

FIG. 1. The resonances are both due to the Cu^{63} isotope. The more intense line is due to CuCl powder. The broader line occurs in Cu metal powder at a frequency higher by about 25 kc.p.s. at a resonance frequency of about 10 mc.p.s. The two dry powders are mixed in the proportion of 100 parts CuCl to 64 parts Cu by weight.

percent, while small frequency differences were accurate to about 0.002 percent of the average frequency.

The lithium and sodium resonances were observed in shavings of the respective metals in kerosene, while the copper and aluminum resonances occurred in metal powders which had been suspended in melted paraffin and subsequently cooled in a mold. The gallium metal was sealed in several capillary tubes, each about one millimeter in diameter. These tubes were placed in the r-f coil with their axes parallel to the coil. The ambient temperature in the case of gallium was above the melting point of that metal. The gallium resonance was not observed when the temperature was lowered below the melting point.

This shift has been observed in separate samples of a particular metal and its salts and in samples of a metal mixed with its salt. In the latter situation, one could be certain that the resonances occurred in exactly the same applied field. Observations have been made on separate runs for precise frequency comparisons, and on single continuous runs (see Fig. 1) in order to display the effect qualitatively. The shift for a given isotope is proportional to the resonance magnetic field (or frequency) within the limits of error stated above. Values of the observed shifts and line widths are

TABLE I. Values of the observed shifts and line widths.

Isotope	Salt*	Resonance frequency in salt (mc.p.s.)	Frequency shift in metal (kc.p.s.)	Line width in metal (kc.p.s.)	Line width in salt (kc.p.s.)
Li^7	LiCl	9.436	$+3.4 \pm 0.2$	1.4 ± 0.2	1.2 ± 0.2
Na^{23}	NaCl	10.123	$+10.5$	0.5	1.4
Al^{27}	AlCl_3	10.145	$+16.2$	9.3	0.8
Cu^{63}	CuCl	10.321	$+23.7$	7.4	2.6
Cu^{65}	CuCl	11.050	$+25.6$	5.8	2.6
Ga^{71}	GaCl_3	7.409	$+33.3$	1.5	3.0

* With the exception of CuCl , which was compressed powder, the samples were in aqueous solution.

given in Table I. It is to be noted that the shift is greater in the heavier metals, a trend which follows qualitatively that of the known values for hyperfine structure splitting.

C. H. Townes has suggested that the shift may be due to the paramagnetic effect of the conduction electrons in the vicinities of the metal nuclei. If this is true, the shift in the metal should be proportional to the hyperfine splitting of the ground state of the free atom. Suppose, then, for sodium that: 1. There is one conduction electron per nucleus on the average in the metal; 2. the value at the metal nucleus of the wave function of this average conduction electron is the same as of the valence electron of the normal free atom; 3. the bulk susceptibility (corrected to give the net paramagnetic part)² divided by the average density of conduction electrons is a measure of the number of conduction electrons which contribute to the shift. Then the product of the susceptibility per electron and the applied magnetic field should give the average effective magnetic moment per electron. The ratio of this quantity to the Bohr magneton should be equal to the ratio of the observed shift in the metal to the hyperfine splitting in the free atom, taken in energy units. Here it is to be noted that the total hyperfine splitting³ should be modified before making the above comparison. First, for the sodium nucleus, three equal transitions are possible in the applied magnetic field, and, second there is a complete Paschen-Back effect when the field is applied to the metal. The effect of these considerations is to reduce the hyperfine splitting by a factor of four before comparing the above ratios.

The results of this simple calculation show that the predicted value of the shift in sodium to be larger than that observed by about fifty percent. A more detailed analysis is being made in an effort to improve this calculation. It is thought that a closer examination of the respective wave functions (see 2, above) will yield information which leads to a closer agreement.

Further experimental work is being done to determine the magnitude of this effect in these and other metals and alloys at varying temperatures, and to determine the possible existence of a shift in resonance frequency when comparing two or more salts of the same metal. Preliminary measurements show that the latter shift, if it exists, is certainly less than 0.001 percent among similar salts of a given metal (CuCl , CuBr , CuI). More accurate measurements are under way to confirm the existence of shifts of about 0.01 percent among some phosphorous compounds. The magnitude of this shift is of the order of the line width or slightly larger.

The author's thanks are due Dr. V. W. Cohen, who has directed this work, and Dr. C. H. Townes for many helpful discussions.

* Work performed at Brookhaven National Laboratory under contract with the AEC.

** Permanent address: Physics Department, Trinity College, Hartford, Connecticut.

¹ R. V. Pound, Phys. Rev. **72**, 527 (1947).

² F. Seitz, Phys. Rev. **58**, 633 (1940).

³ M. Fox and I. I. Rabi, Phys. Rev. **48**, 746 (1935).

A New Determination of the Relative Abundance of Rhenium in Nature*

HARRISON BROWN AND EDWARD GOLDBERG
Institute for Nuclear Studies, University of Chicago

AND

Argonne National Laboratory, Chicago, Illinois
August 29, 1949

IT has become generally recognized that a most peculiar discontinuity exists at $A = 185$ and $A = 187$ in the curve representing the relative abundances of nuclear species as a function of mass number.¹⁻³ It is of interest to determine whether the observed low abundances of Re^{185} and Re^{187} are real, or whether the discontinuity is the result of faulty determinations of rhenium concentrations in meteorites by previous investigators.⁴

In view of the chemical properties of rhenium, one would expect the element to be concentrated primarily in the metal phase of the earth and in the metal phase of meteoritic matter. Conse-

TABLE I. The rhenium contents of five iron meteorites.

Meteorite	Class	Rhenium content (parts per million)
Altonah	Off	0.87
Henbury	Om	1.4
Goos Lake	Og-Om	0.28
Canyon Diablo	Og	0.28
Xiquipilco	Om	0.25
Average		0.62

quently, five iron meteorites have been examined for rhenium utilizing the neutron activation method of analysis described elsewhere.^{5,6} The results of the new determinations are given in Table I.

Each of the individual determinations is precise to about ten percent. The average of only five meteorite specimens has poor statistical precision, and as a result the value for the rhenium abundance in iron meteorites may be given as 0.6 ± 0.2 part per million. Nevertheless, it can be seen that the abundance of rhenium is probably at least 50 times greater than the abundance as reported by the Noddacks.

It is of interest to compare the abundances of odd nuclear species, of the sequence beginning with rhenium, all of which are associated with elements which concentrate in the metal phase. The figures are shown in Table II, and are taken from a recent compilation by one of us.⁷

TABLE II. The abundances of several odd heavy nuclear species.

Species	Re ¹⁸⁵	Re ¹⁸⁷	Os ¹⁸⁹	Ir ¹⁹¹	Ir ¹⁹³	Pt ¹⁹⁵	Au ¹⁹⁷
Abundance (atoms/10 ⁷ atoms Si)	1.1	1.9	5.6	5.4	8.6	29	8.2

The platinum value is probably too high, but the osmium and gold values should be quite reliable. It appears that in this region of the abundance curve, the abundance increases significantly with increasing mass number.

* Declassified April 13, 1949, Unclassified Areas Committee, Argonne National Laboratory, #UAC-82.

¹ V. M. Goldschmidt, *Geochem. Verteilung. Elemente Atom-arten. Oslo, IX* (1938).

² H. Suess, *Zeits. f. Naturforschung* **2a**, 606 (1947).

³ F. C. Frank, *Proc. Phys. Soc. London* **60**, 211 (1948).

⁴ I. and W. Noddack, *Naturwiss.* **35**, 59 (1930).

⁵ H. Brown and E. Goldberg, *Science* **109**, 347 (1949).

⁶ E. Goldberg and H. Brown, *Analytical Chemistry* (in press).

⁷ H. Brown, *Rev. Mod. Phys.* (to be published).

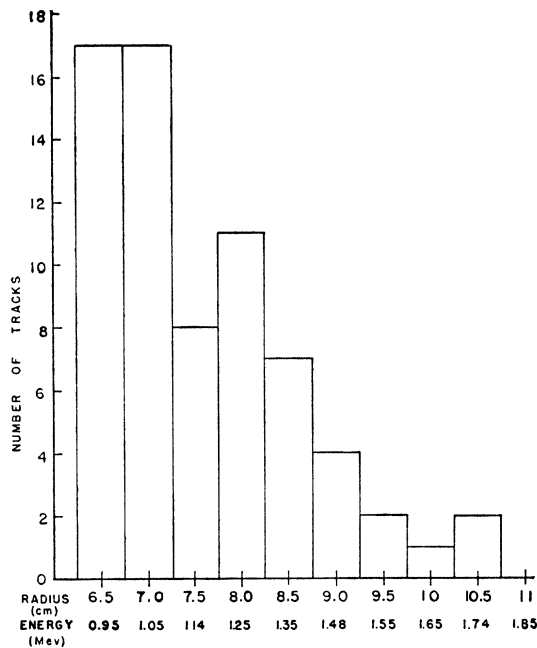
Cloud-Chamber Study of High Energy Positrons from Na²² *

KENNARD H. MORGANSTERN AND KARL P. W. WOLF
Washington University, St. Louis, Missouri
August 26, 1949

THE radioactivity of Na²² has been investigated by a number of physicists. It has been found to have a half-life of 3.0 yr., to give a positron spectrum whose end point is at 0.56 Mev, and to have gamma-photons of 1.3 Mev energy.¹⁻³ The transition to the ground state is found to be highly forbidden empirically. However, there are slight indications of very weak, high energy tails to the regular positron spectrum indicating the possibility of the presence of a higher energy positron spectrum.⁴

Feenberg⁵ concludes from a comparison of the Ne²² to Na²² transition with that of Be¹⁰ and B¹⁰ that a weak, high energy positron spectrum should be present and that its ratio to that of the normal positron spectrum should be of the order of one to ten thousand.

An investigation was made in a cloud chamber to determine the energy and frequency of the higher energy positrons. The chamber employed was 25 cm in diameter and filled with a mixture of hydrogen and alcohol vapor. A weak source of Na²² was placed

FIG. 1. Histogram of higher energy positron tracks from Na²².

on a thin aluminum backing and suspended in the chamber. A glass baffle also was suspended in the chamber to help distinguish positron tracks from tracks of electrons ejected by gamma-rays at the source holder. The chamber was in a pulsed magnetic field of 700 gauss.

Approximately 6000 pictures were taken with sources of varying intensities. Sixty-nine tracks were definitely identified as high energy positron tracks. Their histogram is given in Fig. 1. No significance can be attached to the shape of the histogram because of many difficulties in the method (thick sources, poor resolution, poor geometry). However, the histogram does indicate the presence of a high energy positron spectrum, and the end point agrees satisfactorily with what would be expected in a transition of the Na²² directly to the ground state of Ne²².

At best only a rough estimate could be made of the probability of this occurrence. A very weak source was used to determine the total number of tracks in a single expansion. Comparing then the activity of the weak source with the stronger ones by use of an auxiliary Geiger counter, the number of tracks from the latter could be estimated. It was then calculated that the aggregate of



FIG. 2. Typical cloud-chamber photograph of high energy positron track. Arrow indicates positron track whose radius is 7.5 cm and energy 1.14 Mev.