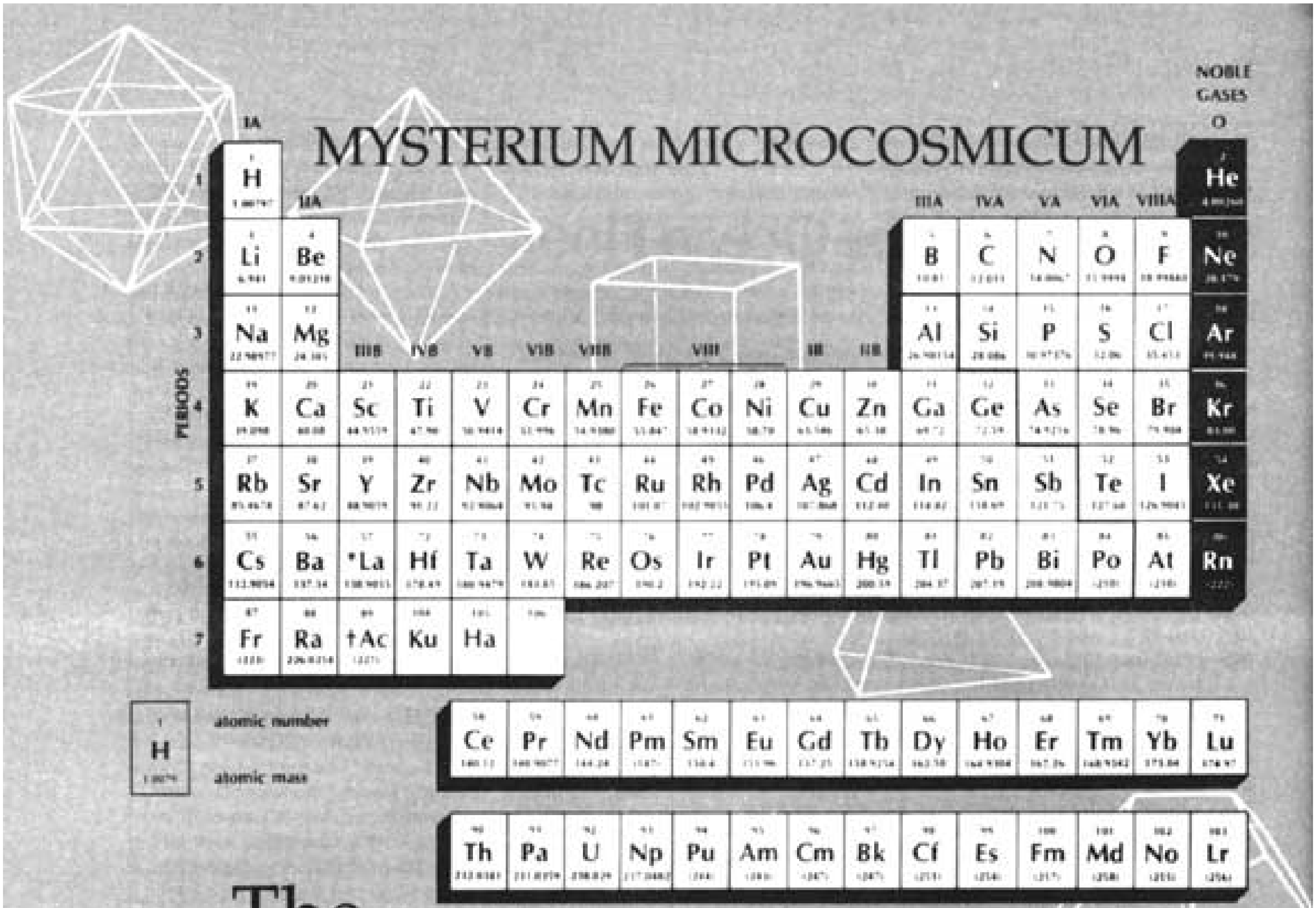


The Geometric Basis for the Periodicity of the Elements

by Laurence Hecht

Although an elaborately refined set of rules exists to explain many phenomena observed at the atomic level, there is no satisfactory model of the atomic nucleus, the central core of the atom around which a precise number of negatively charged electrons is presumed to orbit. Any attempt to produce a coherent theory of orbiting electrons, without knowledge of the structure around which these orbits are constructed, would seem to be doomed to failure. Nonetheless, a highly elaborated algebraic theory of the atom, designed to account for a mass of data gathered from spectral analysis and other operations, does exist in the form of the quantum mechanical model. Most of this theory presumes no more about the atomic nucleus than that it contains a certain number of positively charged particles agglomerated in a central mass.

It would seem past time to arrive at a more developed theory of the atomic nucleus, and from there to rework the cumbersome and very problematical portrait of the atom that the quantum mechanical model has bequeathed us. University of Chicago physicist Dr. Robert J. Moon has proposed a geometrical model of the nucleus to do just that.[1]

Moon has produced a synthetic geometric construction of the periodic table of the elements in such a way as to account geometrically, in a first approximation, for the existence of the 92 naturally occurring elements and many of their physical properties. I have added to Moon's hypothesis a construction that provides a nonmagical cause for the Magic Number theory (the theory that attempts to account for changes in the nuclear properties of the elements), and I have reexamined in a new light some of the original data used to establish the periodicity of the elements. It is hoped that a further working out of this approach will offer a causal explanation for the electron shells and orbitals and so provide a more solid grounding, as it were, for a new quantum mechanics.

Professor Moon's Hypothesis

The existing dogma of nuclear physics requires us to believe that protons, being all of positive charge, will repel each other up to a certain very close distance corresponding to the approximate size of the nucleus. At that point, the theory goes, a binding force takes hold, and forces the little particles to stick together, until they get too close, at which point they repel again. Thus is the holding together of the protons in the nucleus accounted for.

Disdaining such arbitrary notions of "forces," and preferring to view the cause of such phenomena as resulting from a certain characteristic of physical space-time, Moon and the author demanded a different view. Considerations of "least action" suggested to Moon a symmetric arrangement of the charges on a sphere, while the number of such charges (protons), and the existence of shells and orbitals beyond the nucleus (electrons) suggested a nested arrangement of such spheres. Our belief that the universe must be organized according to one set of laws, applying as well to the very large and the very small, suggested that the harmonic proportions which the astronomer Johannes Kepler found in the ordering of the solar system would also be evident in the microcosmic realm, so we looked for this also in the arrangement of the nucleus.

We were led immediately to the five regular or Platonic solids—the tetrahedron, cube, octahedron, icosahedron, and dodecahedron (Figure 1). Moon developed a nested model, using the Platonic solids to define the atomic nucleus in much the same way that Kepler determined the orbits of the planets of the solar system. In Moon's "Keplerian atom," the 92 protons of the naturally occurring elements are determined by the vertices of two identical pairs of nested solids. Before elaborating the construction of this model, let us review the properties of the Platonic solids.

The five Platonic solids define a type of limit of what can be perfectly constructed in three-dimensional space. These solids are the only ones that can be formed with faces that are equal, regular plane figures (the equilateral triangle, square, and pentagon) and equal solid angles. A derivative set of solids, the semiregular or Archimedean solids, can be formed using two or three regular plane figures for faces in each figure. Both species of solids can be circumscribed by a sphere, the *circumsphere*, such that all the vertices of the figure are just touched by the sphere. The Platonic solids are unique in that each has just one sphere, the *insphere*, that will sit inside, just tangent to the interior of each one of the faces (Figure 2). The Archimedean solids must have either two or three distinct inspheres.

A third species of sphere, the *midsphere*, is formed by a radius connecting the center of the solid with the midpoint of each of its edges, and is associated with both the Platonic and Archimedean solids (Figure 3). The surface of the midsphere pokes both inside and outside the faces of the figure. Two of the Archimedean solids, the cuboctahedron and the icosidodecahedron, actually are formed by the midspheres of the Platonic solids.

The surfaces of the Platonic solids and related regular solids represent unique divisions of the surface of a sphere according to a least-action principle.[2]

How the Model Works

In Moon's "Keplerian atom," the 92 protons of the naturally occurring elements are determined by two identical sets of nested solids each containing 46 vertices. Moon's proposed arrangement is as follows:

Two pairs of regular Platonic solids, the cube-octahedron pair and the icosahedron-dodecahedron pair, may be called duals: one will fit inside the other such that its vertices fit centrally on the faces of the other, each fitting perfectly inside a sphere whose surface is thus perfectly and symmetrically divided by the vertices (Figure 4). The tetrahedron is dual unto itself and therefore plays a different role.

The four dual solids may be arranged in a nested sequence—cube, octahedron, icosahedron, dodecahedron—such that the sum of the vertices is 46 (Figure 5):

Cube	= 8
Octahedron	= 6
Icosahedron	= 12
Dodecahedron	= 20
Total	= 46

The nesting of the cube-octahedron and icosahedron-dodecahedron is clear from a study of the duality relationship. However, to fit the first pair of duals into the next pair appears at first to be a problem: The 6 vertices of the octahedron do not fit obviously into the 20 faces of the icosahedron, nor could the fourfold axial symmetry of the former be simply inserted into the fivefold axial symmetry of the latter. Yet, the octahedron may still be placed within the icosahedron in a manner that is fitting and beautiful. Six vertices of the octahedron may be placed near to six vertices of the icosahedron, such that the distance from the nearby vertex of the icosahedron to the edge opposite it is divided in the divine proportion [$\phi = (\sqrt{5} + 1)/2 =$ approximately 1.618] (Figure 6).[3]

The axis of the cube-octahedron pair is thus skew to the axis of the icosahedron-dodecahedron dual, and a special relationship exists at this point of singularity in the model.

Examining the edges of the figures so nested, and designating the length of the smallest inner figure, the cube, as unity (1), we find:

Edge of cube	1.00
Edge of octahedron	2.12
Edge of icosahedron	1.89
Edge of dodecahedron	1.618

Then taking the radius of the sphere circumscribing the

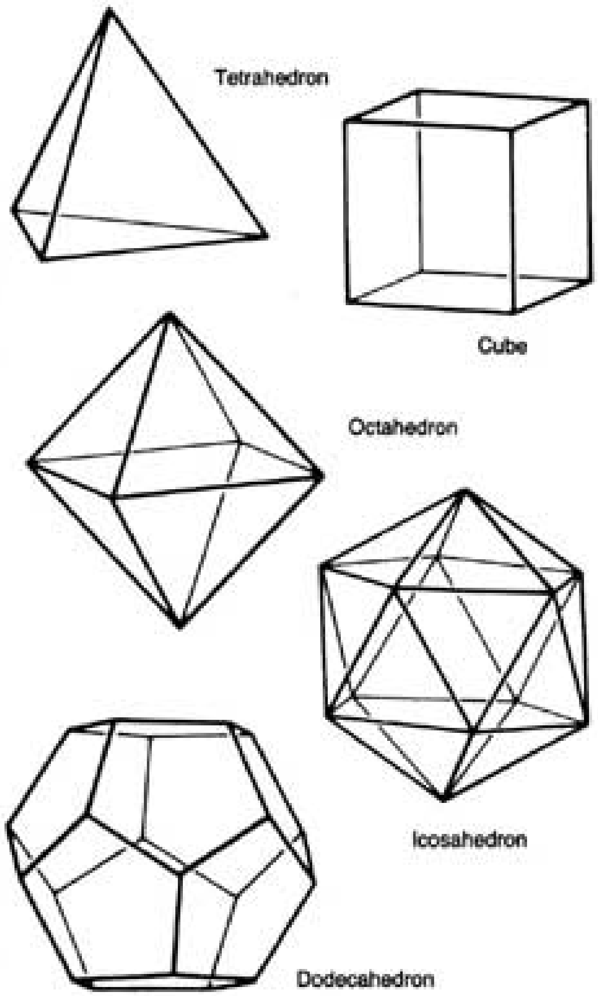


Figure 1
THE FIVE PLATONIC SOLIDS
The five regular or Platonic solids represent a limit of constructibility in three-dimensional space. Euler's formula correlates the relationship of vertices (V), faces (F), and edges (E) for each solid as $V + F = E - 2$.

Polyhedron Name	Vertices	Faces	Edges
Tetrahedron	4	4	6
Cube	8	6	12
Octahedron	6	8	12
Icosahedron	12	20	30
Dodecahedron	20	12	30

cube to be unity, the radii of circumscribing spheres stand in proportion:

Cube	1.00
Octahedron	1.733
Icosahedron	2.187
Dodecahedron	2.618

Note that the ratio of edges between the inner and the outer figures is in the divine proportion. Also, the ratio of radii between inner and outer spheres is the square of the divine proportion (approximately 2.618).

Building the Nucleus

If we now take the vertices of the solids so arranged to be the singularities in space where the protons are found, a remarkable structure to the nucleus appears. First we see a sort of periodicity in the nucleus, formed by the completion of each of the "shells," as we might call the circumspheres of the cube, octahedron, icosahedron, and dodecahedron.

Let us first look at which unique elements correspond to the completed "shells":

Oxygen (8)	= completed cube
Silicon (14)	= completed octahedron
Iron (26)	= completed icosahedron
Palladium (46)	= completed dodecahedron
. . .	. . .
Uranium (92)	= completed twin nested figures

Thus, highly stable oxygen, which makes up 62.55 percent of the total number of atoms in the Earth's crust, and silicon, which makes up 21.22 percent, are represented by the first two completed figures. Together these two elements account for 84 percent of all the atoms in the Earth's crust. Although the curve of the relative abundance of the elements declines exponentially with increasing atomic number, iron, the completed icosahedron, is three orders of magnitude higher than the elements near it on the atomic number scale and makes up 1.20 percent of the atoms in the Earth's crust, and 5 percent by weight. Iron is also a most unique element in that it represents the minimum of the mass packing fraction and the endpoint of the natural fusion process.

A look at the graph of atomic volumes (Figure 7) is also very thought-provoking in this regard. The periodicity exhibited in the atomic volumes (atomic weight divided by the density of each element) was being examined by the German scientist Lothar Meyer in 1869 at the time he and Russian scientist Dmitri Mendeleyev simultaneously developed the concept of periodicity. It was later discovered that other physical properties—compressibility, coefficient of expansion, and reciprocal melting point—obey the same periodicity (Figure 8).

Most textbooks discuss the maxima of these properties occurring at atomic numbers 3, 11, 19, and so on, the so-called Group 1a, or alkalies. Moon's construction drew my attention, however, to the minima. The minima occurring in the range of 4-8, 13-14, 26, and 46 suggest that a minimal space-filling and maximal structural stability occur at the completion of each Platonic solid within the nucleus. We shall see later how a second periodicity of the neutron structure can be derived from the same geometric picture to account for the maxima observed, thus defining both the maxima and minima of these periodic properties from within the nucleus.

Fission of the Nucleus

Moon's model beautifully accounts for the process of fission. Filling out with protons the outermost figure, the dodecahedron, brings us to palladium, atomic number 46, an element that has an unusually symmetric character. First, a look at the table of electron configurations (Table 1) shows palladium to be the only element in which an outer electron shell, previously occupied, is completely abandoned by the extra-nuclear electrons. Second, palladium is a singularity in the fission process, falling at a minimum on the table of distribution of fission products. Palladium also marks the boundary point for the sort of fission that occurs with very high energy (for example, protons of billion-electron-volt energies), when nuclei are split up into two parts of similar size. Silver, atomic number 47, is the lightest of the elements that may split this way.

To go beyond palladium in our model, a twin structure joins at one of the faces of the dodecahedron (Figure 9) and begins to fill up its vertex positions with protons, beginning on the outermost figure. (Silver, atomic number 47, is the first.) Six positions are unavailable to it—the five vertex positions on the binding face of the second figure and the one at the face center where a vertex of the inscribed icosahedron pokes through.

Thus on the second nested dodecahedron figure, 15 out of 20 of the dodecahedral vertices are available, and 11 out of 12 of the icosahedral vertices. We now fill 11 of the available dodecahedral vertices, thus creating 47-silver and continuing through 57-lanthanum. At this point, one face of the dodecahedron remains open to allow filling of the inner figures. The cube and octahedron fill next, producing the 14 elements of the lanthanide, or rare earth series (58-cerium to 71-lutetium). Placing the proton charges on the inner solids causes a corresponding inward pulling of the electron orbitals. Thus, the otherwise unaccounted for filling of the previously unfilled 4-*f* orbitals (see Table 1), and the mystery of the period of 14 for the rare earths are explained.

The figure is complete at radon, atomic number 86, the last of the noble gases. To allow the last six protons to find their places, the twin dodecahedra must open up, using one of the edges of the binding face as a "hinge" (Figure 10).

The element 87-francium, the most unstable of the first 101 elements of the periodic system, tries to find its place on the thus-opened figure, but unsuccessfully so. Less than one ounce of this ephemeral substance can be found at any one time in the totality of the Earth's crust. Then 88-radium, 89-actinium, and 90-thorium find their places on the remaining vertices. Two more transformations are then necessary before we reach the last of the 92 naturally occurring elements.

To allow for 91-protactinium, the hinge is broken, and the figure held together at only one point (Figure 11).

The construction of 92-uranium requires that the last proton be placed at the point of joining, and the one solid slightly displaced to penetrate the other, in order to avoid two protons occupying the same position. This obviously unstable structure is ready to break apart at a slight provocation. And so we have the fission of the uranium atom, as hypothesized by Dr. Robert J. Moon, one of the scientists who first made fission happen in a wartime laboratory on the University of Chicago football field.

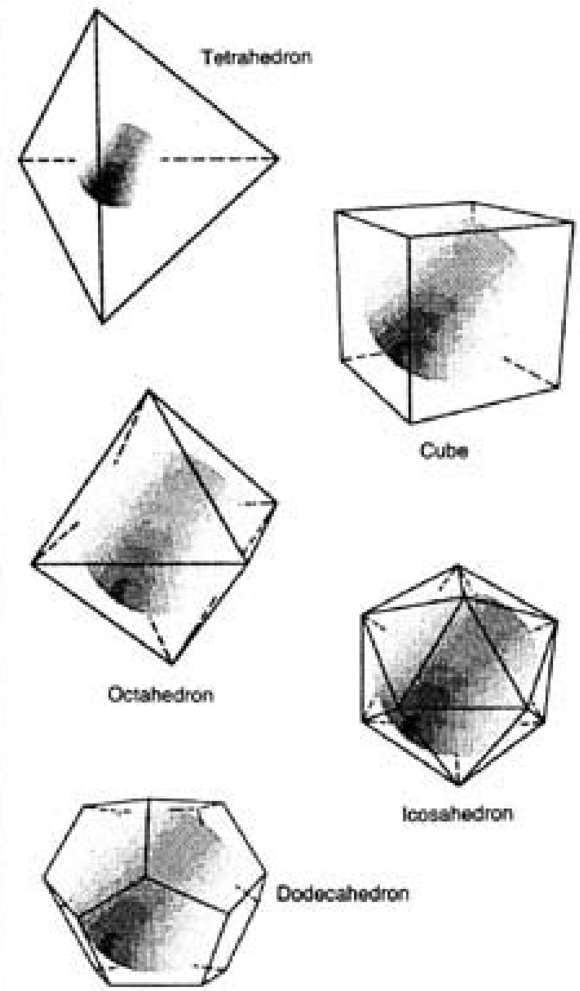


Figure 2
INSCRIBING THE PLATONIC SOLIDS
Both the Platonic and Archimedean solids may be circumscribed by a single sphere (the circumsphere), but the five Platonic solids are unique in having only one sphere that may be inscribed within them (the insphere), as shown.

How Free Is Free Space?

Before proceeding, let us pause to consider the implications of this model. The sympathetic reader is perhaps intrigued with the model, but probably wondering whether we actually intend him to believe that protons find their way into these pretty little shapes and if so, how and why they do it.

The answer to the first part of the question is, yes. As to the second part, the reader would best find the answer by

Table 1
THE ELECTRON ORBITS OF THE ELEMENTS
(Atomic numbers 1–54)

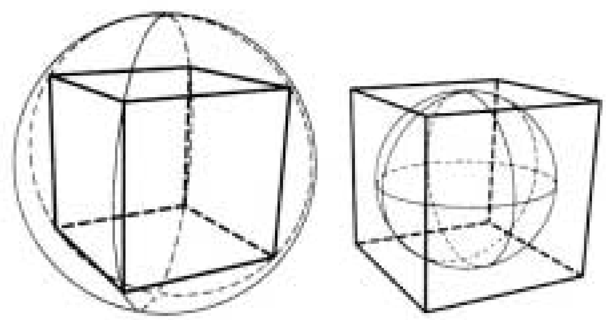
Atomic No.	Element	K 1 s	L 2 s p	M 3 s p d	N 4 s p d f	O 5 s p d f
1	H	1				
2	He	2				
3	Li	2	1			
4	Be	2	2			
5	B	2	2 1			
6	C	2	2 2			
7	N	2	2 3			
8	O	2	2 4			
9	F	2	2 5			
10	Ne	2	2 6			
11	Na	2	2 6	1		
12	Mg	2	2 6	2		
13	Al	2	2 6	2 1		
14	Si	2	2 6	2 2		
15	P	2	2 6	2 3		
16	S	2	2 6	2 4		
17	Cl	2	2 6	2 5		
18	Ar	2	2 6	2 6		
19	K	2	2 6	2 6 ..	1	
20	Ca	2	2 6	2 6 ..	2	
21	Sc	2	2 6	2 6 1	2	
22	Ti	2	2 6	2 6 2	2	
23	V	2	2 6	2 6 3	2	
24	Cr	2	2 6	2 6 5*	1	
25	Mn	2	2 6	2 6 5	2	
26	Fe	2	2 6	2 6 6	2	
27	Co	2	2 6	2 6 7	2	
28	Ni	2	2 6	2 6 8	2	
29	Cu	2	2 6	2 6 10*	1	
30	Zn	2	2 6	2 6 10	2	
31	Ga	2	2 6	2 6 10	2 1	
32	Ge	2	2 6	2 6 10	2 2	
33	As	2	2 6	2 6 10	2 3	
34	Se	2	2 6	2 6 10	2 4	
35	Br	2	2 6	2 6 10	2 5	
36	Kr	2	2 6	2 6 10	2 6	
37	Rb	2	2 6	2 6 10	2 6 ..	1
38	Sr	2	2 6	2 6 10	2 6 ..	2
39	Y	2	2 6	2 6 10	2 6 1	2
40	Zr	2	2 6	2 6 10	2 6 2 ..	2
41	Nb	2	2 6	2 6 10	2 6 4* ..	1
42	Mo	2	2 6	2 6 10	2 6 5 ..	1
43	Tc	2	2 6	2 6 10	2 6 6 ..	1
44	Ru	2	2 6	2 6 10	2 6 7 ..	1
45	Rh	2	2 6	2 6 10	2 6 8* ..	1
46	Pd	2	2 6	2 6 10	2 6 10* ..	0
47	Ag	2	2 6	2 6 10	2 6 10 ..	1
48	Cd	2	2 6	2 6 10	2 6 10 ..	1
49	In	2	2 6	2 6 10	2 6 10 ..	2 1
50	Sn	2	2 6	2 6 10	2 6 10 ..	2 2
51	Sb	2	2 6	2 6 10	2 6 10 ..	2 3
52	Te	2	2 6	2 6 10	2 6 10 ..	2 4
53	I	2	2 6	2 6 10	2 6 10 ..	2 5
54	Xe	2	2 6	2 6 10	2 6 10 ..	2 6

* Note irregularity.

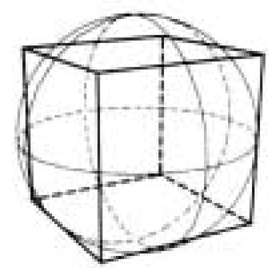
Source: Adapted from Laurence S. Foster's compilation in the *Handbook of Chemistry and Physics* (Boca Raton, Fla.: CRC Press, 1980), p. B-1.

asking himself a question: How otherwise would he expect to find elementary particles arranged? The reader probably does not have an answer, but might, if pressed, retort: "Any one of a million possible ways, but why yours?" The reader who answers this way has made some assumptions about the nature of space-time and matter, probably without even realizing it. He has assumed that "things," like protons, are pretty much free to move about in "empty space," except insofar as certain universal "forces," like "charge," "gravitation," and the like might prevent them from doing so. These are assumptions that have no place in thinking about such matters as these.

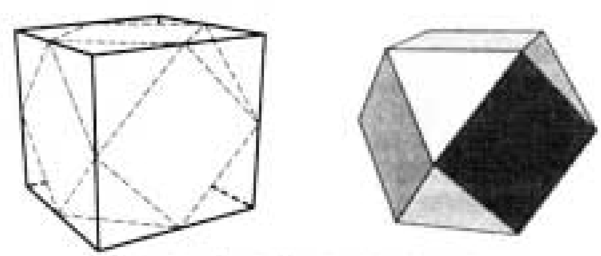
Take one example, which is relevant to the thinking that went into the development of this nuclear model:



(a) Cube with circumsphere and insphere



(b) Cube with midsphere



(c) 12 points of cube forming the cuboctahedron

Figure 3
FORMING THE CUBOCTAHEDRON FROM THE CUBE
The cube is shown (a) with the circumsphere, which is internally tangent to the 8 vertices, and insphere, which is tangent to the interior of the 6 faces. The midsphere (b) is tangent to the midpoints of the 12 edges. When these 12 points are connected (c), the figure formed is the Archimedean solid known as the cuboctahedron. The midsphere of the cube is the circumsphere of the cuboctahedron.

There is a certain maximum-minimum relationship in electrical conductivity. There is the impedance of free space of 376 ohms, a value used for the tuning of antennae, for instance. There is also the "natural resistance" of 25,813 ohms, demonstrated by Nobel prize winner Klaus von Klitzing in his experiments with very thin semiconductor surfaces (see *Fusion*, May-June 1986, pp. 28-31). The ratio of the two is 1: 68.5, and when the pairing of electrons is allowed for, it is seen to be twice this, or 1:137. The same ratio also appears in the fine structure constant and in the ratio of the velocity of an electron in the lowest orbit to the velocity of light. Von Klitzing also found a quantization in his results. The resistance reached plateaus and appeared as a step function downward from the maximum, suggesting a discrete relationship between the number of electrons and impedance.

The most important thing to observe is that there is a continuity of relationship between the impedance of "free space" (the vacuum) and the resistance found in a thin semiconductor sheet. The point is elaborated in the accompanying article on the subject written by Moon (page 26). We are led to question how "free" is free space. Indeed, the very idea of empty space, filled by particulate matter, must come into question. We look instead to identify the appropriate geometry or curvature of space-time. A proper solution would lead immediately to a solution of the puzzle of superconductivity, and a great many more problems facing science today.

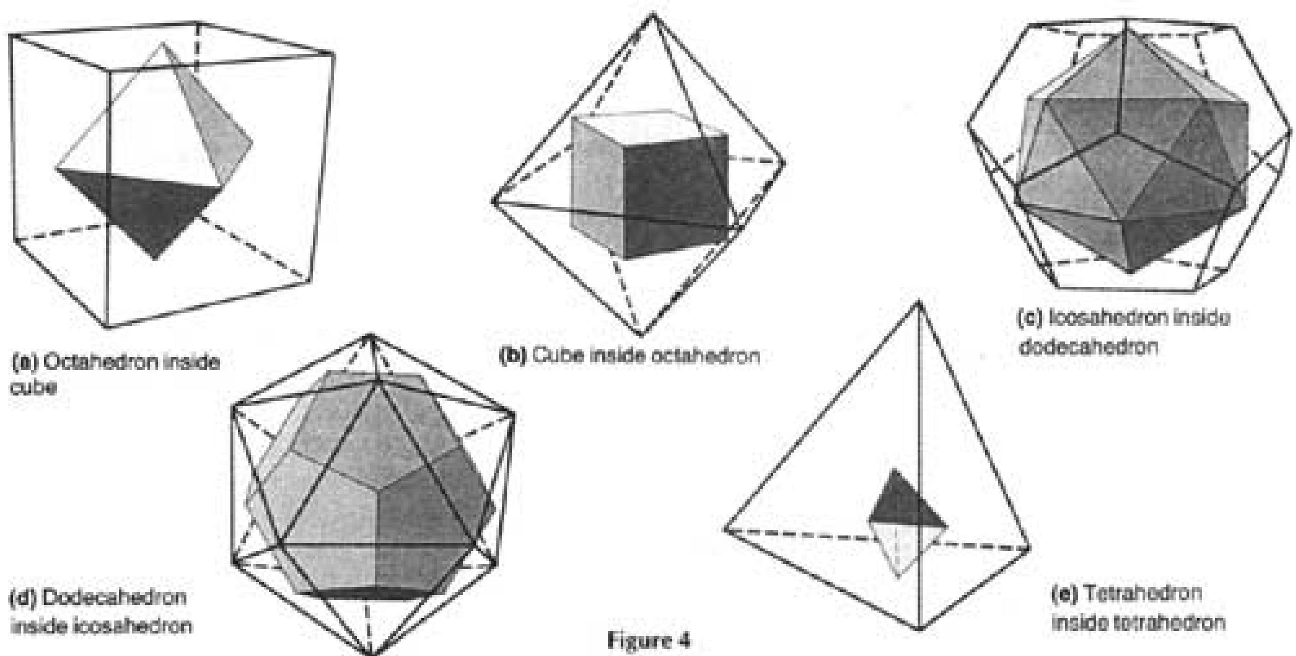
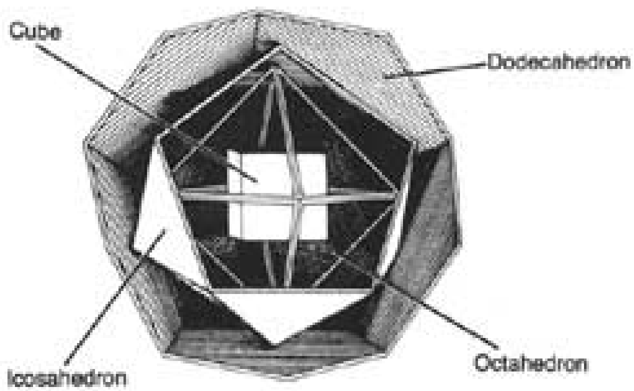
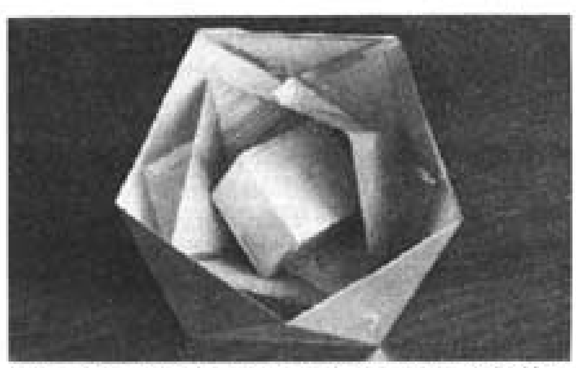


Figure 4
THE PLATONIC DUALS
The cube and octahedron are dual, meaning that they fit one inside the other (a, b). Similarly, the icosahedron and dodecahedron are dual (c, d). The tetrahedron is dual to itself (e).





This working model of the four nested solids was made for Moon by George Hamann out of used offset printing plates. For information on obtaining copies, see page 5.

Figure 5
The sequence of four solids whose 46 vertices form half of the "Keplerian atom."

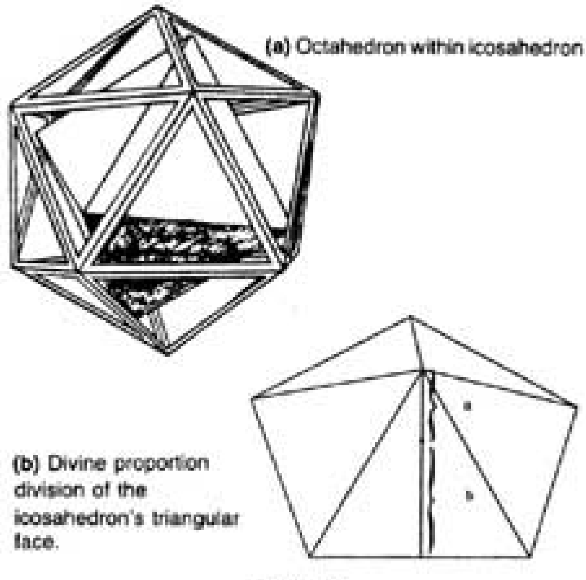
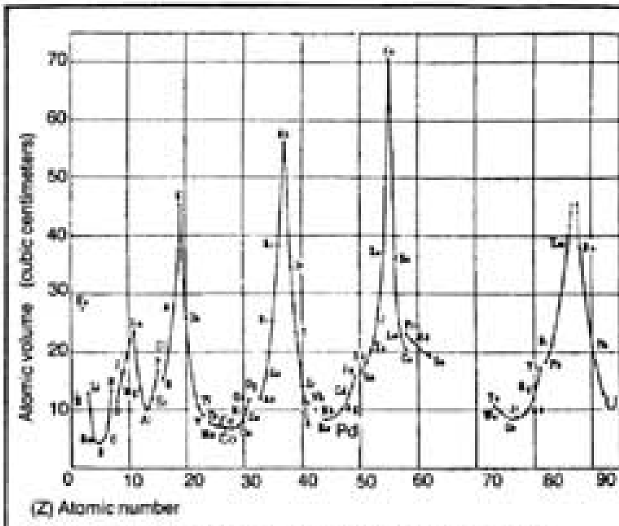


Figure 6
THE OCTAHEDRON INSIDE THE ICOSAHEDRON
The octahedron fits within the icosahedron (a) such that 6 of the 20 faces of the icosahedron receive vertices of the octahedron. The vertices strike the triangular face of the icosahedron (b) so as to divide the altitude line in the divine proportion. Thus, a/b = b/(a + b).



Source: Arnold Sommerfeld, *Atomic Structure and Spectral Lines*, p. 144.

Figure 7
PERIODICITY OF ATOMIC VOLUME
The periodicity of the atomic volumes (the ratio of atomic weight/density) of the elements guided the 19th-century German scientist Lothar Meyer in developing the periodic table. The maxima at atomic numbers 3, 11, 19, 37, 55, and 87 identify the Group 1a elements that begin each period. Notice how minima occur at or near the atomic numbers 8, 14, 26, 46, which mark the completed proton shells.

Implications for the Periodic Table

We have hinted in some ways—for example, in the case of the rare earths—how such an arrangement of the nucleus might be reflected in the arrangement of extra-nuclear electrons. It remains the case, however, that the *periodicity of physical and chemical properties*, as demonstrated in the crowning achievement of 19th and early 20th century chemistry, the periodic table of the elements, is not the same as the *periodicity of the proton shells*. The latter, we have shown, follow the sequence 8, 14, 26, 46, as determined by the Platonic solids. The former are governed by the great periods of 18 and 32, and the small periods of 8, once called the octets.

Years after the establishment of the periodic table, its truth was verified by the data of spectroscopy, which established that the extra-nuclear electrons are found in shells (labeled *K, L, M, N,* and so on), each containing one or more subshells, designated *s, p, d,* and *f* from the appearance of their spectral lines. The "occupancy level" of each shell and subshell is well established and can be seen in the electron configurations in Table 1. The ordering of successive subshells, as follows,

2	= 2
2, 6	= 8
2, 6	= 8
10, 2, 6	= 18
10, 2, 6	= 18
14, 10, 2, 6	= 32

corresponds to the ordering of the number of elements that can be seen in the periods (rows) in the table of the elements—the small and great periods.

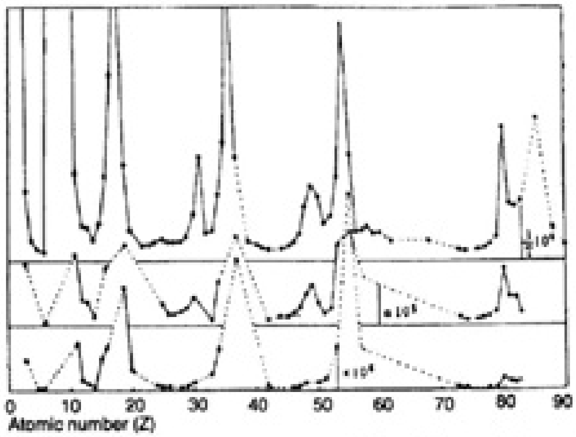
What causes this number series is one of the great mysteries. Rydberg, one of the early contributors to the development of quantum theory, was fond of presenting it in a manner which the great German physicist of the time, Arnold Sommerfeld, characterized as "the cabalistic form":

$$2 \times 1^2 = 2$$
$$2 \times 2^2 = 8$$
$$2 \times 3^2 = 18$$
$$2 \times 4^2 = 32.$$

'Magic Numbers'

The modern theory of the atom is also premised on another mystery series, this one more aptly named "Magic Numbers" by its discoverer, physicist Maria Goeppert-Mayer. Careful observation of the nuclear properties of the elements showed certain patterns that seemed to abruptly change at certain key elements. Goeppert-Mayer noticed that whether we were looking at the atomic number (*Z*), which tells us the number of protons in the nucleus, or the number of neutrons (*N*), or the sum of the two, which is known as the mass number (*A*), there were certain so-called Magic Numbers that identified abrupt changes in nuclear properties. These numbers are:

2, 8, 20, 28, 50, 82, 126.



Source: Arnold Sommerfeld, *Atomic Structure and Spectral Lines*, p. 145.

Figure 8
OTHER PERIODIC PROPERTIES OF THE ELEMENTS
Many other physical properties of the elements, including compressibility (bottom line), coefficient of expansion (middle), and reciprocal melting point (top), obey the same periodicity as atomic volume.

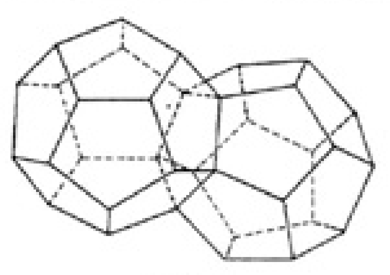


Figure 9
THE TWIN DODECAHEDRA
To go beyond palladium (atomic number 46), which is represented by the completed dodecahedron, an identical dodecahedron joins the first dodecahedron at a face. When fully joined in this way, the two figures represent the nucleus of radon (atomic number 86).

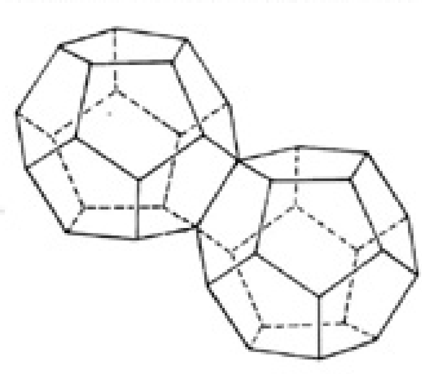


Figure 10
HINGING THE TWIN DODECAHEDRA
To go beyond radon (atomic number 86), the twin dodecahedra open up, using a common edge as if it were a hinge.

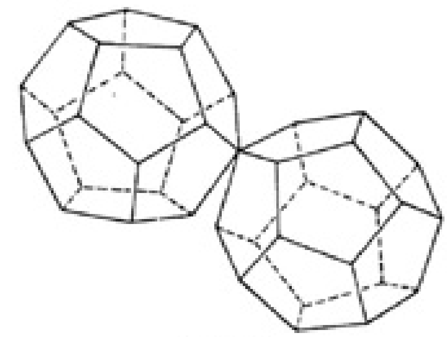


Figure 11
BREAKING THE HINGE
To create 91-protactinium, the hinge is broken at one end, staying attached at the other end.

An element containing such a Magic Number either as its atomic number (for example, 2 for helium, or 82 for lead), or its neutron number (also 2 for helium, or 8 for oxygen, or 126 for lead or bismuth), or its mass number (for example, 20 for neon, or 28 for silicon) is likely to manifest an abrupt change in nuclear properties from its nearby neighbors in the periodic table. This is not a hard-and-fast rule, but a tendency.

But what can be the cause for this strange series of numbers? Can it be that the same Creator who built into the structure of the atom the simple and harmonious arrangement of the 92 protons, which we have shown here, would leave to chance the configuration of the rest of his creation?

A Hypothesis on Neutron Configuration

I could not believe this, and so I struggled with the problem, until I had a solution. I had already noticed one peculiar thing about the Magic Numbers—the first-order differences of part of the sequence corresponds to the numbers of the edges of the Platonic solids. Thus, $8 - 2 = 6$, the edges of the tetrahedron; $20 - 8 = 12$, the number of edges for the cube and octahedron; and, skipping 28, $50 - 20 = 30$, the number of edges in the icosahedron and dodecahedron.

It was necessary, also, that the neutrons have a lawful place in the structure of the nucleus, for otherwise, why should some isotopes exist in abundance and others not? However, lacking charge, the neutrons would not have to have the same degree of symmetry as the protons. It was while considering the question why iron and palladium, two key singularities in the proton structure of the nucleus, did not appear as Magic Numbers that the idea for a lawful placement of the neutrons within the hypothesized structure of the proton shells came to me.

Iron has 30 neutrons, palladium 60. The sum of the edges of the tetrahedron (6), cube (12), and octahedron (12) is equal to 30. The tetrahedron fits within the cube such that the midpoints of its edges lie one on the center of each cubic face (Figure 12). Within the tetrahedron, can sit an-

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DR. ROBERT J. MOON:

'Space Must Be Quantized'

Robert J. Moon, professor emeritus at the University of Chicago, discussed the idea that led to his hypothesis of the geometry of the nucleus in an interview published in Executive Intelligence Review, *Nov. 6, 1987. His remarks are excerpted here.*

The particular experiment that provided the immediate spark leading to the development of my model of the nucleus was one by Nobel Prize winner Klaus von Klitzing.

Von Klitzing is a German who looked at the conductivity of very thin pieces of semiconductor. A couple of electrodes are placed on it. The electrodes are designed to keep a constant current running through the thin semiconductor strip. A uniform magnetic field is applied perpendicular to the thin strip, cutting across the flow of the electron current in the semiconductor strip. This applied magnetic field, thus, bends the conduction electrons in the semiconductor so that they move toward the side. If the field is of sufficient strength, the electrons become trapped into circular orbits.

Philip Ulanowsky

This alteration of the paths of the conduction electrons produces what appears to be a charge potential across the strip and perpendicular to the original current flow, producing a resistance. If you measure this new potential as you increase the magnetic field, you find that the horizontal charge potential will rise until a plateau is reached. You can continue to increase the magnetic field without anything happening, within certain boundaries, but then once the magnetic field is increased beyond a certain value, the potential will begin to rise again until another plateau is reached, where, within certain boundaries, the potential again does not increase with an increasing magnetic field.

What is being measured is the Hall resistance, the voltage across the current flow, horizontal to the direction of the original current, divided by the original current.

All of this was done by von Klitzing at liquid hydrogen temperatures to keep it cool and prevent the vibration of particles in the semiconductor lattice, a silicon semiconductor. The current was kept constant by the electrodes embedded in it.

Under these special conditions, as the current is plotted as a function of the magnetic field, we find that plateaus emerge. There are five distinct plateaus. At the highest field strength the resistance turns out to be 25,812.815 ohms. As we reduce the field, we find the next plateau at 12,906 ohms, and so on, until after the fifth, the plateaus become less distinct.

The theory is that the strong magnetic field forces the electrons of a two-dimensional electron gas into closed paths. Just as in the atomic nucleus, only a definite number of rotational states is possible, and only a definite number of electrons can belong to the same state. This rotational state is called the Landau level.

What we have here is a slowly increasing magnetic induction, and resistance increases until plateau values are found. At these values, there is no further drop in voltage over a certain band of increased magnetic induction. Some electrons now appear to travel through the semiconductor as if it were a superconductor.

Dr. Robert J. Moon: "I began to conclude that there must be structure in space, and that space must be quantized."

The question I asked myself was, why at higher field strengths did no more plateaus appear? Why did no higher plateau appear, for example, at 51,625 ohms? At the lower end it was clear what the boundary was—at the point at which six pairs of electrons were orbiting together, the electrons would be close-packed, but the magnetic field was too weak to create such a geometry. However, I asked myself what the limit was at the upper end.

This was what led to my model of the structure of the atomic nucleus. I started out by considering that the orbital structure of the electrons would have to account for the occurrence of the plateaus von Klitzing found, and I realized that the electrons had to be spinning together in pairs as well as orbiting. That was the significance of the upper boundary occurring at the value of 25,000-plus ohms.

I first concluded that this happens because the electron has a spin. It spins around its axis and a current is produced by the spin, and the spinning charges produce a little magnet.

According to Ohm's law, the current is equal to the field divided by the resistance, so that the resistance is equal to the field divided by the current. Von Klitzing found that the resistance in the last plateau was 25,812 ohms. I wanted to find out why this was the last distinct plateau.

First of all, I realized that the electrons seem to like each other very well. They travel around in pairs, especially in solid-state materials such as semiconductors. The spins will be in opposite directions, so that the north pole of one will match up with the south pole of the other.

Well, as long as we are limited to a two-dimensional space, then we see that by the time we get six pairs orbiting, we will have close packing. We see a geometry emerging, a structure of the electron flow in the semiconductor.

Now, the Hall resistance is determined by Planck's constant divided by the ratio of the charge squared. But we also find this term in the fine structure constant. Here, however, the Hall resistance must be multiplied by the term ($\mu_0 \times c$) [c = the velocity of light]; in other words, we must take the ratio of the Hall resistance to the impedance of free space. We can look at this as a ratio of two different kinds of resistance, that within a medium to that within free space itself.

This led me to look for a three-space geometry analogous to that which I had found in the two-dimensional space in which the Hall effect takes place. I began to wonder how many electron pairs could be put together in three-space, and I saw that one might go up to 68 pairs plus a single electron, in order to produce 137, which is the inverse of the fine structure constant.

Well, that's the way ideas begin to grow. Then it becomes very exciting. And then you begin to wonder, why these pairs, and why does this happen?

Space Has a Structure

The velocity of light times the permeability of free space is what we call the impedance of free space. There is something very interesting about the impedance of free space. According to accepted theory, free space is a vacuum. If this is so, how can it exhibit impedance? But it does. The answer, of course, is that there is no such thing as a vacuum, and what we call free space has a structure.

The impedance of free space is called reactive impedance, since we can store energy in it without the energy dissipating. Similarly, radiation will travel through a vacuum without losing energy. Since there is no matter in free space, there is nothing there to dissipate the energy. There is nothing for the radiation to collide with, so to speak, or be absorbed by, so the energy just keeps there. This is what we call the reactive component.

It is "reactive," because it does not dissipate the energy, but is passive. And this equals 376+ ohms. This reactive impedance is one of the important components of the equation of the fine structure constant.

The equations for the fine structure constant will always involve the ratio, 1:137, and actually this ratio, as Bohr looked at it, was the ratio of the velocity of the electron in the first Bohr orbit to the velocity of light. That is, if you multiply the velocity of the electron in the first Bohr orbit of the hydrogen atom by 137, you get the velocity of light.

The orbiting electron is bound to the hydrogen atom around which it is orbiting. This stuck in my mind for several years. Immediately as you begin looking at this ratio, you see that this is identical with the impedance in a material medium, like the semiconductor von Klitzing experimented with, compared to the permeability of space.

No Empty Space

Since the Hall resistance is dissipative, then we have here a ratio between two different kinds of resistance, a resistance within a material medium and a resistance of "space." That being the case, we are entitled to seek a geometry of space—or in other words, we are no longer able to talk about "empty space." From looking at von Klitzing's experiment, I was led to these new conclusions.

This is the equation for α, the fine structure constant:

$$1/\alpha = 2h/(e^2\mu_0 c).$$

Another conclusion I was able to draw, was why the number "2" appears in the fine structure constant. Well, it turns out that the 2 indicates the pairing of the electrons. And when you get this ratio, this turns out to be 1:137. So you have the ratio of the impedance of free space, which is nondissipative, over the impedance in a material media, as measured by von Klitzing, which is dissipative, giving you approximately 1:137. We have seen major advances in semiconductors in recent decades which permit us to make very accurate measurements of the fine structure constant.

Today, we have even better methods based on superconductors. In a superconductor, the impedance will be very low, like that of free space. There is no place for the electron in the superconductor to lose energy.

As a result of this, I began to conclude that there must be structure in space, and that space must be quantized. Of course, I had been thinking about these ideas in a more general way, for a long time, but looking at von Klitzing's work in this way, allowed me to put them together in a new way, and make some new discoveries.

other smaller tetrahedron, dual to its parent (Figure 13). The connection of the midpoints of the edges of the other four solids creates, respectively, the cuboctahedron—from the cube or octahedron—and the icosidodecahedron—from the icosahedron or dodecahedron (Figure 14).

These are the key concepts of geometry needed to see how the neutrons are lawfully placed on the already existing structure of the nucleus. Once this is done, it can be seen that the periodicity of Meyer and Mendeleyev's periodic table is completely coherent with this new view of the nucleus. *The points of completion of the proton shells define the points of greatest stability of the nucleus, reflected in the abundancy of these elements, while the completion of the neutron shells corresponds to the ends of the periods of the periodic table.* The neutron shells also have a highly symmetric and sometimes complete configuration in the elements for which the proton shells are complete. This is all readily seen in the table of neutron configurations I have hypothesized (Table 2).

The structure begins with a helium nucleus, or alpha particle—a tetrahedron containing two protons and two neutrons at its four vertices. To go on to the third element, lithium, the protons must move outward to start building up their first shell on the vertices of a cube. The two neu-

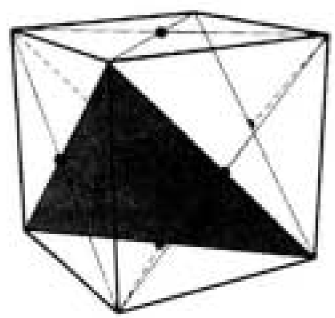

Figure 12
TETRAHEDRON INSCRIBED IN A CUBE
Every cube implies a tetrahedron. Four diagonally opposite vertices of the cube form the vertices of the tetrahedron. The six edges of the tetrahedron form the diagonals of the cube's faces, and their midpoints are equivalent to the center of the cubic faces.

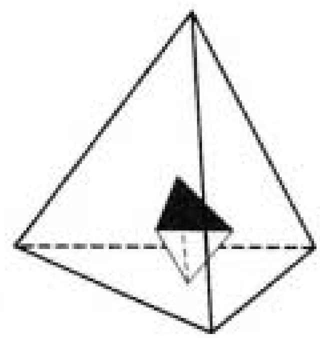

Figure 13
ALPHA PARTICLE AND TETRAHEDRON
The smaller dual tetrahedron, which represents the alpha particle, has an edge length only one third that of its parent.

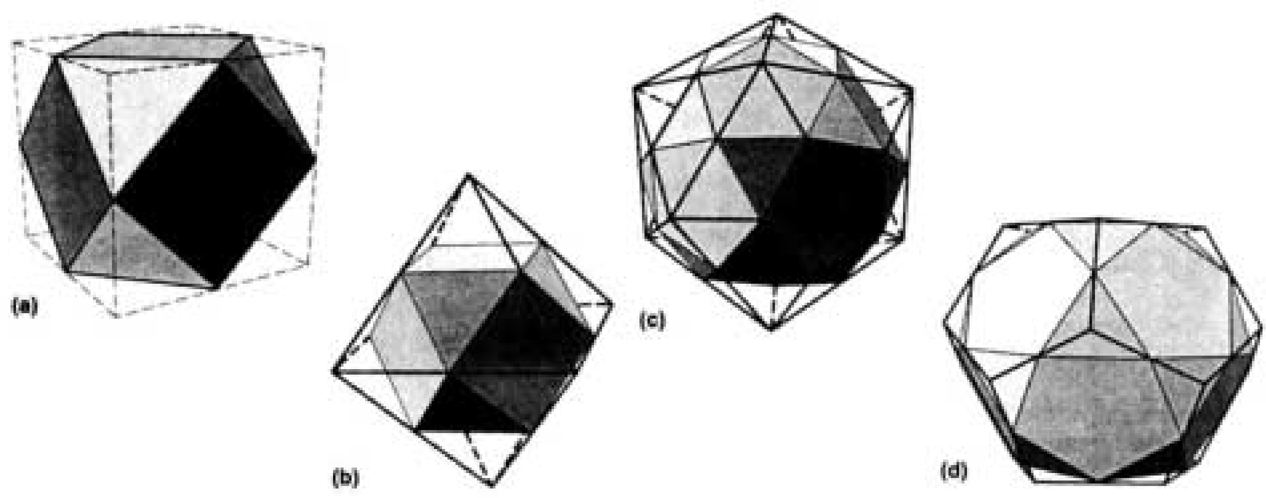

Figure 14
CUBOCTAHEDRON AND ICOSIDODECAHEDRON
The Archimedean solid known as the cuboctahedron can be derived by connecting the midpoints of the 12 edges of either the cube (a) or the octahedron (b). Similarly, the icosidodecahedron is derived by connecting the midpoints of either the icosahedron (c) or the dodecahedron (d).

trons that were on the vertices of the alpha particle have no need to leave. However, any additional neutrons will place themselves at the centers of the faces of the cube, which is the same place as the midpoints of the edges of the larger tetrahedron. (The smaller tetrahedron is called the alpha particle.) Thus, at 6-carbon-12, there are two neutrons on the alpha particle and four on the faces of the cube (Figure 15).[4] For clarity, here is another example: the proton structure of 8-oxygen-16 (Figure 16). Of the eight neutrons, two are on the inner alpha particle and six on the midpoints of the six edges of the larger tetrahedron (or, the same thing, the face centers of the cube), marking the completion of this shell. The eight protons locate on the eight vertices of the cube. Thus, not only is oxygen highly symmetrical with respect to its proton configuration, but also one of its neutron shells is complete.

Now, to go on to the end of the period, there are only two more places where the neutrons can go: that is, on the

Table 2
PROPOSED NEUTRON DISTRIBUTION CHART

Element	N=	Alpha particle	Edges of Tetrahedron	Edges of Cube	Edges of Octahedron	Edges of Icosahedron	
2-He-4	2	2	Complete period				
3-Li-7	4	2	2				
4-Be-9	5	2	3				
5-B-10	5	2	3				
6-C-12	6	2	4				
7-N-14	7	2	5				
8-O-16	8	2	6				Complete proton shell
9-F-19	10	4	6				
10-Ne-20	10	4	6				Complete period
11-Na-23	12	4	6	2			
12-Mg-24	12	4	6	2			
13-Al-27	14	4	6	4			
14-Si-28	14	4	6	4			Complete proton shell
15-P-31	16	4	6	6			
16-S-32	16	4	6	6			
17-Cl-35	18	4	6	8			
18-Ar-40	22	4	6	12			Complete period
19-K-39	20	4	6	10	0		
20-Ca-40	20	4	6	10	0		
21-Sc-45	24	4	6	12	2		
22-Ti-48	26	4	6	12	4		
23-V-51	28	4	6	12	6		
24-Cr-52	28	4	6	12	6		
25-Mn-55	30	4	6	12	8		
26-Fe-56	30	—	6	12	12		Complete proton shell
27-Co-59	32	—	6	12	12	2	
28-Ni-59	31	—	6	12	12	1	
29-Cu-64	35	—	6	12	12	5	
30-Zn-65	35	—	6	12	12	5	
31-Ga-70	40	—	6	12	12	10	
32-Ge-73	41	—	6	12	12	11	
33-As-75	42	—	6	12	12	12	
34-Se-79	45	—	6	12	12	15	
35-Br-80	45	—	6	12	12	15	
36-Kr-84	48	—	6	12	—	30	Complete period
37-Rb-85	48	—	6	12	12	18	
38-Sr-88	50	—	6	12	12	20	
39-Y-89	50	—	6	12	12	20	
40-Zr-92	52	—	6	12	12	22	
41-Nb-93	52	—	6	12	12	22	
42-Mo-96	54	—	6	12	12	24	
43-Tc-98	55	—	6	12	12	25	
44-Ru-101	57	—	6	12	12	27	
45-Rh-103	58	—	6	12	12	28	
46-Pd-106	60	—	6	12	12	30	Complete proton shell

remaining two vertices of the inner alpha particle. This is the configuration for 10-neon-20, the noble gas that ends the first small period. A similar situation, in which the neutron shells are completely filled, occurs with respect to the noble gases 18-argon-40 and 36-krypton-84, the latter with a slight perturbation.

At iron, the inner tetrahedron ceases to exist as a configuration for the neutrons, though, as we know, the configuration appears again as a mode of emission in the alpha decay of the heavier elements. Iron has an extraordinary symmetry for both its proton and neutron configurations, as shown in Table 2. Finally, at palladium, the symmetry is perfect and complete. The proton shells are entirely filled and so are those of the neutrons. Note that the neutrons always remain on the inside of the nucleus, one level deeper than the protons. Their existence outside this realm is precarious, where they have a half-life of only about 12 minutes.

The neutron configuration beyond palladium is structured on the same model, though it is not as simply represented since the figures making up the proton shells do not close until 86-radon. But the continuation of the same system all the way through the last natural element can be simply accounted for.

To close the case, let us take the last element, uranium. How, one might ask, can we account for uranium-238, which has 146 neutrons—considerably more than twice the 60 found in palladium? Recall that there were a few empty spaces left over on the faces of the icosahedron. When the octahedron was fit inside, its vertices took up only 6 of the 20 faces, leaving 14 open. Counting both "halves" of the uranium nucleus, that leaves 28 extra locations for the neutrons to fit symmetrically; 26 of them are used to create uranium-238, the preferred configuration. But uranium-240, the heaviest isotope of the last naturally occurring element, with a half-life of 14.1 hours, takes up all those possible places with its 148 neutrons.

Laurence Hecht, a geometer by avocation, worked closely with Robert J. Moon to elaborate Moon's hypothesis for the geometry of the nucleus.

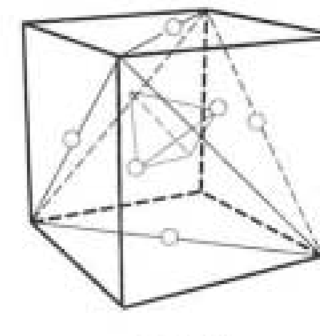

Figure 15
PROBABLE LOCATION OF CARBON NEUTRONS
In the author's scheme, the six neutrons in the carbon nucleus are positioned as shown: two on the vertices of the inner tetrahedron, four on the edge midpoints of the larger tetrahedron (which are the same as the face centers of the cube).

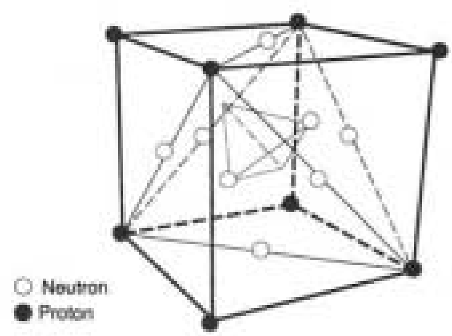

Figure 16
PROBABLE LOCATION OF THE OXYGEN-16 NEUTRONS AND PROTONS
Shown here are the likely locations of the eight neutrons (open) and eight protons (solid) in the oxygen-16 nucleus. There is a neutron on all six faces of the cube and on two of the four vertices of the alpha particle. Eight protons cover the eight vertices of the cube.

Notes

1. Dr. Moon developed his theory of the nucleus in spring 1986, shortly after his 75th birthday, while working at the Fusion Energy Foundation in Leesburg, Va. For a personal account of the development of his theory, see his two-part interview in the *Executive Intelligence Review*, Oct. 30, 1987, p. 31, and Nov. 6, 1987, p. 18.
2. All the Platonic solids can be formed by the intersections of great circles on a sphere, the great circle being the least-action path on the surface of the sphere, and the sphere the minimal three-dimensional volume created by elementary rotational action. The best way to see this is to consider the intersections of the great circles in a Torrianian, or Copernico-Pythagorean planetarium [cf. Johannes Kepler, *Mysterium Cosmographicum*, Dedicatory letter, trans. A.M. Duncan (New York: Abaris Press, 1981).]

   In the device constructed by Giovanni Torriani to demonstrate Kepler's nested solid model for the solar system, the vertices of the regular solids are formed by the intersections of great circles. Three great circles intersect doubly to form an octahedron. Six great circles intersect triply in 8 places to form the vertices of a cube and doubly in 6 places over the faces of the cube. Fifteen great circles intersect 5-at-a-time in 12 locations, 3-at-a-time in 20 locations, and 2-at-a-time in 30 locations, forming respectively, the vertices of the icosahedron, dodecahedron, and icosidodecahedron.

   It is interesting that the tetrahedron is not uniquely determined in this construction, but is derivative from the vertices of the cube.
3. The divine proportion, also known as the golden mean or the golden section, defines the geometry of growth for living systems, plants and animals alike—from the seashell, to the leaf arrangement on a branch, to the proportions of the human body. It is also the characteristic ratio for nonliving processes in the very large and the small. The divine proportion divides a line so that the ratio of the full length of a line to its largest segment is proportional to the ratio of the segments to each other. When a decagon is inscribed in a circle, the ratio of the radius to an edge is the divine proportion. Designated mathematically as ϕ, the divine proportion ratio is $(\sqrt{5} + 1)/2$ or approximately 1.618.
4. This allows a speculation on the relation to extranuclear properties, viz. the carbon problem. Carbon has a tetrahedral bonding which is conventionally explained by the fact that the inner 1s orbital is held more tightly, while the four "valence" electrons do the bonding. Why? Now we can see that the tight bonding of the inner orbital might be caused by the alpha particle inside. For carbon, only four of the protons might move to the cube, locating themselves on the four vertices of the cube which correspond to a tetrahedral symmetry. These would be the four charges that determine the carbon bond. To maintain the charge symmetry, the other two would be held in the original alpha particle.