5. J. A. Miskel and M. L. Perlman, *ibid.* **87**, 543 (1952); M. L. Perlman and J. A. Miskel, *ibid.* **91**, 899 (1953).
6. R. W. Kiser and W. H. Johnston, *J. Amer. Chem. Soc.* **81**, 1810 (1959).
7. H. Zeldes *et al.*, *Phys. Rev.* **86**, 811 (1952).
8. R. W. Stoenner, O. A. Schaeffer, R. Davis, Jr., *J. Geophys. Res.* **65**, 3025 (1960).
9. S. Katcoff, *Phys. Rev.* **87**, 886 (1952).
10. J. B. Cumming, *Application of Computers to Nuclear and Radiochemistry*, National Academy of Sciences–National Research Council, Nuclear Science Series NAS-NS-3107 (Washington, D.C., 1962), p. 25.
11. O. A. Schaeffer, "High Sensitivity Mass Spectrometry of the Rare Gases," U.S. Atom. Energy Comm. Report BNL 581(T-161) (Brookhaven National Laboratory, Upton, N.Y., 1959).
12. N. Jarmie and M. G. Silbert, *Phys. Rev.* **123**, 909 (1961).
13. W. Bernstein and R. Ballentine, *Rev. Sci. Instr.* **21**, 158 (1950).
14. R. Davis, Jr., R. W. Stoenner, O. A. Schaeffer, *IAEA Conference on Radioactive Dating*, Athens, Greece (International Atomic Energy Agency, Vienna, Austria, 1962).
15. O. A. Schaeffer, R. Davis, Jr., R. W. Stoenner, D. Heymann, *International Conference on Cosmic Rays*, Jaipur, India (1963), 5 vols. in press.
16. We thank Dr. R. Davis, Jr. for helpful discussions. Supported by the AEC.

8 March 1965

Solar Activity during the First 14 Months of the International Years of the Quiet Sun

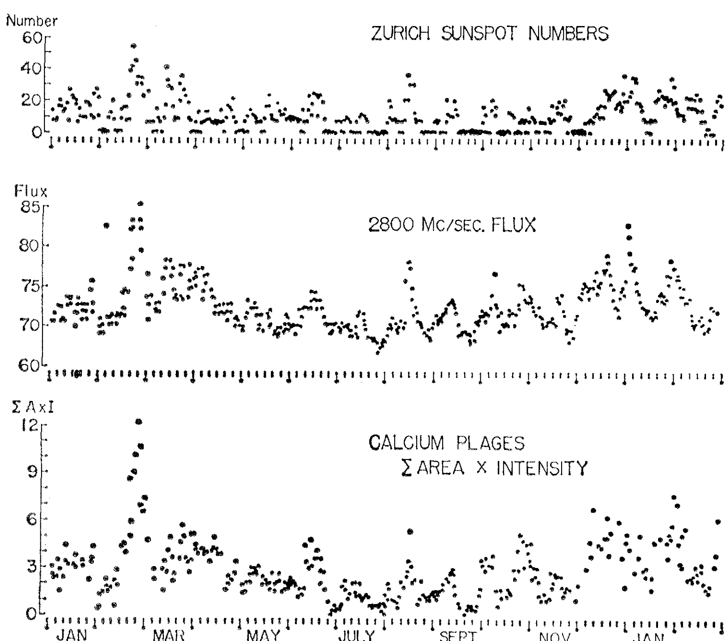
This report is the third in a series of studies, by the staff of the McMath-Hulbert Observatory, of solar activity during the International Years of the Quiet Sun (IQSY). It brings together solar data for the interval January 1964 to February 1965 inclusive.

The first 14 months of IQSY have included a minimum in solar activity, insofar as solar activity is measured by sunspot number, the area and intensity of calcium plages, and daily flux at 2800 Mcy/sec (Table 1 and Fig. 1). According to these three parameters the interval May to November 1964 was flanked by periods of increased solar activity, and July 1964 was the quietest month within the interval.

During the first 14 months of IQSY, activity of cycle 19 diminished but did not cease (Fig. 2). Old-cycle spots and plages continued to form in both the northern and southern hemispheres, and on 5 February 1965 a bright flare of importance 2+, with concomitant bursts at radio frequencies, occurred in an old-cycle region at 08°N, 25°W. A proton event, polarcap absorption, was reported as starting on 6 February.

These 14 months also witnessed a marked increase in the number, size, and duration of plages and sunspots at high latitudes and with polarities (when known) appropriate to the new cycle. The number of days per month on which new-cycle spots were visible rose to levels attained in the past four cycles only after minimum in the cycle had been passed (see Fig. 3). In July 1964, Giovanelli reported that his studies of old- and new-cycle spots indicated that, after that date, the number of new-cycle spots would, on the average, exceed the number of old-cycle spots. This prediction has been borne out by observations in succeeding months.

The foregoing considerations all suggest that the minimum between cycles 19 and 20 occurred in mid-1964. If it did, it was a minimum without long intervals of solar quiet and with a relatively small number of days



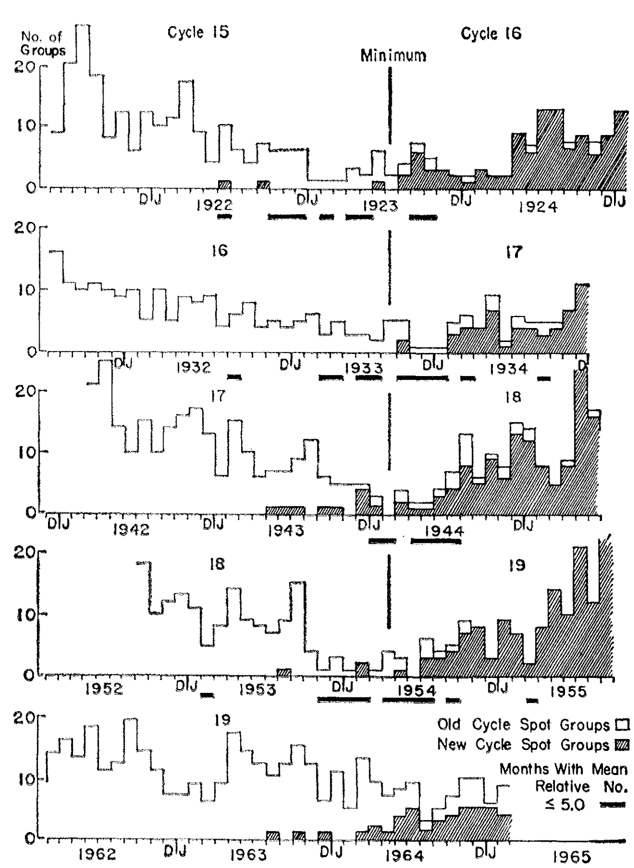


Fig. 1 (above). Daily values of Zurich sunspot number, flux at 2800 Mcy/sec (Ottawa) adjusted to an orbital distance of 1 astronomical unit, and summed values for area time intensity of the calcium plages (McMath-Hulbert Observatory) for the 14 months January 1964 through February 1965. Fig. 2 (right). Number of old-cycle and new-cycle sunspot groups per month and the months with mean relative Zurich sunspot number ≲ 5.0 for years centered on four preceding solar minima and for 1962 through February 1965. The time of "minimum" as indicated by the smoothed monthly means of Zurich relative sunspot numbers is shown by a vertical line.

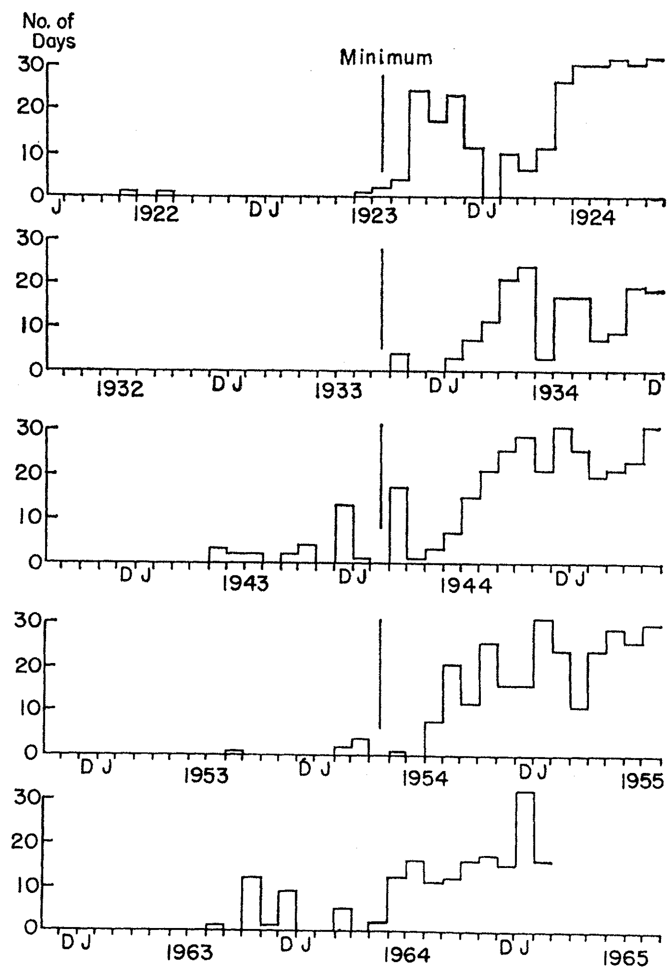
without visible spots (Zurich sunspot number = 0) (see Fig. 4). The periods 26–28 June, 26–30 July, and 16–27 September appear to have been the intervals of most sustained solar calm in 1964. Comparison with data covering the past century suggests that, in spite of the absence of long intervals of "quiet sun," the residual activity may not have been abnormally high. In June 1964 the mean smoothed sunspot number, averaged over 13 months, dropped to 10. This value lies well below the minimum of the mean curve of corresponding values for cycles 8 to 18. The mean smoothed value of sunspot numbers rose slightly in July; this suggests that statistical "minimum" occurred in June 1964.

There has been an outstanding asymmetry in the development of activ-

Table 1. Summary of solar data for the period January 1964 through February 1965.

Month	Mean relative sunspot number (Zurich)	Number of spotless days (Zurich sunspot number = 0)	Number of spots		Mean flux* at 2800 Mcy/sec	
			Old-cycle	New-cycle	Measured (Ottawa)	Adjusted to 1 A.U.
			1964			
January	14.6	1	11	0	74.4	72.0
February	16.3	9	5	0	76.1	74.3
March	14.5	6	12	1	75.5	74.8
April	7.7	7	7	2	72.5	73.0
May	9.4	4	6	1	69.1	70.7
June	9.3	9	4	4	69.0	71.3
July	3.4	19	4	5	67.0	69.2
August	8.9	11	2	1	69.3	71.0
September	4.4	18	2	3	70.0	70.7
October	5.6	16	4	3	72.9	72.4
November	6.9	11	5	5	72.8	71.3
December	14.6	5	5	6	77.5	75.0
			1965			
January	18.5	2	2	5	77.5	75.0
February	14.3	4	5	5	74.6	72.7

* Flux is measured in watts per square meter per cycle of bandwidth ($\times 10^{-22}$).



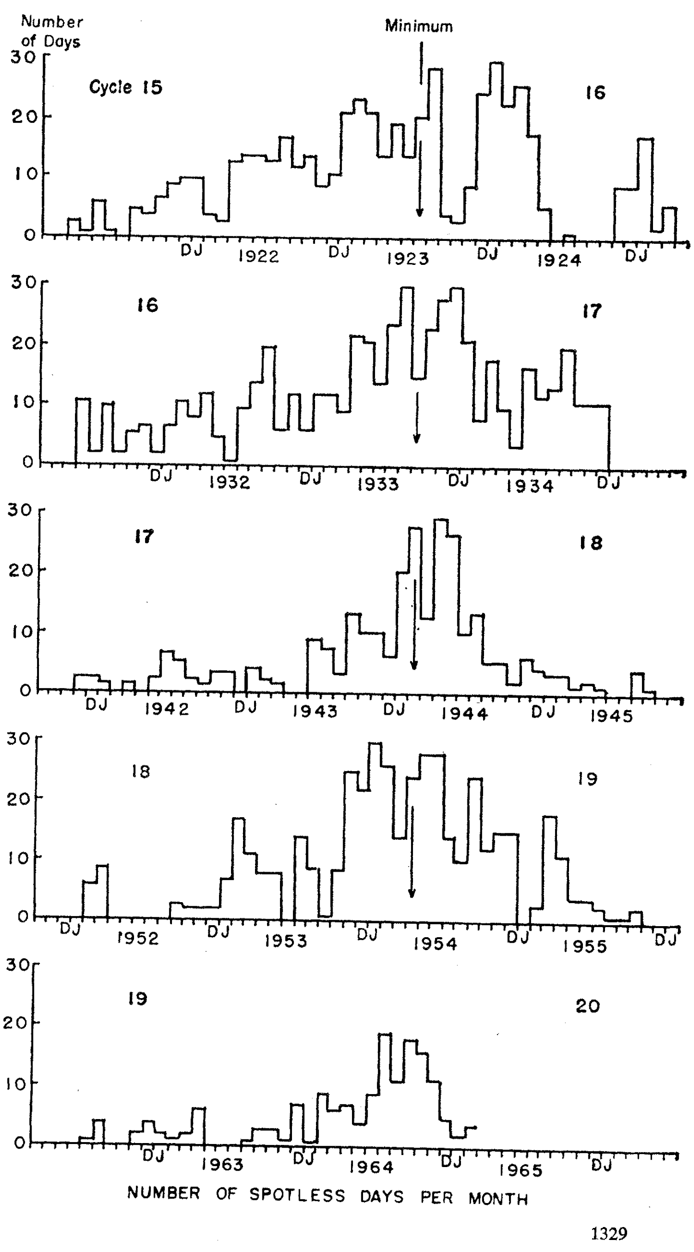
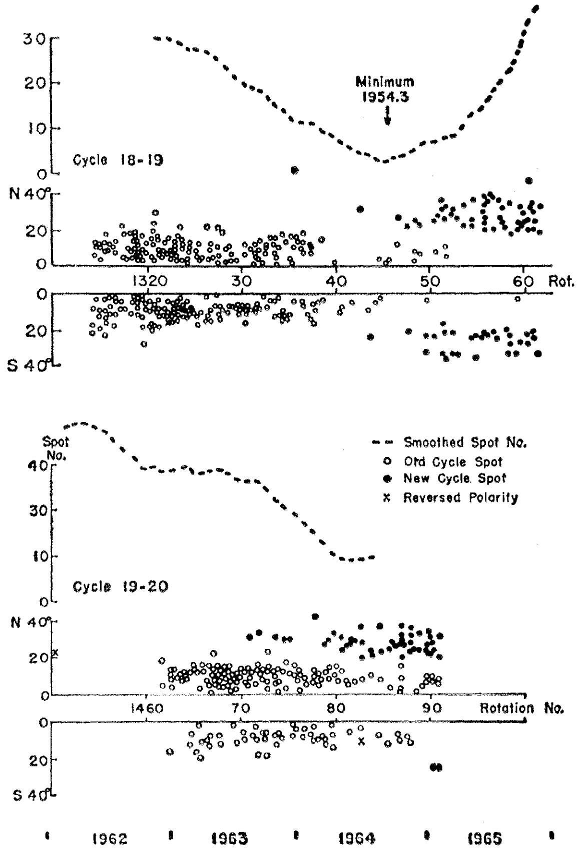
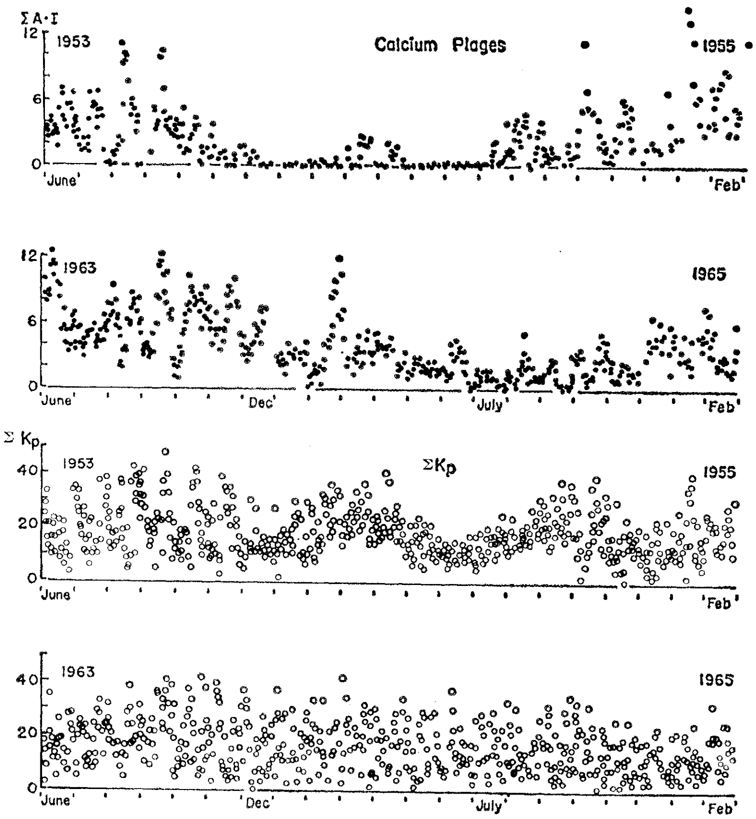
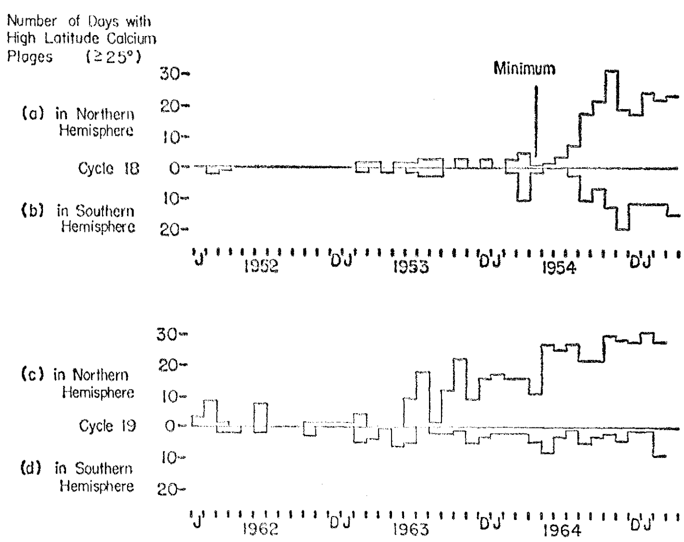


Fig. 3 (above). Number of days in each month with new-cycle spots visible on the solar disk for years centered on the four preceding solar minima and for 1962 through February 1965. The time of "minimum" as indicated by the smoothed monthly means of Zurich relative sunspot numbers is shown by a vertical line. Fig. 4 (right). Number of spotless days per month for the years centered on the four preceding solar minima and for 1962 through February 1965. The time of "minimum" as indicated by the smoothed monthly means of Zurich relative sunspot numbers is shown by a vertical line.







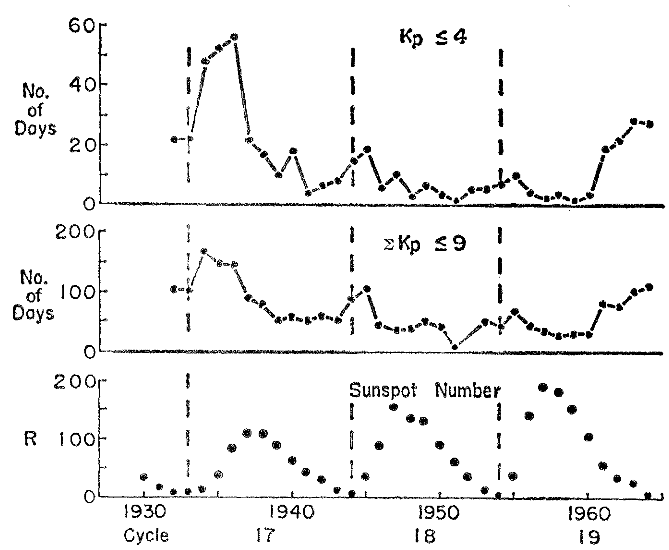


Fig. 5 (top left). Comparison of old-cycle and new-cycle spots at the minimum of 1954 (Mount Wilson observations) and during the period 1963 through February 1965 (Mount Wilson and McMath-Hulbert observations). Each spot is plotted at its observed latitude in either the northern or southern hemisphere, and all data are given according to solar rotations (27.3 days). Fig. 6 (bottom left). Number of days per month on which calcium plages at high latitudes in the northern and southern hemispheres were observed on McMath-Hulbert Observatory records for years centered on the preceding minimum and for 1962 through February 1965. Fig. 7 (top right). Comparison of daily summed values for area times intensity of the calcium plages and geomagnetic indices (ΣK_p) for the periods June 1953 through February 1955 and June 1963 through February 1965. Fig. 8 (bottom right). Number of "quiet earth" days ($\Sigma K_p \leq 4$ and ≤ 9) per year for the period 1932–1964 and annual sunspot numbers for cycles 17–19.

ity of cycle 20. For 16 months, with the possible exception of minor plages and a few spots for which the polarity classification is ambiguous, activity of the new cycle was confined to the northern hemisphere of the sun (see Figs. 5 and 6). In January and February 1965, new-cycle activity was seen to increase in the southern hemisphere, with the occurrence of spots at latitude $\geq$ 25°S. The white-light patrol at Sacramento Peak Observatory photographed such spots on 5 and 27 January 1965 as well as the more widely observed southern-hemisphere spot of 20 and 21 February.

The existence of marked asymmetries in solar activity between the northern and southern hemispheres is well known. Waldmeier and Kopecky, especially, have drawn attention to the frequent occurrence of an apparent phase difference between the two hemispheres. However, according to our evaluation of the data, the asymmetry in the development of cycle 20 is greater than that shown at the onset of any cycle in the preceding 100 years. If it is true that new-cycle activity as vigorous as that already shown by cycle 20 will continue to increase in spite of hemispheric asymmetries, then it is indeed probable that the minimum between cycles 19 and 20 has been passed.

The IQSY programs designed to study geophysical circumstances during 1964 and 1965 were undertaken in the hope of studying the earth-sun system under circumstances of solar quiet. The minimum of 1954, with its long intervals without spots or significant plages, was fresh in the memory of many of the planners. That 1964 failed to provide similarly long periods of solar quiet is all too apparent when summed values for area times intensity (Σ area $\times$ intensity) for the calcium plages for each day in 1954 are compared with similar data for 1964. However, in spite of the higher level of solar activity in 1964, there were many more days when geomagnetic indices were very low ($\Sigma K_p \lesssim 4$ and $\lesssim 9$) in 1964 than in 1954 (see Fig. 7). This anomaly appears to be only part of the somewhat peculiar overall relationships that have existed during the last 32 years between geomagnetically quiet days and solar activity (see Fig. 8). Factors other than the phase and magnitude of the solar activity cycle appear to have influenced strongly the number of days per year on which the earth's magnetic field was without significant disturbance. If the geomagnetic indices K_p are truly homogeneous for the 32-year interval for which they are available, some explanation should be sought for the large numbers of geomagnetically quiet days in the period 1934–36 and the relatively small number of quiet days in 1954–55. Circumstances that favor extreme quiet in the earth's magnetic field may be almost as hard to recognize as those that lead to severe disturbance. These problems will be met, and perhaps answered, through the IQSY programs, already formulated, for the detailed study of chosen intervals of "quiet earth" and "quiet sun."

HELEN W. DODSON
E. RUTH HEDEMAN
FREDERIC L. STEWART
McMath-Hulbert Observatory, University of Michigan, Pontiac 48055

Bibliography

W. Brunner, *Publ. Zurich Obs.* **7**, pt. 6, 42 (1943).
H. W. Dodson and E. R. Hedeman, *Science* **143**, 237 (1964).
——— and F. L. Stewart, *ibid.* **145**, 1050 (1964).
R. G. Giovanelli, *Observatory* **84**, 57 (1964); *Natl. Bur. Std. U.S. Publ. CRPL-F-242* (1964), pt. B.
M. Kopecky, *Bull. Astron. Inst. Czechoslovakia* **11**, 35 (1960).
S. B. Nicholson, and E. E. Sternberg, *Publ. Astron. Soc. Pacific* **46**, 62 (1934).
M. Waldmeier, *Z. Astrophys.* **43**, 149 (1957); "Report of Arcetri Conference on Sunspots, Sept. 1964," in press.

Note

This study has been supported in part by contract Nonr-1224(19) with the Office of Naval Research.

29 March 1965

Periodic Compounds: Syntheses at High Pressures and Temperatures

Abstract. *A new class of compounds, called "periodic compounds," identified by the selection rule* $\overline{G} = \Sigma d_i e_i / \Sigma d_i$, *where* $\overline{G}$ *assumes the integral values 1, 2, 3, . . . corresponding to the periodic table groups I, II, III, . . ., is discussed. The number of bonding electrons contributed by an atom of kind* i *is designated* e_i, *and* d_i *gives the number, per formula weight, of atoms of this kind. Both* e_i *and* d_i *assume integral values. Periodic compounds consist of symmetrical and unsymmetrical types. The recent synthesis of the unsymmetrical periodic compound* B_2O, *an isoelectronic analog of carbon, suggests that many more unsymmetrical types may be amenable to synthesis, particularly by high-pressure and high-temperature techniques.*

The high-pressure, high-temperature synthesis of B_2O (*1*), an isoelectronic analog of carbon, has opened the door to the possible synthesis of a host of compounds that have not been considered before. Isoelectronic substances contain the same average number of valence electrons per atom. Thus, in the compound of composition B_2O there are two boron atoms with three valence electrons each and one oxygen atom with six valence electrons. This adds up to a total of 12 valence electrons for three atoms, which gives an average of four valence electrons per atom. Carbon, which is in the same row of the periodic table (principal quantum number $n = 2$) as boron and oxygen, has four valence electrons per atom. Consequently, B_2O is an isoelectronic analog of carbon, and such analogs display both similar and different properties.

The compound B_2O is an "unsymmetrical" analog of carbon and, as such, is the first representative of its kind. It is classed as unsymmetrical because boron and oxygen are not symmetrically disposed with respect to the location of carbon in the periodic table. Boron has an atomic number, Z, of 5, whereas Z is 6 for carbon and 8 for oxygen. On the other hand, the compound BN with Z's of 5 and 7 is symmetrical with respect to carbon. Symmetrical analogs of group IV elements in the periodic table are well known and have been much studied because of their importance as abrasives (low Z elements), semiconductors, photoconductors, and so forth. Examples of such compounds are BN, AlP, GaAs, InSb, ZnS, AgI, and CdTe. Apparently the unsymmetrical isoelectronic analogs have been completely overlooked; and I now report a way to identify and systematize them along with the symmetrical analogs.

All the possible (symmetrical and unsymmetrical) analogs of carbon which utilize two kinds of atoms are listed (Table 1) along with the difference in electronegativity Δx of the two kinds of combining atoms. The greater the electronegativity difference Δx, the less the compound is like carbon. Thus, BN simulates carbon most closely and is known in both a graphite and diamond-like form. High pressure and high temperature are required to transform "graphitic" BN to "diamond" BN (*2*); this is also the case for transforming ordinary graphite to diamond (*3*). Beryllium oxide is known in a diamond-like form (hexagonal wurtzite structure) with tetrahedral bonding. The bonding in BeO, however, is probably more ionic than covalent. The compound LiF is known only in a rock-salt structure where ionic bonding prevails and resembles carbon the least. The new compound B_2O has hexagonal crystal symmetry related to graphite and may also exist in a diamond-like form (attempts to make the diamond form are encouraging but inconclusive). It should be possible to prepare the compound BeN_2 in a form as closely related to carbon as B_2O is. Next in line in similarity stand LiN_3, B_3F, and finally the pair

Table 1. Isoelectronic analogs of carbon which utilize two kinds of atoms. The numbers in parentheses are the absolute values of the electronegativity difference of the combining atoms.

Symmetrical	Unsymmetrical	
BN (1.0)	BeN_2 (1.5)	B_2O (1.5)
BeO (2.0)	LiN_3 (2.0)	B_3F (2.0)
LiF (3.0)	Li_2O_3 (2.5)	Be_3F_2 (2.5)