dehydration and explains the difficulty in forming kernite from borax.

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5. I thank C. L. Christ and Joan R. Clark for comments regarding the transformation.

31 October 1966

Ozone-Induced Chemiluminescence of Organic Compounds

Abstract. *Chemiluminescence was observed when organic compounds in a dry state, as well as in organic solvents, were exposed to ozone in oxygen. The peak intensity of the light emission is related quantitatively to the amount of compound. Many compounds can be identified by this method, and some are listed. Sensitivity of detection approximates that of fluorescence methods and extends to less-than-nanogram quantities for some compounds. Ozone-induced chemiluminescence of compounds in acetone solution was less sensitive than it was in the dry analysis.*

Although there have been reports (*1, 2*) of luminescence induced with ozone, this phenomenon has not been studied extensively. We have been impressed by the brilliant chemiluminescence evident in solutions of certain organic compounds into which ozone (*3*) had been bubbled. For instance, the dye safranin (10 mg/ml in acetone) emitted enough light to read by when exposed to ozone. It occurred to us that this chemiluminescence might be used to detect and measure small amounts of chemicals, and we now report on the examination of some organic compounds in apparatus of our own design.

In order to find out if ozone would induce visible chemiluminescence a large number of organic compounds were examined by adding 50 mg of each compound to about 5 ml of acetone and observing whether light was produced as ozone was bubbled through the solution, the experiment being conducted in a darkened room (Table 1). We also observed the effect of the test substance in acetone solutions containing potassium hydroxide pellets, which have been reported to promote chemiluminescence on heating (*2*, pp. 18 to 21), and the effect of other additives and solvents as well (Table 1). In the cases of anthracene, 4-methylumbelliferone, and kynurenic acid, KOH altered the results from a "negative" to a "bright" reaction with ozone. Generally, where a positive result was obtained, the chemiluminescence persisted in solution as much as a minute after ozone bubbling was stopped.

Next, it was desirable to devise a method whereby the amount of light could be quantitatively related to the amount of material present. We found that it was not necessary to have the compounds in solution in order to observe the chemiluminescence; solutes al-

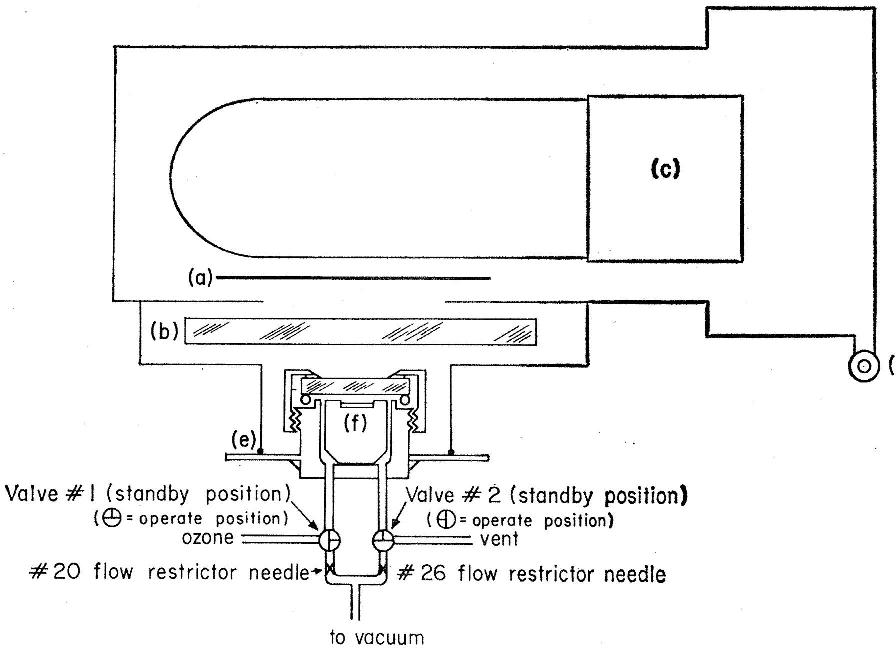

Fig. 1. Arrangement of optical parts for light measurement during exposure of samples to ozone. *a*, Shutter; *b*, optical filter if required; *c*, photomultiplier (RCA 1P28); *d*, hinge, permitting raising and lowering of the phototube housing assembly; *e*, soft rubber light seal; *f*, stainless steel holder has substrate in recess. Ozone is admitted to sample chamber when the valves are in the "operate" position.

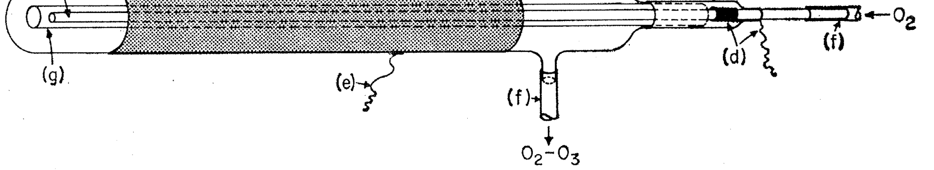

Fig. 2. Ozonizer. *a*, Stainless steel tube 1.5 mm in diameter (oxygen inlet and high-voltage electrode); *b*, aluminum foil (ground electrode) on glass tube (1 × 10 cm); *c*, shrinkable Teflon glass-to-metal seal; *d* and *e*, leads to Tesla coil and ground; *f*, 2.25-mm Teflon tubing; *g*, glass-tube centering (*a*).