calculated from H^3 using a perturbation method to take account of the Coulomb interaction.

We would like to thank Professor H. S. W. Massey for his interest in the work and Dr. H. N. Yadav for providing us with his interaction constants in advance of publication.

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† The notation should be clear by reference to Gerjuoy and Schwinger, reference 1. (Owing to typographical difficulties the symbols S and P with superposed tildas have been replaced by S' and P'—Ed.)

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Equivalence of Protons and Neutrons in Nuclei*

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IN 1917 it was found[1] that in the meteorites and on earth the elements of even atomic (proton) number are very much more abundant than those of odd number. This became known as Harkins' rule. In 1922 it was found that this rule applies as well to neutrons as to protons. In general, elements of even number P_e are, in the universe, very much more abundant than those of adjacent odd number $P_e \pm 1$, and those of even number N_e of neutrons are very much more abundant than those of odd number $N_e \pm 1$. If on one chart the abundance A is plotted against the proton number and on another against the neutron number, the two charts have an almost identical appearance to a casual observer. The even-odd relation is the same on both, and the general regions of high and low abundance are similar; e.g., high at 8 to 18 and very low at 21 for either N or P. In this sense protons and neutrons may be said to be equivalent.

These relations are made much more prominent by use of the recent data of Harrison Brown.

A remarkable relation is exhibited by the most recent data, which indicate that in the universe 99 percent of all complex nuclei exhibit equality of the numbers of protons and neutrons ($N=P$). Only in about one percent is N greater than P.

In only one relatively abundant element, iron, is N not equal to P.

If helium, the most abundant species in which $N=P$, is omitted, even then 95 percent of the other species exhibit equality of N and P.

In nearly all complex nuclei both the number of protons (P) and of neutrons (N) is even (Class I $E_p \cdot E_n$). From $P=8$ to 29, or for 22 elements (oxygen to cobalt) consider 22 million nuclei, an average of one million per element of the $E \cdot E$ class (Fig. 1).

Relative Number of Nuclei per Element

$E \cdot E$	$E \cdot O$	$O \cdot E$	$O \cdot O$
Elements 8 to 29			
1,000,000	6800	6400	0
Elements 30 to 92			
28	2.8	1.3	0

FIG. 1. If helium ($P=2$) is included, the even-even ($E \cdot E$) class rises to 70 million, owing to the great abundance of this element in the universe.

The number of Class II E_pO_n species becomes 6800 and of Class III O_pE_n, 6400. These two numbers are equal within the limits of accuracy of the data. Thus in the production of these nuclei in the universe it has been a matter of indifference as to whether the protons or the neutrons are even.

Between these limits of $P=8$ to 20, the number of stable nuclei of Class IV, $O_p \cdot O_n$ is zero. No nuclei are stable if the number of protons and of neutrons is odd and larger than 7.

Thus 7 is a special number, which as an odd number exhibits a relation similar to the "magic" number 20, since 7 is the highest odd number for which stability is exhibited with $N_p = N_n$ and 20 is the highest even number for which this is true.

The newer data exhibit very plainly the relatively great rarity of elements 30 to 92 since for Class I, $E \cdot E$, 1,000,000 is reduced to 28, for Class II, $E \cdot O$, 6800 is reduced to 2.8 and for Class III 6400 to 1.3. When the relatively low accuracy for heavier nuclei is considered, 1.3 is not essentially different from 2.8.

Nuclear Shells. The numbers which according to Feenberg, Maria Mayer, and Nordheim represent the closing of nuclear shells (2, 8, (10), 20, (28), 50, and 82) are the same for neutrons and protons, and thus represent entire equivalence between the two types of particles. The only exception is 126 for neutrons, which, due to their charge, is too high for protons.

Departures from equivalence, as is well known, are due largely to the charge on the proton.

* 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).

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Pressure behind a Shock Wave Diffracted through a Small Angle*

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THE problem of the reflection of a shock wave on a rigid wall has been reviewed by Bleakney and Taub,[1] and brief mention was made by them of the theory of Bargmann[2] for nearly glancing incidence together with some experimental verification of this phenomenon. Recently Lighthill[3] has reported on a method for calculating the pressures on a wall when a shock wave travels along the wall and passes by a convex corner. Both of these treatments require that the deflection at the corner be small, and both should apply to either positive or negative angles.

As an extension of the work reported by the present authors,[4] an experimental test has been performed to compare with these theoretical treatments. The shock wave was produced in the shock tube described by Bleakney, Weimer, and Fletcher[5] and the densities in the diffracted flow were measured interferometrically. The shock waves used were of strength $p_2/p_1=2$, corresponding to Fig. 2 of Lighthill's paper. The shock waves were diffracted at a convex angle of 0.1 radian ($\epsilon=+0.1$) or were reflected at a concave angle of the same magnitude ($\epsilon=-0.1$).

In the case of the concave angle, the density of the gas along the wall was measured on an interferogram with parallel fringes as described in reference 5. In the case of the convex angle, the measurements were made along the wave normal through the corner. This was done to avoid the boundary effects along the wall and should introduce a negligible error. Pressures were obtained from the densities by assuming the behavior of the gas behind the original shock to be isentropic. The results are pre-

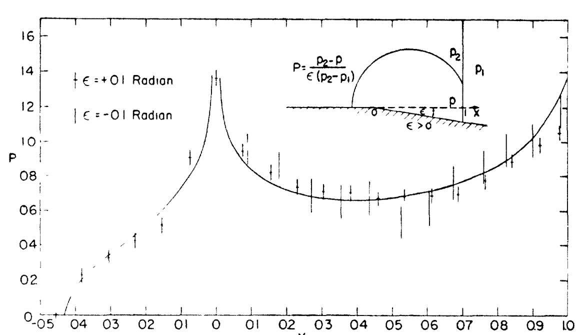

FIG. 1. Diffraction of a shock wave at a corner. Reduced pressure defect along the wall as a function of position along the wall. $p_2/p_1=2$, $\epsilon=\pm 0.1$ radian. The vertical length of the experimental points indicates approximately the reliability of the measurements.

sented in Fig. 1. The abscissa represents distance along the normal to the original shock with the origin at the corner, the scale being so arranged that the original shock has advanced a unit distance. The ordinate is the reduced pressure defect as determined by Lighthill, $P=(p_2-p)/\epsilon(p_2-p_1)$, where p is the pressure along the wall, p_1 and p_2 are respectively the pressures ahead of and behind the original shock and ϵ is the angle of the bend in the wall. The sign of the quantity P is observed to be positive for both concave and convex corners. The theoretical treatment shows a logarithmic infinity in the pressure at the corner. This, of course, would not be obtained experimentally, but a relative maximum in the pressure does exist there.

* This research was supported by the ONR of the Navy Department.

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Superconductivity of Lead

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April 11, 1950

NUMEROUS determinations of the zero-field transition temperature of lead have been made. A summary of these is given in Table I. All of these observations, except that of Daunt, were made by the direct measurement of electrical resistance. Daunt's method involved the shielding effect of persistent currents in a hollow cylinder.

In our work on columbium to be described in a forthcoming paper, an a.c. induction method[1] was used for the measurement of superconducting transitions. The superconductor was mounted as a cylindrical core of a coil which functioned as the secondary of a mutual inductance. The primary coil was actuated by an oscillator which provided a maximum a.c. field within the secondary of 1.5 oersteds at a frequency of 1000 cycles per second. The secondary e.m.f. which was dependent for its magnitude on the permeability of the core, was amplified, rectified, and observed on a recording potentiometer. During the application of this method to the study of columbium it appeared that a further check on the zero-field transition temperature of lead would be worth while, especially if agreement between results for very pure samples could be obtained using this method. Such a result would help in establishing the lead transition temperature as a reasonably reproducible reference point in the region between 4° and 10°K.

The lead used in the present investigation was made available to us through the courtesy of Dr. C. H. Hack and Mr. E. J. Dunn, Jr., of the National Lead Company. It had been analyzed as follows (No. A-586A):

Ag 0.00065%	Zn 0.0001%	As	no perceptible amounts.
Cu 0.00022%	Bi 0.0002%	Cd	
Fe 0.00018%	Mn 0.00005%	Co	
		Ni	
		Sn	

The samples were in the form of cylinders 1.5 mm in diameter and 5 cm long, attached by a copper rod to the desorption cryostat described in the forthcoming report on the superconductivity of columbium. Temperatures were determined to the nearest 0.01°K with the aid of a helium gas thermometer which was filled to 1 atmos. at 20.4°K. Corrections were applied for gas imperfection, room temperature volume, and temperature gradients in the capillary. The hydrogen triple point was checked within 0.02°K.

The collected results of the transition temperatures observed in the present experiments are given in Table II. The observations were made on two samples in a series of experiments in which the gas thermometer was refilled at the beginning of each run, usually to 1 atmos. but in one case to $\frac{1}{2}$ atmos. to check the consistency of the thermometer corrections. A typical transition is shown in Fig. 1. Neither specimen showed hysteresis, but since thermometer response was more immediate on warming cycles, the data shown were taken on transitions proceeding from the superconducting to the normal state. Changes of oscillator frequency from 500 to 2000 cycles/sec. and of amplitude over the full range available did not affect the transitions.

As a further check on the magnetic purity of the material, observations were made of the $H-T$ curve in the vicinity of the zero-field transition temperature both in transverse and in longi-

Table I. Transition temperature of lead.

Investigators	Year	Source, purity	Temperature °K
Onnes, Tuyn[a]	1922	Kahlbaum: 99.99%	7.22; 7.26
de Haas, de Boer, van den Berg[b]	1934	Kahlbaum: 99.99%	7.19$_3$; 7.20$_6$
Daunt[c]	1937	Hilger: 99.999%	7.22
Bruksch, Ziegler[d]	1942	(evaporated films)	7.23 ±0.03
Bruksch, Ziegler, Hickman[e]	1942	Baker (thin wires)	7.20 ±0.01
van Itterbeck, de Greve, Lambeir, Celis[f]	1949	(sputtered films)	7.20
		Average:	7.216°

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[b] de Haas, de Boer, and van den Berg, Leiden Comm. No. 233b.
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Table II. Zero-field transition temperatures of lead by a.c. induction method.

Transition temperature, °K	No. of separate observations
7.26	1
7.25	1
7.24	5
7.22	5
7.21	1
7.20	2
7.17	1
Average: 7.22$_4$°K	
Mean deviation: 0.02°K	

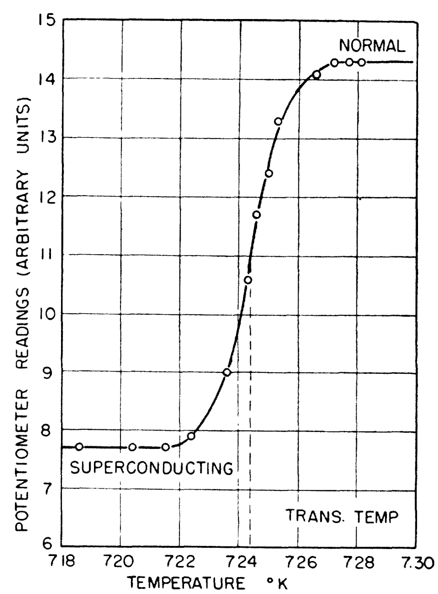

Fig. 1. Typical zero-field transition curve for Pb.