Their presence does not appear to complicate the picture, however, for they will not interfere in any serious way with the generation of additional prismatic dislocations on the surface of the prism. It should be added that a single dislocation ring on one face of the prism may, on reaching the edge of this face, start moving along a second face which meets the first at the edge. For the ring will have the character of a Burgers or screw dislocation at the point of contact with the edge; a screw dislocation may move in any slip plane. In this way a single ring, generated on one face of the prism, may become wrapped around the prism and on meeting itself after complete circumnavigation, form two prismatic dislocations of opposite sign. Similarly a dislocation spiral in one face of the prism, or a pair of oppositely wound spirals which are joined, can produce an unlimited number of prismatic dislocations by wrapping around the surface of the prism.

Once a sequence of prismatic dislocations of the α-type have been started down the cylinder, they may transmit stresses to one another because of their mutual repulsion. Thus the force impressed on the prismatic dislocation nearest the surface *ABDF* will be transmitted along the entire line to that nearest the opposite end of the prism. The prismatic dislocations α and β shown in Fig. 1c are composed of straight-line segments on each of the four bounding planes. Actually, the segments may be curved. The sequence of events portrayed here evidently could occur on the surfaces of two or more prisms whose axes lie along different slip directions, but which have a common intercept at the area where the indenter is applied.

The writer is indebted to Professor A. H. Cottrell for a stimulating discussion of this topic.

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[1] A. Smakula and M. W. Klein, J. Opt. Soc. Am. **39**, 445 (1949).

Special and Magic Numbers as Factors in Nuclear Stability and Abundance*

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In the years 1915 to 1923, the following concept was introduced into nuclear science in about 20 papers.[1] The stability and abundances of nuclear species are determined largely by the relations of special numbers. This concept was received by Rutherford, and later by Goldschmidt, with much approval, but did not meet with so much favor from certain theorists.

It was stated that of all special numbers, 2 is preeminent. The later data of astronomers,[2] and of Goldschmidt,[3] Brown[4] and others indicates that the importance of the number 2 is greater than was supposed initially. In 1920 both Rutherford and the writer indicated that the nucleus consists of protons and neutrons, and Harkins indicated the composition of all nuclei as $(pn)_P n_I$, first expressed by the formula $(pep)_P(pe)_I$ in which it was stated "*pe* represents a neutron." *P* is the atomic and *I* the isotopic number.

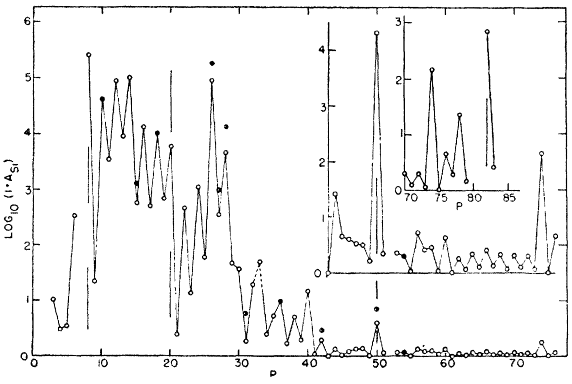

Fig. 1. Abundance of the elements in the meteorites: (A) as compared with that of silicon. The rare gases have been added by a comparison with the composition of the sun and stars. The upper right-hand corner presents values on expanded scales. Values for the ends of nuclear shells are represented by vertical lines. The most striking relative increase in abundance related to a magic number is that for $P=50$, which represents tin.

Table I. Atoms per million with even and odd protons.

Element	*P* even	*P* odd	*P* even	*P* odd	P_e/P_0
Carbon	6		177000		
Nitrogen		7		350000	
Oxygen	8		490000		
Fluorine		9		200	2950
Neon	10		100000		
Sodium		11		1020	60
Magnesium	12		20000		
Aluminum		13		2000	10.5
Silicon	14		22000		
Phosphorus		15		290	52
Sulfur	16		7800		
Chlorine		17		380	13
Argon	18		2200		
Potassium		19		180	11
Calcium	20		1800		
Scandium		21		0.4	2300
Titanium	22		58		
Vanadium		23		5.5	24
Chromium	24		210		
Manganese		25		170	120
Iron	26		40000		
Cobalt		27		220	100
Nickel	28		3000		
Copper		29		10	150
Zinc	30		3.6		
Gallium		31		1.4	3.3
Germanium	32		5.5		
Arsenic		33		10.7	100
Selenium	34		(2200?)		
Bromine		35		0.93	
Krypton	36				
Rubidium		37		0.10	
Strontium	38		0.9		
Yttrium		39		0.22	9.5
Zirconium	40		3.3		
Columbium		41		0.02	9.3
Molybdenum	42		0.42		

The number 2 is represented by the helium nucleus with its two neutrons and two protons. This species is estimated by astronomers[2] to be 70 times more abundant in the universe than the sum of all others. This excludes hydrogen from consideration since in this sense a proton is a simple nucleus.

Also every multiple of two is a special number. Thus each element which has in its nuclei an even number P_e of protons is in general very much more abundant than either of the adjacent elements with an odd number of protons. Figure 1 shows this but the relation is exhibited much better in Table I. The ratio of $P_{\rm even}$ to $P_{\rm odd}$ varies from *ca.* 3000 to 1.1, the latter for the ratio of Pd+Cd to Ag. (Note: Table I does not go so high as Ag due to lack of space.)

It is apparent that the abundance exhibits waves, in which in general high abundance for even elements are associated with relatively high abundances for odd elements, and peaks occur at oxygen and iron.

Figure 2 shows that in general the abundance of species with any certain even number of neutrons (N_e) is very much greater than that for the adjacent odd number, $N_e\pm1$. Also the peaks and troughs in abundance lie in relative positions very similar for those for protons, with peaks at 2, 8, 20, 30 and presumably 82 neutrons.

For values of *P* or of *N* above 2 the effect on the abundance relations is much more striking in general for *even* numbers than for *magic* numbers. The latter are accompanied by a somewhat greater abundance than the adjacent even numbers.

The value 50 *P* (tin) exhibits strikingly the increase in abundance related to the end of the 50 *P* shell. The values 9 *P* and 21 *P* show a great lowering in abundance which occurs just after the respective shell (8 *P* or 20 *P*) ends. This same type of decrease in abundance occurs just after the closing of the 8, 20, 28 and 50, and 82 *N* shells, at 9, 21, 29, 51 and 83 *N*.

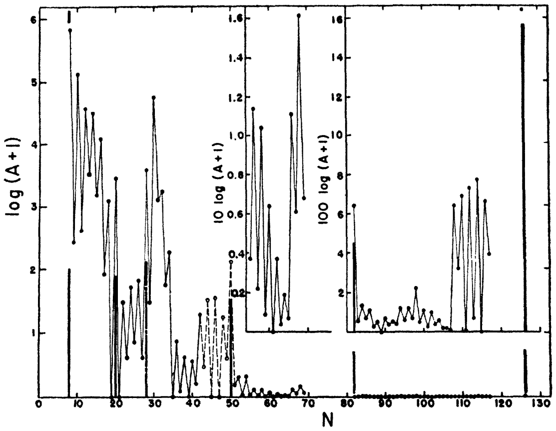

FIG. 2. The same as Fig. 1 except that the abundance is plotted as a function of the number of neutrons (isosteres). In the region of high N where the abundances are low a strikingly high relative abundance is indicated for $N=108$ to $N=116$.

In this communication only relations made more prominent by recent data are considered: many others are discussed in earlier papers.

The earliest suggestion (1915 to 1923) that certain proton and neutron numbers are related to high and low stability and abundance was made by the writer, but the first definite introduction of the concept of nuclear shells appears to be that of Bartlett.[5]

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* From a paper on special numbers, presented as an introduction to the symposium on nuclear shells, New York Meeting of the American Physical Society (February 4, 1950).

[1] W. D. Harkins and E. D. Wilson, J. Am. Chem. Soc. **37**, 1367, 1383, 1396 (1915); Proc. Nat. Acad. Sci. **1**, 276 (1915); W. D. Harkins, Phil. Mag. **30**, 723 (1915). See also references 1–14, Phys. Rev. **76**, 989 (1949).

[2] Values collected by J. Greenstein as cited by G. P. Kuiper, *Atmospheres of the Earth and Planets* (University of Chicago Press, Chicago, 1949), p. 309. See also A. Unsöld, Zeits. f. Astrophys. **24**, 323 (1948); **21**, 1 (1941); L. H. Aller and D. H. Menzel, Astrophys. J. **102**, 239 (1945); D. H. Menzel—see Goldberg and Aller, *Atoms, Stars and Nebulae* (The Blakiston Company, Philadelphia, 1943).

[3] D. M. Goldschmidt, *Die Mengenverhältnisse der Elemente und der Atom-Arten* (Oslo, 1938).

[4] H. Brown, Rev. Mod. Phys. **21**, 625 (1949).

[5] J. H. Bartlett, Nature **130**, 165 (1932).

Yields of Photo-Neutrons with Calorimetrically Measured 320-Mev Bremsstrahlung*

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THE numbers of neutrons per erg of 320-Mev bremsstrahlung from samples hung in the beam six meters from the target were detected by a rhodium foil in a large paraffin block. Except for the calorimeter, the equipment and method were the same as those used with the 22-Mev betatron.[1] Corrections generally about 10 percent had to be made because of the distribution of beam intensity over the sample. A correction for the x-ray attenuation in the samples of heavy elements was never greater than 4.5 percent. This correction was not the calculated fractional loss of intensity due to absorption; rather, the correction was found by placing graphite detectors in front of and behind the sample and determining the relative activities. This empirical determination was necessary since degradation of high energy photons passing through the sample largely compensates for absorption of x-rays in the 20-Mev region where $\gamma-n$ processes occur. The rhodium-paraffin detector was calibrated with a known radium-beryllium source of neutrons. An uncertainty in all results described here is due to the unknown variation of efficiency of the detector for the neutron spectra from different elements and from the calibrating source.

For the calorimetric determination of x-ray intensity a collimated beam was absorbed in a lead block whose temperature was compared by thermocouples with that of a similar block not in the beam. The result was that our intermediate standard, a Victoreen 100r ionization chamber behind 0.125 in. of lead, indicated 7.8×10^{-4} joules/cm^2/r. Figure 1 shows the yields plotted with the yields[1] determined at 22 Mev for comparison. The numerical ordinates refer only to the 320-Mev yields.

If the bremsstrahlung spectrum is known, and if the effective photon energy for the disintegration is known, then the integral $\Pi=\int\sigma dE$ can be determined from these yields. For the case of deuterium the theoretical cross section can be used to estimate the yield for comparison with observation. Using the energy dependence of the deuterium cross section given by Bethe and Peierls with a maximum cross section of 24×10^{-28} cm^2, and using the theoretical spectrum used by the Berkeley synchroton group for a platinum target 0.020 in. thick, we calculate 6.3 neutrons/gram atom/erg/cm^2 averaged over all angles. We observe 6.9 neutrons/gram atom/erg/cm^2 after correcting the yield in the figure for the angular distribution and for the sensitivity of our apparatus as observed earlier.[1] Thus we observe 10 percent more than theory predicts. Another spectrum calculation for thin targets by Schiff[2] gives a theoretical yield 14 percent lower than is observed. Recent work of Almy and Diven with photo-disintegra-

TABLE I. Integrated cross sections, $\Pi=\int\sigma dE$.

Element	Assumed effective $h\nu$ (Mev)	Our values (Mev-barns)	Other determinations (Mev-barns)
C	30	0.11	0.14[a,b]
Cu	21	1.5	1.4[a,b]
U	16	11.	0.8[c]

[a] J. L. Lawson and M. L. Perlman, Phys. Rev. **74**, 1190 (1948).
[b] G. C. Baldwin and F. R. Elder, Phys. Rev. **78**, 76 (1950).
[c] G. C. Baldwin and G. S. Klaiber, Phys. Rev. **71**, 3 (1947).

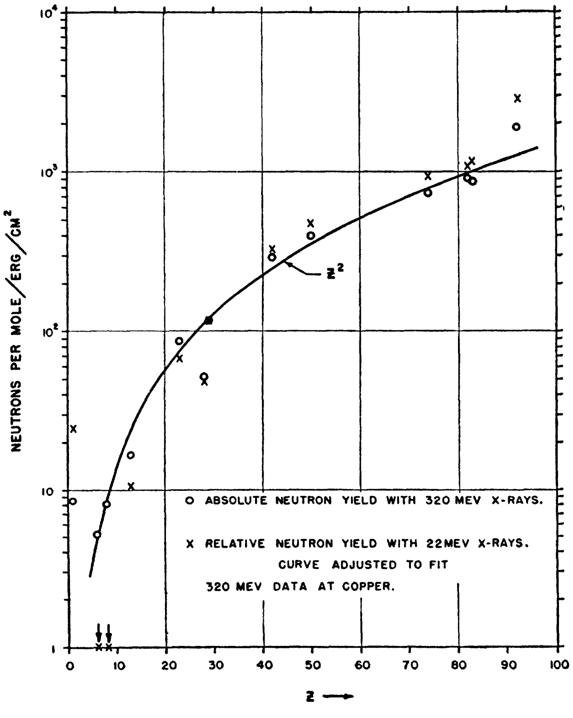

FIG. 1. Observed neutron yields at 320-Mev bremsstrahlung. The 22-Mev yield curve is adjusted to coincide at copper. The numerical ordinates refer only to the 320-Mev curve.