It is important to observe, however, that the temperature coefficient is not independent of the methyl alcohol concentration, but that the ratios of the velocity constants at 30 and 20°, and at 35 and 25°, increase with increasing methyl alcohol content, as shown by the sixth and seventh columns of the third part of Table I.

The writer takes this opportunity to thank Professor Herbert S. Harned for help and suggestions obtained from him during the course of this work.

Summary

1. The reaction velocity constant of decomposition of diacetone alcohol catalyzed by hydroxides has been measured at 20, 25, 30 and 35° in aqueous solutions of sodium hydroxide of different concentrations, in aqueous hydroxide–salt solutions, and in water–methyl alcohol mixtures containing sodium hydroxide.

2. The temperature coefficient of reaction velocity is independent of the strength of hydroxide. It is also independent of the sodium chloride concentration in the hydroxide–salt mixtures.

3. The temperature coefficient, however, is not independent of the concentration of methyl alcohol in the alcohol–water mixtures containing 0.1 *M* sodium hydroxide.

4. The energy of activation has been computed and is found to be 18,000 cal. The error in this observation is approximately ±0.7%.

New Haven, Connecticut

[Contribution from the Chemical Laboratory of the University of California]

A THEORY OF THE ARRANGEMENT OF PROTONS AND ELECTRONS IN THE ATOMIC NUCLEUS

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From a study of the number of protons and electrons in those atomic species whose atomic weights are approximately integral multiples of four, together with data on their abundance, I have been led to a geometrical representation of the atomic nuclei in which the protons and electrons are arranged in a definite space lattice. It appears certain that the nucleus must be held together by the coupling of the proton spins, and the model may be interpreted as the pattern determined by the directions of the spin vectors. In the proposed model the angle between any two proton vectors is that formed by lines from two corners of a tetrahedron to its center, and this in the new quantum mechanics is the angle at which two elementary spin vectors add to give a resultant of two units.

It seems reasonable to expect that existing relations would appear more clearly defined in the case of the atomic species with atomic weights multiples of four, since, at least in the lighter elements, these nuclei possess no resultant spin and have therefore a higher degree of symmetry. This nuclear type contains an even number of electrons and thus occurs only in elements of even atomic number with the exception of the two very unstable elements, Mesothorium II with a half life period of six hours, and Thorium c″ with a half period of 3.2 minutes. Every even atomic number from 2 to 90 appears to have at least one atomic species of this type, generally the most abundant form of the element; in fact, approximately 80% of the earth's crust is composed of such atoms.

In analogy to the known facts of radioactive disintegration, it has frequently been suggested[1] that these elements are composed of alpha particles, that is, united of four protons and two electrons, together with that number of extra or "cementing" electrons which, with the number of alpha particles, gives its atomic number. The numbers of these alpha particles and extra electrons are summarized in Table I; the figures in the table are the number of alpha particles for the element with the atomic number given at the left of the same row, and the number of extra electrons in the nucleus is given by the number at the top of the corresponding column.

TABLE I

A REPRESENTATION OF THE NUMBER OF ALPHA PARTICLES AND EXTRA ELECTRONS IN THE NUCLEI OF THE ELEMENTS WITH ATOMIC WEIGHT INTEGRAL MULTIPLES OF FOUR

Element	Atomic number	Number of extra electrons													
		0	2	4	6	8	10	12	14	16	18	20	22	24	26
He	2	1													
Be	4	2													
C	6	3													
O	8	4													
Ne	10	5													
Mg	12	6													
Si	14	7													
S	16	8													
A	18	9	10												
Ca	20	10	11												
Ti	22		12												
Cr	24		13												
Fe	26		14												
Ni	28		15												
Zn	30		16	17											
Ge	32			18											
Se	34			19	20										
Kr	36			20	21										
Sr	38				22										
Zr	40				23										
Mo	42			23	24	25									

[1] See Harkins, *Chem. Rev.*, **5**, 371 (1928), and other papers referred to in this reference.

TABLE I (*Concluded*)

Element	Atomic number	Number of extra electrons													
		0	2	4	6	8	10	12	14	16	18	20	22	24	26
Ru	44				25[a]										
Pd	46					27[a]									
Cd	48					28	29								
Sn	50					29	30	31							
Te	52							32							
Xe	54					31	32	33							
Ba	56							34							
Ce	58							35							
Nd	60							36							
Sa	62								38[a]						
Gd	64								39[a]						
Dy	66									41[a]					
Er	68									42[a]					
Yb	70									43[a]					
Hf	72										45[a]				
W	74										46[a]				
Os	76											48[a]			
Pt	78											49[a]			
Hg	80											50	51		
Pb	82												52	53	
Po	84												53	54	
Rn	86													55	
Ra	88													56	
Th	90													57	58
U	92														

[a] From chemical atomic weight and estimated packing fraction. Other values as determined by mass spectrograph.

It is to be observed that the lighter elements may be considered as composed of alpha particles alone, but the maximum number of alpha particles in nuclei of this type is 10, *i. e.*, in Calcium, 40. We also find Argon, 40, which contains two extra electrons. Argon 36 and Argon 40 constitute the first example of an element having two isotopes differing in atomic weight by four.

The greatest number of alpha particles found in nuclei which contain two extra electrons is 16 and from this point on the number of extra electrons increases rapidly. Thus, thorium, 232, the heaviest known member of the class, may be thought of as containing 58 alpha particles and 26 extra electrons. It may also be noted from Table I, that nuclear types containing 6, 12 and 24 extra electrons occur with a large range of atomic weights.

Data on the abundance of the various nuclear species may be expected to give some measure of the relative stabilities of various nuclear structures. In Fig. 1 the abundance, expressed as the logarithm of the percentage of the species in the earth's crust, has been plotted against the number of alpha particles in the various atoms listed in Table I. The data are those given by Harkins[1] for the abundance of the elements, corrected in case the element is a mixture of isotopes, to give the amounts of the element belonging to this nuclear type. Approximate values have been added also for neon and argon. The elements above atomic number 30 constitute but 0.15% of the earth's crust, and as the data regarding their abundance are not reliable the plot has not been extended beyond this point.

These, then, are the facts we wish to correlate with the model, first, that a given number of protons is associated with the number of electrons as given in Table I and, second, that certain groups of protons and electrons appear to be more stable than others as judged by their greater abundance.

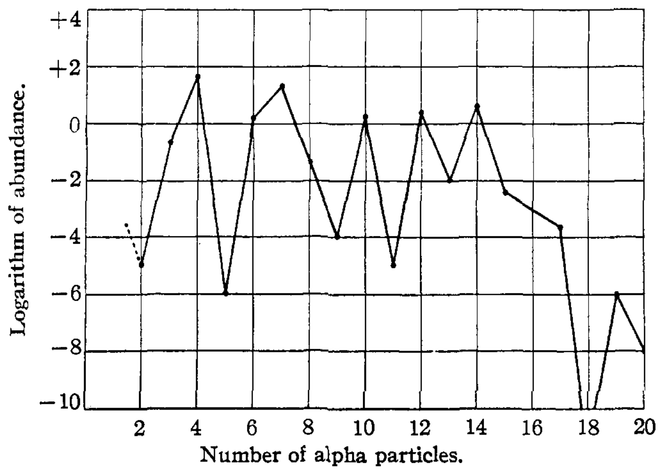

Fig. 1.—The abundance as the log of the percentage of the nuclear species in the earth's crust plotted against the number of alpha particles.

Maxima occur in the abundance curve at 4, 7, 10, 12 and 14 alpha particles. These numbers at once suggest that the alpha particles are combined in a tetrahedral pattern, with one alpha particle at each corner of the unit tetrahedron. Thus, one tetrahedron requires 4 alpha particles; two tetrahedra with one corner in common, seven, and three tetrahedra with a common corner, ten. Such a grouping occurs in face-centered cubic lattice types; the three tetrahedra have their bases in the same plane and share one corner together at the center of the hexagon formed by the outer edges of the base. If we continue this arrangement of tetrahedra, building toward spherical symmetry, we would place a layer of three tetrahedra above the first three as indicated in Fig. 2. With the completion of the first tetrahedron of this new layer we have 12 alpha particles, with the second 14 alpha particles, and with the third 16. Now it appears highly significant that in this arrangement of alpha particles the completion of each of the first five tetrahedra corresponds exactly to the first five maxima of the abundance curve. Moreover, the completion of the first group of three tetrahedra corresponds to the end of the first column of nuclei in Table I, that is, to the nuclei with no extra electrons, and the completion of the second layer of three tetrahedra to the second column of nuclei with two extra electrons. However, to give an explanation of this correspondence it is first necessary to discuss the coupling of the four alpha particles in the unit tetrahedron.

If we represent the alpha particle itself as a tetrahedral arrangement of four protons about an electron pair with zero resultant spin, and assume the four proton spin vectors are directed toward the center of the figure, then the whole alpha particle should have zero spin, in agreement with the experimental facts.[2] Now we wish to group four of these small tetrahedra (alpha particles) into a tetrahedron with such coupling of the spin vectors that a continuation of the pattern will give the arrangement of tetrahedra in Fig. 2. Such a coupling pattern is given in Fig. 3, which then is to be taken as our model of the oxygen nucleus.

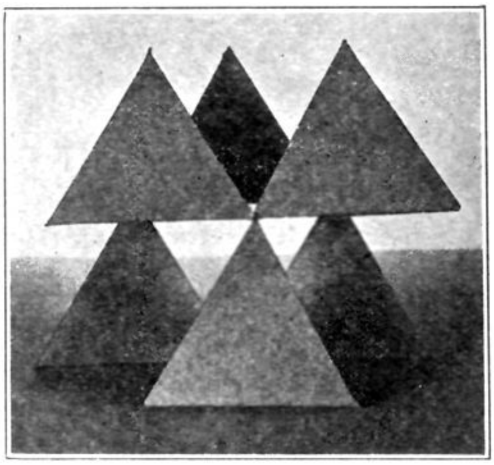

Fig. 2.—Representing the arrangement of 16 alpha particles at the corners of 6 unit tetrahedra.

As the pattern is continued to form the first group of three tetrahedra, we find with the addition of the tenth alpha particle that there is now a point (see A in Fig. 4) about which four spin vectors converge in the same manner as in the unit alpha particle, and it would seem that here too we should have an electron pair. This, then, appears to be an explanation of the entrance of the first pair of extra electrons at 10 alpha particles and provides a basis for the complete interpretation of the number of alpha particles and extra electrons which occur in the atomic nuclei as given in Table I.

[2] I have no doubt that the idea of the probable tetrahedral structure of the alpha particle has suggested itself *to many men and it seems to me that this direction of* spin vectors is a logical consequence of such a structure. Since preparing this manuscript Dr. O. K. Rice has written that he suggested the idea to me in a conversation a year ago. In the development of the theory I had not recalled his suggestions; however, I have never considered that this postulate regarding the alpha particle was at all original with me.

Several years ago Professor E. D. Eastman of this Laboratory observed that the abundance maxima occurred with a periodicity of 6 atomic numbers in the lighter elements. This observation may now be interpreted in the tetrahedral arrangement of the alpha particles.

As the pattern, by which the alpha particles are coupled, is continued, it is necessary to add a pair of extra electrons whenever four protons come together

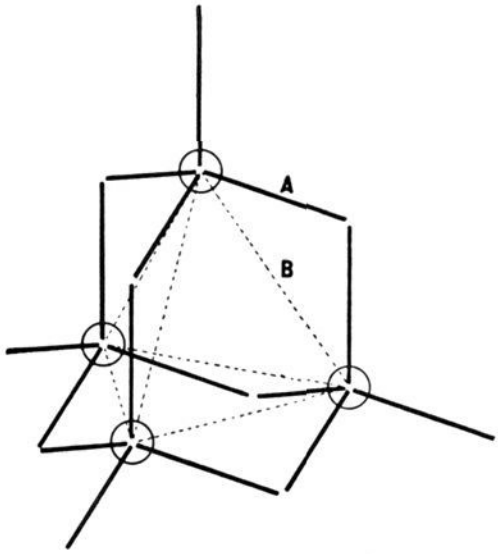

Fig. 3.—The coupling of 4 alpha particles in the unit tetrahedron. Electron pairs located at the positions of the circles and a proton located along each vector.

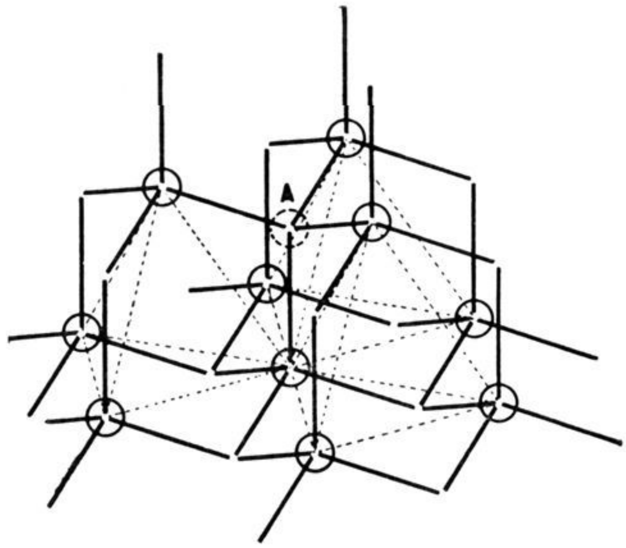

Fig. 4.—The group of 10 alpha particles constituting the first 3 unit tetrahedra. "A" indicates the position of the first pair of extra electrons.

at a point and there only. Thus the extra electrons convert the face-centered cubic arrangement of alpha particles into a diamond type lattice of electron pairs, each pair surrounded by four protons which serve as bonds to four other electron pairs. In such a lattice the original alpha particles now appear to have lost their identity. (However, for the sake of clarity in exposition, in all diagrams these extra electron pairs have been represented by black balls, and the electron pairs of the original alpha particles by white balls.)

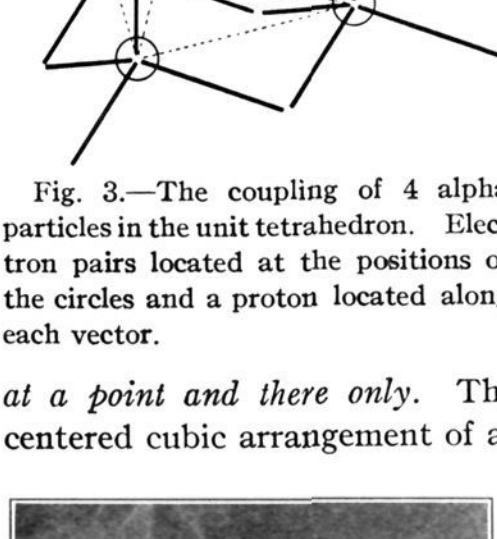

Fig. 5.—A model representing the same group of 10 alpha particles diagrammed in Fig. 4. Electron pairs represented by balls and protons by vectors, *i. e.*, the connecting bars. The model shows the 4 protons coming together at the center.

The method of combining alpha particles is such that it would lead to successive tetrahedra of 20, 35 and 56 alpha particles with 1, 4 and 10 extra electron pairs, respectively. However, the nuclei appear to tend toward spherical form due probably to coulombic forces and a new layer on one of the faces is always started before each of the above tetrahedra is completed, although in each case the figure reaches or approaches very closely the tetrahedra without the corners, that is figures of 16, 31 and 52 alpha particles with the 1, 4 and 10 extra electron pairs. (See Figs. 6, 7 and 8.)

When a new layer is started, one, and then very quickly another electron pair enter and thus we find the groups of electrons, 2 + 4 = 6, 8 + 4 = 12 and 20 + 4 = 24, corresponding, respectively, to the completion of the tetrahedra of 20, 35 and 56 alpha particles and the simultaneous starting of a new layer. This would seem to account for the long columns (see Table I) found with these numbers of extra electrons. Moreover, the evidence seems quite conclusive that when one electron pair goes into a new face, the additional pairs go into the same face of the figure.

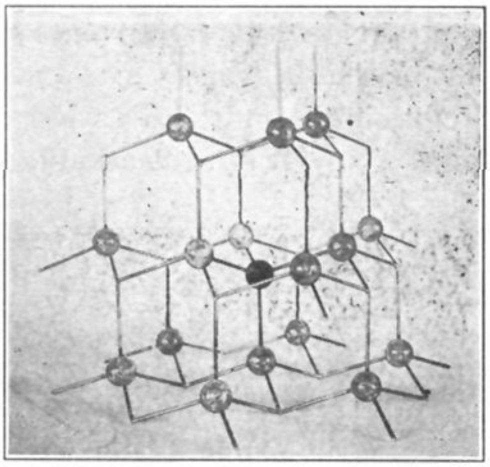

Fig. 6.—The group of 16 alpha particles, with one pair of extra electrons (black ball) at center of figure.

The radioactive thorium series corresponds to the last of these processes of starting a new layer. Thorium, 232, has three extra electron pairs and six alpha particles more than the 52 alpha particle structure of Fig. 8. However, it is not possible to say what should be the most probable location of these additional particles. The end product, lead 208, obviously has one additional pair of electrons in the surface of the 52 alpha particle structure, but again it is not possible to decide whether its alpha particle arrangement is just that of Fig. 8 or some slight variation from it.

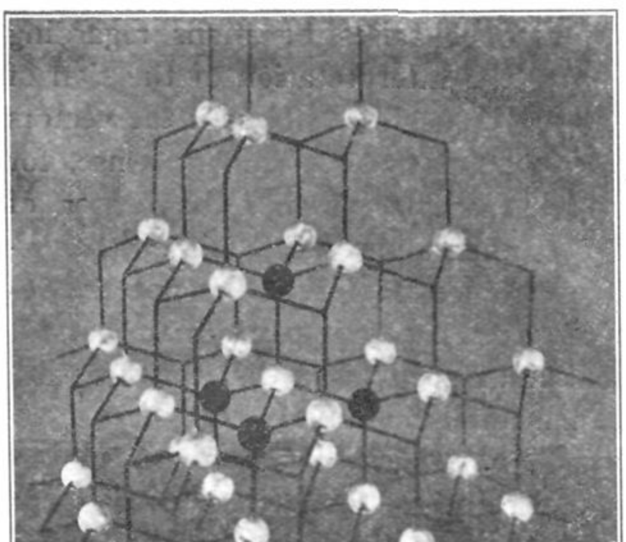

Fig. 7.—The group of 31 alpha particles and 4 pairs of extra electrons.

Although it is not planned to discuss in detail in this paper those elements whose atomic weights are not integral multiples of four, it may be pointed out that the heaviest known stable elements of odd atomic number, bismuth, 209, and thallium, 203, have 10 pairs of extra electrons, as does also lead 206. The latter may correspond to Fig. 8 with two protons removed.

If this proposed nuclear structure is correct in principle, the method of combining the spin vectors certainly should be in agreement with the quantum mechanic rule for vector combination.[3] The radical change introduced by the new mechanics is the use of the quantity $\frac{1}{2}\sqrt{n(n+2)}$ as the magnitude of the vector representing n units of spin, and only resultants with integral values of n are permitted. Thus the vector for one unit of spin becomes $\frac{1}{2}\sqrt{3}$ and the only permitted resultants for two such vectors are 0 and $\sqrt{2}$, as judged by the known combinations of electron spins. Now it is a remarkable fact that if the length of the unit vector, A, of Fig. 3 is $\frac{1}{2}\sqrt{3}$, then the resultant distance, B, of two such vectors is $\sqrt{2}$. In other words, *the geometry of the tetrahedron is just that demanded by the quantum mechanics for the combination of two unit spin vectors.*

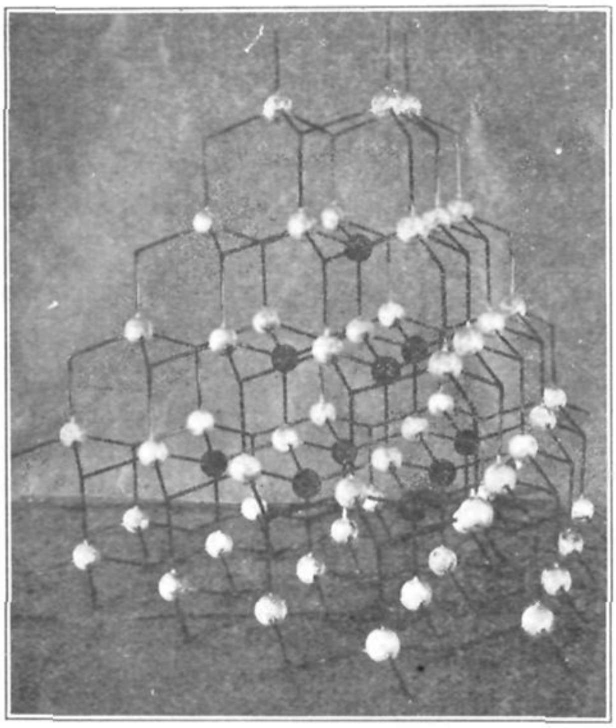

Fig. 8.—Fifty-two alpha particles and 10 pairs of extra electrons.

Unit vectors in two of the directions of the tetrahedron give a resultant of two; unit vectors in three directions, a resultant of one and unit vectors in each of the four directions, a resultant of zero. However, the model at once raises questions regarding the interpretation of the sign of the vectors. Thus if the vectors point in the ordinary sense, for example, toward the center of each alpha particle, then the distance B of Fig. 3 is not the resultant of two unit vectors. Also the extra electron pairs in the lattice would differ from those of the original alpha particles in that the direction of the four spin vectors would be out instead of in, and it might be expected that two kinds of alpha particles and helium atoms would exist corresponding to the two vector forms; yet the existence of the latter appears to be precluded by Lewis' application of the principle of identity to the helium spectrum.[4] However, since in the quantum mechanic vector rule the combination of two unit vectors in the same line can only give zero resultant, the question may be raised as to whether the sign of the vector has meaning in the ordinary sense.

The method of coupling alpha particles leads to a number of cases of

[3] I am indebted to Professor R. T. Birge for first calling my attention to this requirement.

[4] G. N. Lewis, *Phys. Rev.*, **36**, 1144 (1930).

nuclear isomers even among the lighter ments. Thus in Fig. 9, there is given another possible form of calcium 40. This form is not directly obtainable by tearing down the model of Fig. 6, since in that figure the top tetrahedron is not complete; however, if calcium has been formed largely by building up processes rather than by the tearing down of heavier elements, it would seem that this should be an abundant form of the element. This model for calcium minus the four corners gives a very symmetrical form of magnesium, 24.

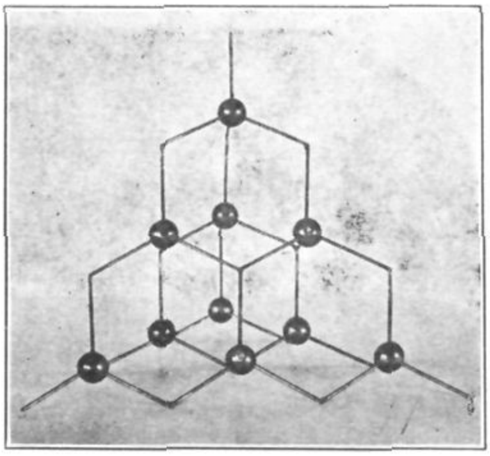

Fig. 9.—An isomeric arrangement of 10 alpha particles. Compare Fig. 5.

Although there are numerous other phases of the theory which might be discussed, the author feels that a detailed development should not be undertaken without additional confirmation of the principles involved. It would seem that a study of those elements which have a resultant nuclear spin, may provide this confirmation. For example, if the other types of nuclei are in general derived from those nuclei with weights multiples of four by the removal of one, two or three protons, then the resultant spin should follow at once from the model, provided, of course, that the electrons are all coupled in such a way as to give a zero resultant. However, from the rather meager data we have at present there appears to be some question regarding the validity of this last assumption.

In conclusion the author wishes to express his indebtedness to Professor Gilbert N. Lewis for many valuable suggestions regarding the presentation of the theory.

Summary

An analysis has been made of the nuclear species whose atomic weights are approximately integral multiples of four with reference to the number of alpha particles and extra electrons present.

The abundance curve for the lighter elements of this series shows maxima for 4, 7, 10, 12 and 14 alpha particles which suggests that the alpha particles are arranged in a tetrahedral pattern.

A pattern is proposed for the arrangement of 4 alpha particles in a tetrahedron with a certain coupling of proton spins. A continuation of the pattern to 10 alpha particles leads to a point in the lattice about which four protons converge in the same manner as in the alpha particle. The entrance of a pair of electrons at this point explains the first pair of extra electrons found in argon 40, and an extension of the principle appears

to give a complete explanation of the numbers of extra electrons required in the heavier elements.

With the addition of the extra electrons the proposed nuclear structure becomes a diamond type lattice of electron pairs joined by protons.

The method of coupling proton spins appears to be that demanded by the quantum mechanic rule for vector combination.

BERKELEY, CALIFORNIA

NOTE

Filtering Disks of Sintered Pyrex Glass.—The recent development of the use of sintered Jena or quartz glass disks and alundum plates for filtration, in addition to numerous other applications,[1] makes it very desirable to devise similar material which can readily be fused to pyrex glass. For some time alundum disks have been used in pyrex apparatus, but it is very difficult to obtain a dependable Alundum to pyrex contact. The fact that the two materials have different coefficients of expansion results either in an imperfect junction or in a dangerous strain even after the most careful cooling. The use of sintered pyrex disks would avoid these difficulties. Although these plates are not available from commercial sources, we are able to recommend a procedure whereby a person can, with a little care, prepare for himself satisfactory filtering disks of sintered pyrex.

Scrap pyrex glass crushed to a convenient size is ground to a fairly fine powder either in a pyrex or porcelain mortar or in a grinding machine. The powder is separated into several portions by sifting, *e. g.:* (a) the coarse material which will not pass through a sieve with sixty meshes to the inch, and which should be reground; (b) the part that passes a sixty-mesh sieve, but not an eighty-mesh sieve, and which can be used for making coarse-grained filters; (c) the particles which fall through an eighty-mesh sieve, but do not pass a one hundred-mesh net; (d) the fine powder which is not held by a one hundred-mesh sieve. When a metallic grinding machine is used, the third and especially the fourth portions are contaminated with finely divided metal which gives the disks a grayish cast unless it is removed by acid before sintering.

The apparatus for sintering includes a cylindrical mold, for which we used about one centimeter of nickel tubing with an internal diameter of one centimeter. As indicated in the figure, this cylinder rests on a nickel plate about two and a half centimeters square. The plate may be made large enough to accommodate molds of various sizes if this is desired. In suitable holes drilled at the corners of the plate are fastened nichrome wires arranged to serve both as a handle and as a guide and stay for the

[1] **Prausnitz,** *Arch. Pharm.*, **268,** 170–184 (1930); *Chem.-Ztg.*, **53,** 935–6 (1930).