

place an upper limit of 20 percent of the lunar radius, or 350 km, on the radius of an iron core in the moon; that is, $I_E \geq 10 I_M$. Altogether, for corresponding states of the magnetic field

$$\left(\frac{\Omega_M}{\Omega_E}\right)^2 \geq 10^4 \quad (2)$$

where, for the purpose of the argument, we have assumed that the electrical conductivity of the lunar core is the same as that of the earth's core (11) and that both dynamos operate in the same state. In the core of the earth, the dynamo is probably operating in its most easily excited dipole state or in its second most easily excited dipole state [the higher states are so unstable that they would reverse more often than the geomagnetic field is known to (7)]. We make the conservative assumption that a lunar dynamo operated in its most easily excited state. Then, if the earth's dynamo operates in its lowest state, Eq. 2 stands as it is; if it operates in its second lowest state the right hand side of Eq. 2 is diminished by a factor of 10 (7).

Therefore, this comparison implies that $\Omega_M \geq 100\Omega_E$ (or $\Omega_M \geq 30\Omega_E$ if the geomagnetic dynamo is in its second lowest state) if the moon had an internal magnetic field produced in the same way as the earth's. This lunar rotation period of approximately 15 minutes (or 45 minutes) is smaller than the rotation period of about 80 minutes at which the moon would break up.

To conclude, the assumption that the moon had a dynamo magnetic field produced in the same way as the earth's magnetic field requires that the moon rotated excessively fast, faster than its breakup angular velocity. While this crude kinematic (12) analysis cannot definitely rule out the possibility that the moon had an internal dynamo (for example, with our lack of knowledge of the properties of a lunar core and, in fact, of the earth's core, there may be some crucial difference between the two) it casts serious doubt on that possibility, even granting that the moon had a molten iron core. In view of this and of the geochemical objections against a molten iron core in the early moon, we suggest that the search for alternate mechanisms to account for the magnetic properties of the moon not be abandoned.

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7. ———, *ibid.* **175**, 573 (1972).
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9. Secular variations in the surface geomagnetic field indicate that this is, in fact, the case for the earth.
10. The secular variation of the geomagnetic field reflects the fluid motions in the core of the earth. See W. M. Elsasser, *Rev. Mod. Phys.* **22**, 1 (1950).
11. If we do not assume equal conductivities, Eq. 2 becomes $(\Omega_M/\Omega_E)^2 \geq 10^4 (\sigma_E/\sigma_M)^2$, where σ is the electrical conductivity of the core.
12. In the kinematic analysis the origin of the fluid motions is not explicitly discussed. In particular, we have not addressed ourselves here to (the unsolved problem of) the inhibition of the fluid motion by the magnetic forces themselves.
13. I thank D. G. Wentzel and H. Frey for stimulating discussions about the moon.
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Phosphorescence of Adsorbed Ionic Organic Molecules at Room Temperature

Abstract. Many salts of polynuclear carboxylic acids, phenols, amines, and sulfonic acids adsorbed on paper, silica, alumina, and other substrates exhibit strong triplet phosphorescence at room temperature, with no evidence of quenching by oxygen. No phosphorescence has been observed with nonionic materials. The spectra are similar to those of frozen solutions at -196°C , and the technique provides a simple means of demonstrating phosphorescence phenomena, identifying unknown materials, and investigating the spectra of triplet states.

With a few exceptions, strong phosphorescence (efficient triplet state emission) of organic molecules has been observed only in the gas phase, or in rigid media, usually at very low temperatures (1). Accordingly, we were surprised to observe that a variety of ionic organic molecules exhibit intense phosphorescence at room temperature when adsorbed on paper, silica, alumina, asbestos, glass fibers, and other supports. We have been unable to find any comparable observation in the literature (2), but essentially every salt of a carboxylic acid, phenol, amine, or sulfonic acid investigated which might be

expected to show visible phosphorescence does so, but no emission was observed from any nonionic material examined nor from any nonadsorbed materials in the solid state (3). Identical results were obtained under O_2 or N_2 , but only thoroughly dried samples phosphoresce, and phosphorescence disappears reversibly when samples are exposed to moist air.

Both excitation and emission spectra obtained with an Aminco-Keirs spectrophotophosphorimeter matched closely (except for slight line broadening) those obtained from frozen solutions at -196°C (Fig. 1). Table 1 is a

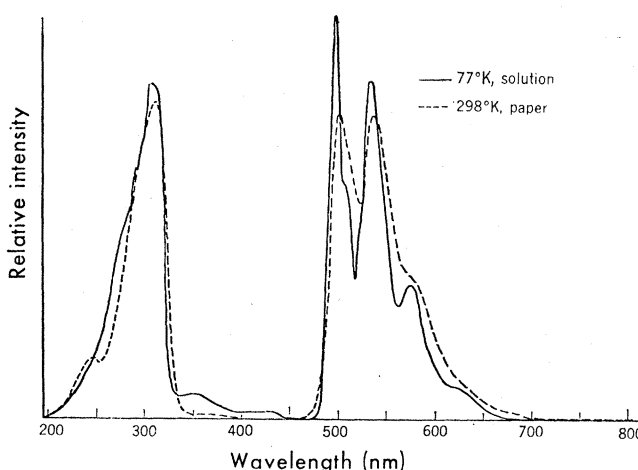


Fig. 1. Comparison of emission and excitation spectra for a frozen solution of 4 mM naphthalic acid in 1M sodium hydroxide at 77°K with those measured on dried paper at ambient temperature.

Table 1. Ambient-temperature phosphorescence spectra of representative compounds absorbed on paper as 4 mM solutions in 1M NaOH (unless otherwise noted) and dried thoroughly.

Compound	Maximum emission wavelength (nm)
4-Biphenylcarboxylic acid	450 482 500-515
Diphenic acid	490
1-Naphthoic acid	500 530 560-575
Naphthalic acid	497 535 570-585
Napthalene- β -sulfonic acid	495-510 525
1-Aminonaphthalene-4-sulfonic acid	505-555
2-Naphthol-6-sulfonic acid	533
Eosin Y (0.5 mM, pH 8)	555 680
Auramine O (0.4 mM, pH 8)	520
Coproporphyrin III (pH 8)	582 625 682

list of representative compounds investigated and the corresponding phosphorescence maxima. Characteristic phosphorescence decay times measured by flash photolysis ranged from 0.1 to 0.7 second. In favorable cases excitation with a 15-watt ultraviolet Mineralight produces phosphorescence plainly visible under ordinary room light, and visually observable for over 5 seconds in the dark.

Although we do not understand why

surface adsorption should so strongly inhibit the usual processes of non-radiative decay and oxygen quenching, the technique is quite convenient for demonstrating phosphorescence phenomena and obtaining triplet state spectra without the usual requirements of oxygen exclusion or operation at liquid nitrogen temperatures, as well as supplying a simple means for identifying a variety of organic molecules, including many of biological interest. A detailed report of this work is in press (4).

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References and Notes

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2. Polynuclear aromatics have been observed to phosphoresce at 77°K on paper chromatograms [A. Szent-Györgyi, *Science* **126**, 751 (1957)]. Phosphorescence spectra of solutions frozen at 77°K on glass fiber paper, paper, and silica gel have been measured [M. Zander and U. Schimpf, *Angew. Chem.* **70**, 503 (1958); M. Zander, *Erdoel Kohle* **15**, 362 (1962); E. Sawicki and J. D. Pfluff, *Anal. Chim. Acta* **32**, 521 (1965); E. Sawicki and H. Johnson, *Microchem. J.* **8**, 85 (1964)]. There is, of course, extensive literature on phosphorescent emission from trace impurities in host crystals, but we are dealing here with emission from the major component in the system.
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5. Supported by a grant from the National Science Foundation. We thank Dr. A. R. Lepley of the Department of Chemistry, Marshall University, for assistance in spectral measurements; Dr. J. D. Spikes of the Biology Department of the University of Utah for the use of his phosphorimeter; and Dr. S. G. Hadley and V. Alvarez of this department for flash photolysis measurements.

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Carbon: A Suggested New Hexagonal Crystal Form

Abstract. Evidence for a new polymorphic form of carbon, similar to but distinct from chaoite, has been discovered. It is trigonal, with $a_0 = 5.33$ angstroms and $c_0 = 12.24$ angstroms. It is produced along with chaoite on the surfaces of graphitic carbons under free-vaporization conditions at low pressures, with temperatures above approximately 2550°K.

We have found evidence for a new hexagonal form of carbon during our studies of chaoite (1). We refer to it provisionally as carbon VI, since graphite, rhombohedral graphite, diamond, lonsdaleite, and chaoite may be regarded as the first five crystal forms of carbon. Carbon VI, if this is indeed its correct identity, is produced under the following conditions. (i) It is

formed along with chaoite when graphitic carbons are heated resistively or radiatively above a threshold temperature of $\sim 2550^\circ\text{K}$ at any pressure in the range from 10^{-4} torr to 1 atm. These pressures define the range studied and do not necessarily represent stability limits. (ii) Laser heating produces carbon VI in greater abundance than resistive heating (2). In

fact, material taken from the walls of laser craters yielded the electron diffraction patterns that made it possible to characterize this carbon form. Moreover, laser heating of glassy carbon produced a large number of well-formed single crystals and twins. (iii) A short-duration (~ 0.05 -second), 50,000-Å arc between graphitic carbon electrodes produced carbon VI almost exclusively in a very small yield (3).

We studied carbon VI entirely by electron diffraction techniques, because all of the crystals were ~ 0.5 μm in their largest dimension and were difficult to separate from graphite and chaoite. An electron micrograph of a twinned crystal of carbon VI is shown in Fig. 1A; a c -axis electron diffraction pattern is shown in Fig. 1B. Most of the patterns were single-crystal or twinned crystal patterns; ring patterns were rather rare. Four tilted crystal patterns made it possible to get a value for c_0 . The values found for the cell parameters were as follows: $a_0 = 5.33 \pm 0.05$ Å and $c_0 = 12.24 \pm 0.18$ Å. In c -axis diffraction patterns of carbon VI, all reflections are present. The c -axis diffraction patterns of chaoite, on the other hand, obey the condition $-h + k = 3n$. In addition, the reflections given in Table 1 have been observed in patterns from tilted crystals. We were able to determine the orientation of the axes by correlating electron diffraction patterns with electron micrographs, and we found that alternate edges of the six-sided basal-plane platelets were two types of steep second-order pyramids.

The unit cell dimensions of carbon VI appear to be related to those of lonsdaleite in that a_0 for carbon VI is close to $2a_0$ for lonsdaleite and c_0 for carbon VI is very close to $3c_0$ for lonsdaleite. On the other hand, the lattice parameters of the larger H-cell for carbon VI bear some resemblance to those of chaoite; a_0 is 9.24 Å for carbon VI and 8.95 Å for chaoite, and c_0 is 12.24 Å for carbon VI and 14.07 Å for chaoite. By means of a careful study of the morphology and especially of the twinning of the small crystallites we established that both chaoite and carbon VI belong to point group 3. The space group of carbon VI may be either $P3$ or $P3_{1,2}$ (and the same is true of chaoite). This finding implies that both of these carbon forms may be optically active and pyroelectric, may