Oct. 4, 1966 K. D. SNELSON 3,276,148

MODEL FOR ATOMIC FORMS

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FIG. 1

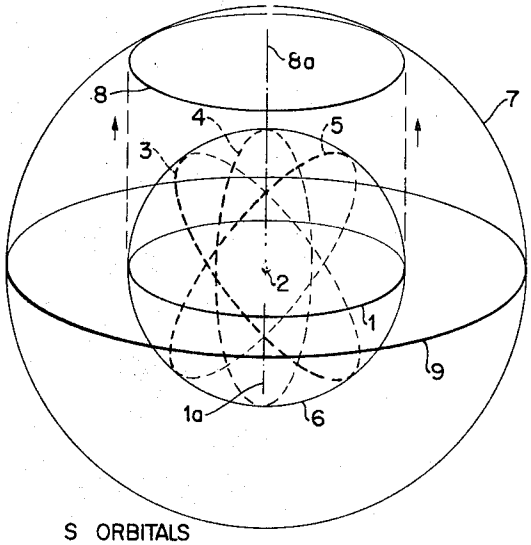


FIG. 2

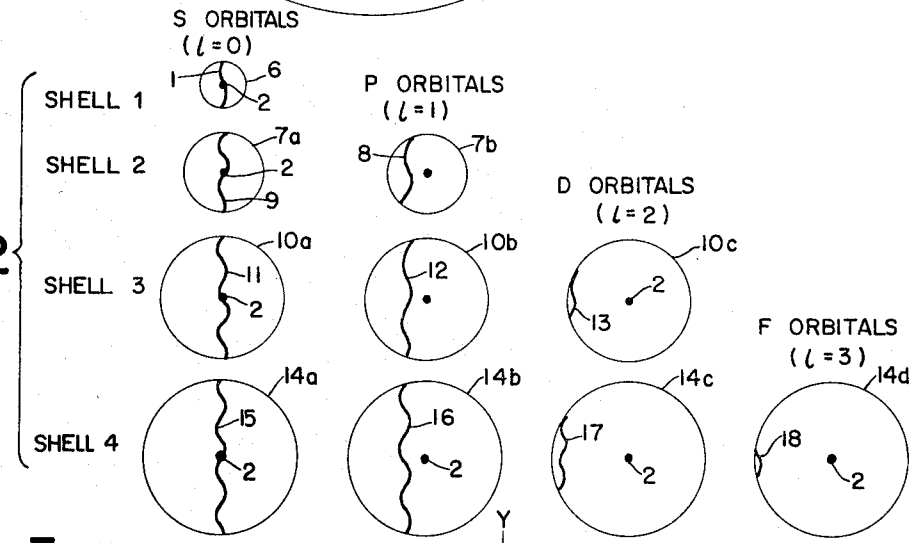
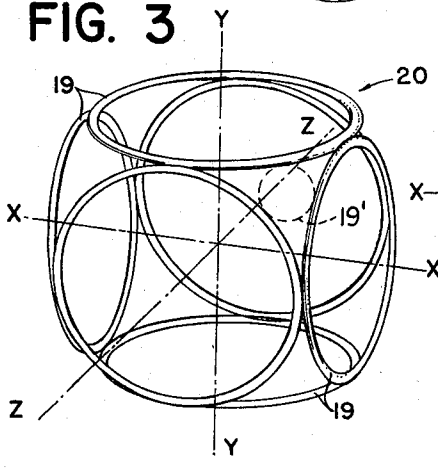


FIG. 3



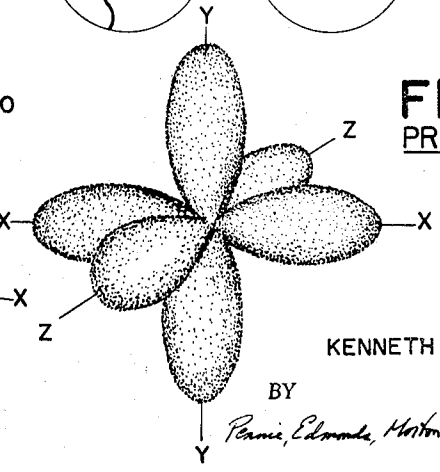


FIG. 4
PRIOR ART

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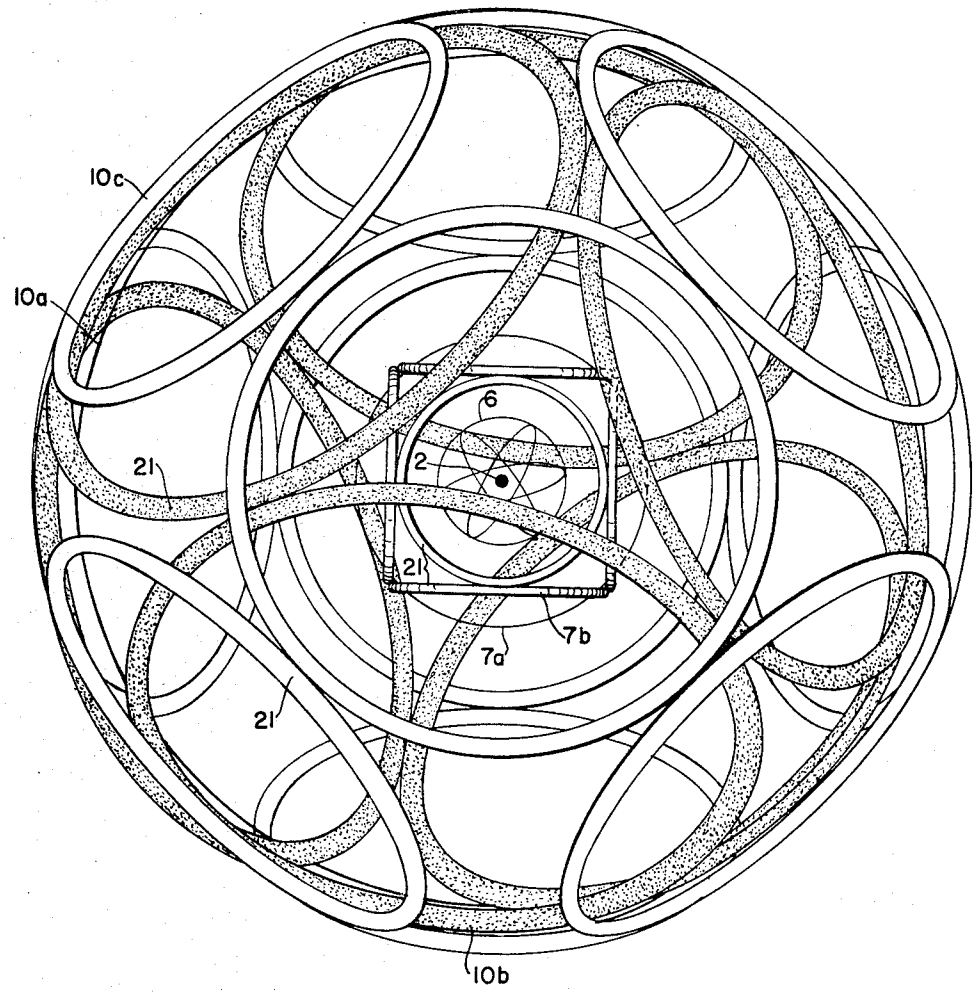

FIG. 5

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FIG. 6

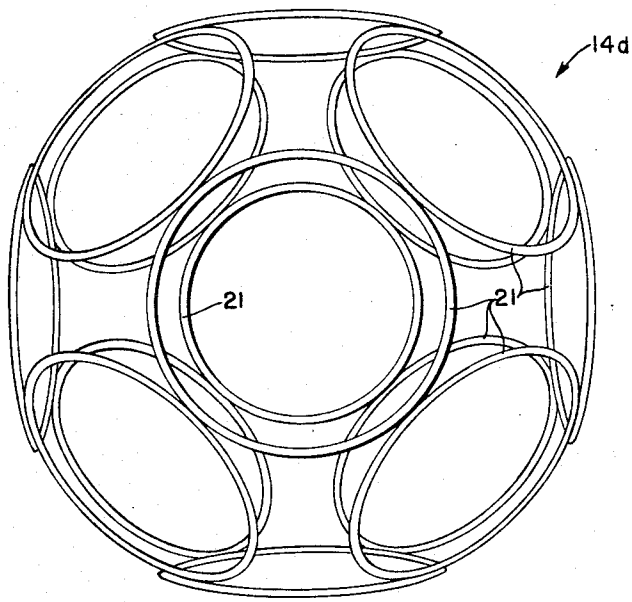

FIG. 7

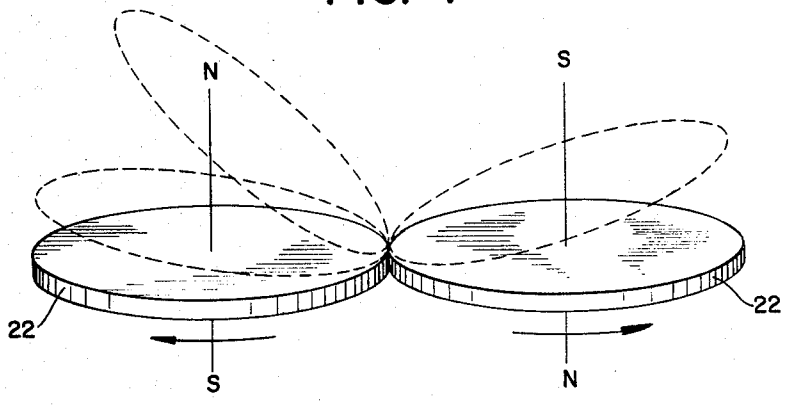

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FIG. 8

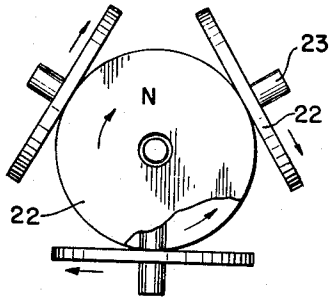


FIG. 9

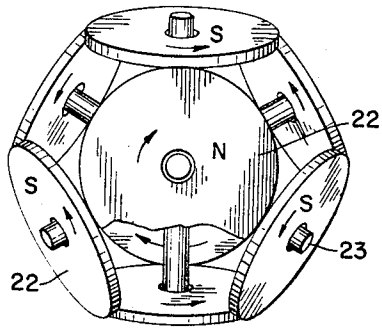


FIG. 10

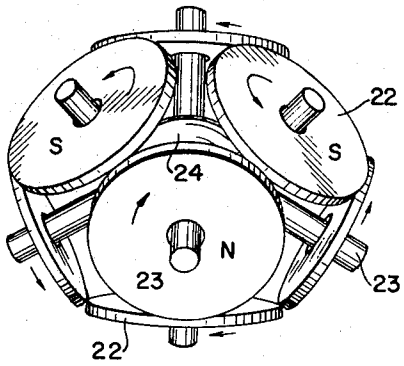
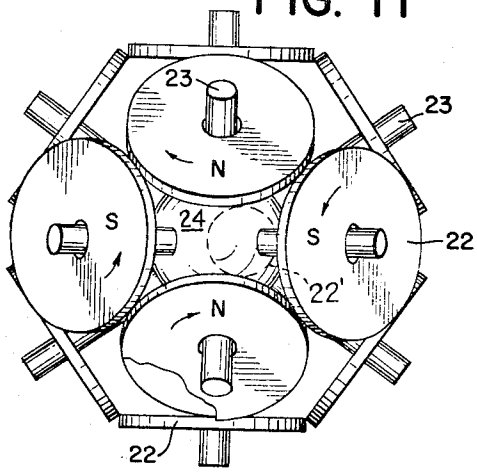


FIG. 11



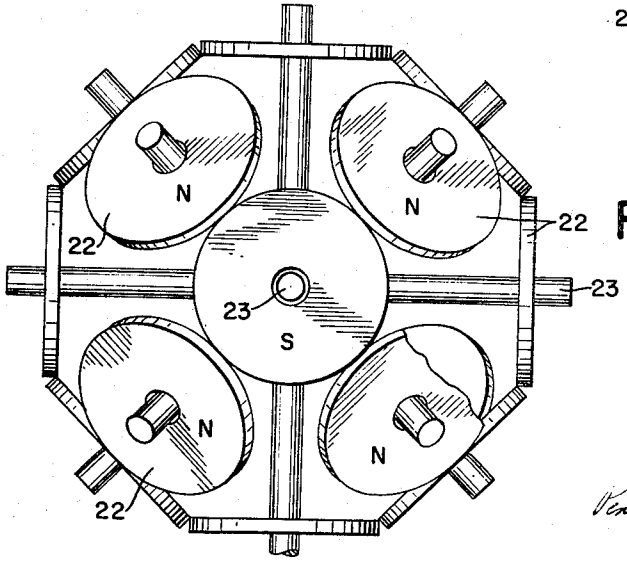


FIG. 12

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FIG. 13

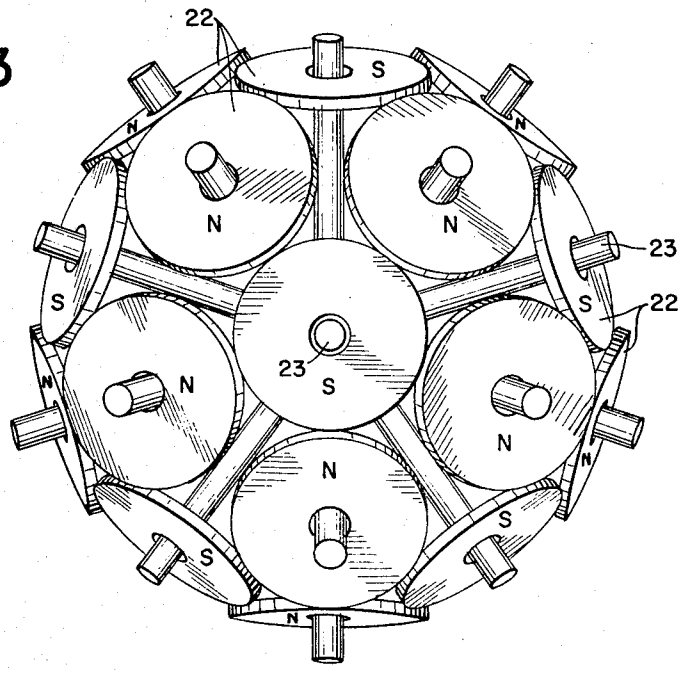
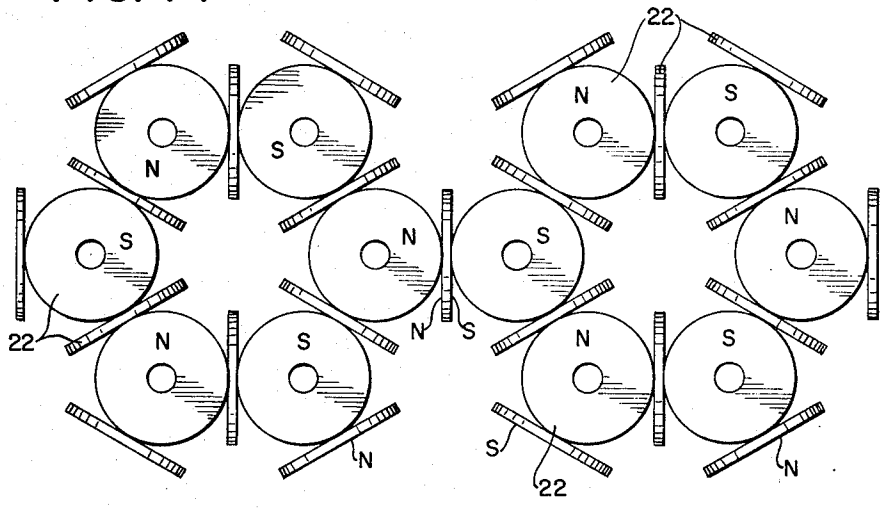


FIG. 14



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MODEL FOR ATOMIC FORMS

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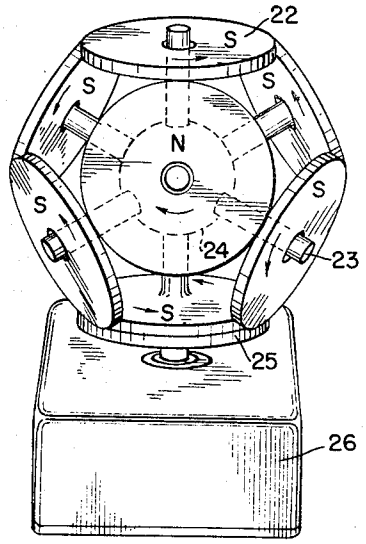
FIG. 15



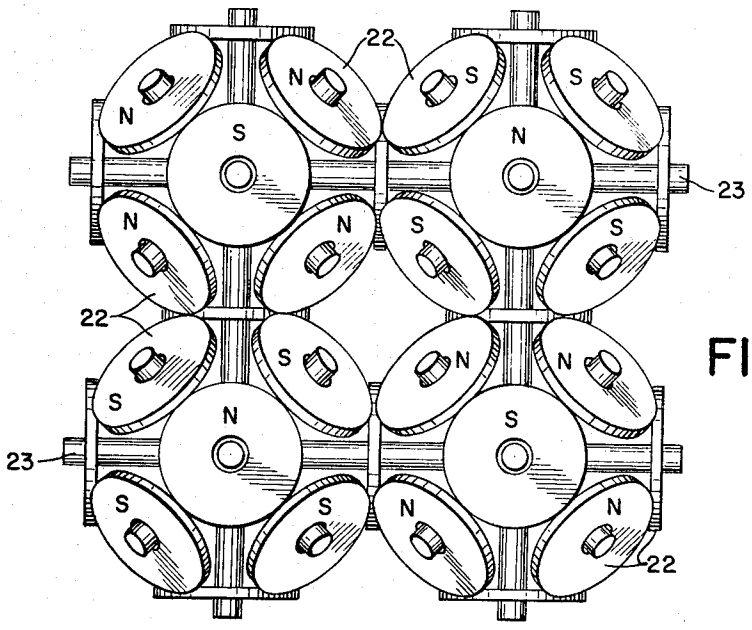


FIG. 16

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United States Patent Office

3,276,148

Patented Oct. 4, 1966

3,276,148

MODEL FOR ATOMIC FORMS

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Filed Jan. 31, 1964, Ser. No. 341,556

8 Claims. (Cl. 35—18)

The present invention relates to a three dimensional model useful as an educational or research device for structurally representing atomic forms and more porticularly to a model which demonstrates structural reasons for the different types of electronic orbitals and shows why only certain numbers of electrons are present at a given energy level. In addition, the model of the present invention defines for the first time a principle of structure involving the electron's orbital magnetic fields.

In the past, various theories have been adanvced to explain the electronic structure of the atom. Structural models of the atom incorporating these theories have, however, left unexplained certain aspects of the quantum theory. The Rutherford-Bohr model of the hydrogen atom which came into being in 1913, represented the atom as a minature planetary system and although this model was reasonable mechanically, it presented other difficulties. According to classical electromagnetic theory, charged particles accelerated by electrical fields are expected to radiate electromagnetic energy. Because of this, an atom with a planetary electron experiencing angular acceleration around the nucleus should collapse in a fraction of a second by loss of energy.

Niels Bohr, therefore, hypothesized that there must be stabilized states at which the electron could rotate about the nucleus and not lose energy. His model of the hydrogen atom represented these "stationary states" or energy levels as concentric circular orbits at which the system was stable. Energy was then given off or absorbed only when the electron jumped from one energy level to another.

This model of the atom as advanced by Bohr was, however, shown to be inadequate in certain respects. Arnold Sommerfeld, a German physicist, noted that Bohr's model could not account for the subtleties in the hydrogen spectra. Sommerfeld considered that Bohr's circular orbits might be supplemented with a system of elliptical orbits in the model to account for these additional lines. The prescribed ellipses had the same major axis as the Bohr form, but narrower minor axes. Since the data which Sommerfeld applied to his model of the atom was known spectroscopic data, the spectral names were attached to the various orbital types. Thus, the letters *s* as used for sharp lines, *p* as used for principal lines, *d* as used for diffused lines, and *f* as used for fundamental lines were employed to designate the electrons of the various new elliptical orbits. In this modified model of the atom, the first energy level or shell required only the circular orbit or *s* electrons while the second shell had two types of orbits, one circular and one elliptical with the electrons of the two orbits designated as *s* and *p* electrons, respectively. The third shell required three types, *s p,* and *d*; and the fourth shell required four *s, p, d,* and *f*.

In a later development, Louis de Broglie postulated that matter, like electromagnetic energy might also have an associated wave aspect in addition to its particle-like qualities. This speculation was proved to be correct where experiments showed that electrons could be diffracted by crystals much in the manner of light waves.

To Bohr's atom was joined the de Broglie wave hypothesis, which explained the stationary states as standing wave periodicities. The resulting theory postulates that the electron can settle at only those distances from the nuclear charge where it can fit whole numbers of complete wavelengths. The circumference of the electron's smallest

orbit is equal to exactly one complete wavelength. The second orbit has that circumferenec which can accommodate two complete wavelengths, the third three, and so on. The reason for this is that the matter-wave of the electron is a standing wave—it is continuous throughout the cycle of orbital motion—and must therefore be in phase with itself, restating its own pattern at each cycle. Without the proper circumference to permit this, it would interfere destructively with itself.

In a successive development Erwin Schrodinger evolved his wave equation based on the earlier work of Bohr, Sommerfeld and De Broglie. Wave mechanics, which resulted from Schrodinger's wrok, defines electron interactions statistically. Its difficulties lie in the many numbers of possible interactions in any atomic system involving several electrons. For this reason the hydrogen atom, with a single electron, still serves as the prototype for all atoms and wave mechanics is founded on the assumption that electron waves surround the nucleus much in the manner of a single electron of hydrogen. When an atom has large numbers of electrons, their interactions can only be dealt with as probabilities.

Modifying this picture is Werner Heisenberg's "uncertainty principle," which describes the limit to which it is possible to be certain where a moving electron can be located. It is proper only to speak of "charge clouds" which describe the probability of finding an electron in a given volume of atomic space.

It is important to note that models which evolved in several stages attained their features additively over a period of time. The most arbitrary additions in terms of experimental evidence were Sommerfeld's elliptical orbits. They were introduced originally to account for energy differences of the various orbits in the same shell in terms of the relativistic mass change which the electron might experience if it were to accelerate and decelerate around the nucleus in an elliptical manner as does the planet Mercury around the Sun. The elliptical electron orbits failed mathematically to account for these variations in energy. For this reason the original purpose was never fulfilled.

The ellipses were also meant to account for the change in angular momentum of *s, p, d* and *f* orbitals by the assumption that the rounder an orbit, the greater was its anular momentum. This required, however, that *s* electrons have orbits with zero minor axes because they have no observable angular momentum. Because they would therefore move only transversely, they would be required to pass through the nucleus, which was clearly not possible. In addition, any elliptical orbit would be required to precess in a perihelion fashion as does, for example, the planet Mercury and therefore would have no stable orientation by which one might observe its angular momentum. So ellipses failed in this respect as well.

In the later forms which elliptical orbits assumed, according to the charge cloud modifications of Schrodinger and Heisenberg, precise orbits were no longer referred to, but the elliptical form was retained as a means of differentiating between orbital types in the same shell. The elliptical orbits also served to provide the electrons' orbits a direction in space relative to the nucleus, thereby making it possible to represent bonding angles in molecular models. The present invention accomplishes this required directionality more effectively and more logically than the previous model. This will be demonstrated below.

Another serious disadvantage of the conventional model is its inability to indicate how the electron moves in order to occupy a charge cloud. Electron motion is nevertheless real and is inevitably discussed in association with orbital angular momentum and orbital magnetic fields.

It is also discussed in regard to the orientation of the electron's spin relative to its orbital motion. The new model provides the required frame of reference to define these relationships.

So far only the individual electron and its various possible orbits as represented by previous models has been discussed. The inadequacies and contradictions presented by these models are further demonstrated when models representing complex atoms are considered with reference to Pauli's "exclusion principle" which provides a classification system by which all electrons in a single complex atom can be differentiated.

The "exclusion principle" assigns each atomic electron four "quantum numbers" in order to describe an energy state. These four factors are: (1) the principal quantum number n which describes the shell number and which can have values of 1, 2, 3, 4 . . . as in Bohr's original planetary model; (2) the azimuthal quantum number 1 which describes the orbital eccentricity—like Sommerfeld's ellipses—as well as the value of the orbit's angular momentum and which can have values of 0, 1, 2, 3 . . . $(n-1)$ corresponding to s, p, d and f electrons; (3) the magnetic quantum number m which describes the direction in which the plane of the orbit faces and which can have values of $-1, -1+1 \ldots 0 \ldots +1$, and (4) the spin quantum number m_s which describes the direction in which the particle electron spins relative to its motion in orbit and which can have values of $\pm\frac{1}{2}$, that is, spin can be in the same or in the opposite direction as the electron's orbit.

No two electrons in the same atom can have identical sets of quantum numbers according to the "exclusion principle." Electrons are shown, therefore, to exclude one another from the energy position which each occupies and are, in this way, similar to larger aggregates of matter which cannot occupy the same space at the same time.

Beginning with hydrogen's single electron, the numbers permitted at consecutive energy levels according to the "exclusion principle" can be reviewed. Helium follows hydrogen in the table of elements with a second nuclear charge and a second electron which also resides in the first level. The fact that helium is chemically inert indicates that its two electrons complete the first shell.

This tightly bound system is due to a phenomenon known as "spin pairing." Electrons, as well as many elementary particles, possess an intrinsic top-like quality whether they are at rest or in motion. Spin provides the particle with a fixed quantity of angular momentum and a small magnetic field. As an electron moves in orbit it can spin in the same direction as its rotation in orbit or in the reverse direction. Helium electrons or any such spherical s pair have opposed spins and they are pictured as following one another about at opposite sides of the nucleus because of the repelling force of their like electrical charges. They can be thought of as two points on a wheel, which can precess freely as the wheel rotates, describing a spherical volume of space. Because they are always opposite to one another, as if fixed in space, their magnetic spin fields are fixed in relation to one another. In order to reach their minimum energy state, the two spin fields assume a magnetically attractive antiparallel association which helps overcome their repelling electrical energies.

Until spin was discovered and incorporated into the "exclusion principle," it was thought that s electrons were simply two point-charges which moved along the same orbit. But now, s electrons, because their antiparallel spin fields were shown to alter each other's courses slightly, are regarded as occupying separate orbits.

Looking at the second completed shell of the atom where there are a total of eight electrons, two subshells are shown. One of the subshells designated as the $2s$ subshell includes two s electrons which form a spherical configuration as in the first shell while the remaining six electrons occupy p orbitals and form the $2p$ subshell.

These p orbitals in the conventional models are not spherically symmetrical charge-clouds, but reflect the elliptical p orbital form described by Sommerfeld and as a configuration they are shown as penetrating the inner shells and extending outward from the nucleus along x, y, z axes of the atom. Due to this, these models have been questioned because they give no explanation as to how the p electrons can move in and out through the first and second shell s electron spheres without interfering with the stability of the system.

This problem becomes more complex with conventional models representing the third and fourth shells of an atom. In the third shell another spherical s subshell is formed plus another subshell of six p electrons with their penetrating charge-clouds. Added to this, however, is a third subshell of ten electrons which also penetrates the inner shells. This is the d subshell or d orbitals. And in the fourth shell, all of the configurations of the third shell are repeated, but this shell further includes another subshell with fourteen penetrating electrons occupying f orbitals.

In any effort to define a workable system or model showing electron trajectories or wave-paths for a many-electron atom, we are therefore confronted with a dilemma in topology as to how a plurality of matter-waves can occupy stationary states and still avoid destructive interference; or in terms of particles, how large numbers of electrons moving about the nucleus can avoid random perturbations.

The problem with present atomic models is a mechanical one, for electrons or any charged particles attract or repel one another by producing and exchanging packets of energy, one to the other. If, however, this were to actually happen at random between electrons of different energies as indicated by present atomic models, the entire conception of stable energy levels would be inexplicable and spectroscopy would not show the sharp and limited lines which are the fingerprints of the different kinds of atoms. The difficulty is further intensified in the heavier atoms because, with the increase of nuclear charge, the kinetic energies of the inner electrons become very great, and there is no way to explain how the outer electrons, with comparatively small kinetic energies, can repeatedly penetrate the inner shells without actually being removed from the atom by internal collisions.

According to the teachings of the present invention, a new model of the atom can be constructed to fill the requirements of the quantum theory by giving a structural and spatial meaning to all four quantum numbers needed for describing the energy state of each electron. Also, the new model of the present invention presents a logical solution to the interference problem of interpenetrating charge-clouds by providing the orbit of each electron with its own domain of spatial occupancy.

In addition, the individual orbits of each subshell as represented in the new model spatially define the magnetic fields which result from the orbital motion of the electron and from the inherent spin of the particle electron and in this way present a structural explanation of the m and s quantum numbers.

Generally, in building the atomic model according to the teachings of the present invention, the first shell will represent two s electrons have one-wave cycles surrounding the nucleus of the atom in an equatorial way. For the second shell of the atom, however, the electron's two-wave cycle is shown as having an alternate orbital form or p orbital which contains just one wave with the circumference of this one-wave orbit having half the circumference of the two-wave orbit or s orbital form. Following this procedure for the remaining shells of the atom, the new model represents all the orbits as standing waves but only with s orbitals surrounding the nucleus in an equatorial way. In the new model, the second, third and fourth shells of the atom are broken down into subshells for separately containing the differ-

ent types of possible orbitals *s, p, d,* and *f*. And in the *p, d,* and *f,* subshells, the electrons are shown as circling in a plurality of individual orbits offset from the nucleus of the atom with the total number of orbits in each completed subshell, in turn, defining that subshell

Referring to the drawings:

FIG. 1 is a partial diagrammatic view of the first and second shells of an atom as represented by the model of the present invention;

FIG. 2 is a schematic chart showing electron energy levels for the first four shells of an atom indicating the number of whole waves contained in the subshells' orbits according to the model of the present invention;

FIG. 3 is a perspective view of one embodiment of the invention for representing the *p* orbitals of an atom;

FIG. 4 is a perspective view of the prior art model for representing the *p* orbitals of an atom;

FIG. 5 is a plan view of one embodiment of the invention for representing a composite model of the first three shells of an atom;

FIG. 6 is a plan view of one embodiment of the invention for representing the fourteen electron *f* orbitals of an atom;

FIG. 7 is a plan view of the arrangement of the current loop magnetic fields of another embodiment of the present invention;

FIG. 8 is a plan view of a magnetic model of the present invention for representing a group of five magnetic elements arranged to define a sphere;

FIG. 9 is a plan view of a magnetic model of the present invention for representing the combined *s* and *p* subshells or the octet configuration for an atom;

FIG. 10 is a perspective view of a magnetic model of the present invention for representing the *d* orbitals of an atom;

FIG. 11 is a plan view of a magnetic model of the present invention for representing the *f* orbitals of an atom;

FIG. 12 is a plan view of a magnetic model of the present invention for representing a composite third shell of an atom;

FIG. 13 is a plan view of a magnetic model of the present invention for representing a composite fourth shell of an atom;

FIG. 14 is a plan view of a model for representing benzine rings;

FIG. 15 is a perspective view showing the driving support for the model shown in FIG. 9; and

FIG. 16 is a plan view of a composite model consisting of four submodels representing the fourteen circle *f* orbital forms.

The new model of the atom can best be examined by reference to a hydrogen atom represented by FIG. 1 in which the single *s* electron orbits in an equatorial path **1** around the proton nucleus **2**. Since the single electron surrounds the nucleus in an equatorial manner with the freedom to precess there is no detectable angular momentum and accordingly $l=0$. In FIG. 1 the paths **3**, **4** and **5** shown in dotted lines indicate that the electron is free to move about the nucleus **2** while precessing with no preferred direction or axis of orbit. Here the electron is at the first energy level or ground state where $n=1$ and defines the spherical surface **6**. In accordance with de Broglie's standing wave theory, the **1***s* orbit of the single *s* electron in this shell would be one wavelength.

If the electron defining this path were to receive energy from an outside source, as from a collision or an entering photon of sufficient energy, the electron would be raised to a higher energy state. The preferred transition according to spectroscopic evidence would be to the **2***p* state in this case. Previous models would represent this **2***p* orbital as an ellipsoidal charge cloud extending as a lobe outwardly from the nucleus; however, in the new model, the circular **1***s* orbit when deflected by the incoming energy is moved along the axis of rotation it possesses at that instant, for example **1***a*, and raised above the nucleus to the second energy level or shell **7**. In this position, it occupies a meridian cap **8** defining the **2***p* orbital on the second shell energy sphere. This occupancy normally lasts less than 10^{-8} seconds before the electron returns to the **1***s* state with the emission of the characteristic first line of the Lyman hydrogen series. According to the new model then, the orbit of the **2***p* state is a one-wave orbit similar to the **1***s* orbit with the difference that it is displaced to the second shell. As a consequence of its displacement away from the nuclear center, the orbit acquires a direction in space in reference to the nucleus and because this includes a detectable directional axis **8***a*, it now has a detectable angular momentum vector.

As shown in FIG. 1, the **2***s* orbital **9** in the new model would be an equatorial orbit, and in accordance with the earlier Bohr-de Broglie model, this **2***s* orbital would have a standard two-wave cycle as shown diagrammatically in FIG. 2. Also, as shown in FIG. 2, the second shell **7** would for purposes of constructing the new model be made up of two subshells **7***a* and **7***b* with subshell **7***a* containing the **2***s* orbitals and subshell **7***b* containing the **2***p* orbitals.

It is important to note here that the electron's de Broglie wave length is dependent on the linear velocity of the electron, and is given by the formula $\lambda=h/mv$ where h=Plank's constant, m=the mass of the electron and v=the velocity of the electron. In restricting the **2***p* electron of the second shell to complete its orbit in but one standing wave, the new model implies that the linear velocity of the electron is substantially the same for both the **2***s* and **2***p* orbitals. Therefore, the electron's wavelength is substantially the same. The difference is that the electron in an orbit of just one wave will complete its orbit in half the time required for the orbit with two waves. As will be shown below, this size reduction from the standard *s* orbital to the smaller offset state represents the differences in angular momentum for the various types of orbit *s, p, d,* and *f* of the same shell.

Referring again to FIG. 2, the third shell of the atom is shown diagrammatically as made up of three subshells **10***a*, **10***b*, and **10***c* since the third shell requires three types of orbitals, **3***s*, **3***p* and **3***d* where $l=0$, 1, and 2, respectively. Extending the deflected orbit hypothesis to this third shell, the normal Bohr-de Broglie three-wave orbit **11** representing the **3***s* orbital is shown as surrounding the nucleus **2** in an equatorial manner while the **3***p* and **3***d* orbitals are shown at **12** and **13**, respectively as offset from the nucleus.

Since the maximum number of waves possible in the normal third shell orbit is three, the offset states or contracted orbits can contain two waves or alternatively, one wave. As discussed earlier, the orbit which is formed in this way will have the same linear velocity as the *s* orbital of that shell. Therefore, the electron which completes the two-wave cycle **12** on the energy surface **10***b* of the third shell will complete each cycle half again as fast as it would in the three-wave orbit.

If the size of the electron's orbit is further reduced in the third shell by an energy interaction it can achieve the one-wave orbit **13** and complete its cycle twice as fast as it does in the two-wave orbit. This accelerated rotation results in an increase of angular momentum just as if the revolutions of a gyroscope were accelerated. Therefore because the **3***d* orbital has twice the angular momentum as the **2***p* state, the one-wave orbit must be the **3***d*, orbital **13**, and the two-wave orbit must be the **3***p*, state **12**. It can now be seen that in the new model, each shell begins with its appropriate equatorial Bohr-de Broglie orbit which contains the same number of waves as the principal quantum number, $n=1$, 2, 3, 4 etc. while each shell also has $(n-1)$ additional types of deflected states containing successively fewer standing waves, the minimum for any orbit being one wave.

Extending the pattern to the fourth shell of the atom which as shown in FIG. 2 is made up of four subshells **14***a*–**14***d*, the four-wave equatorial orbit or **4***s* state shown

at **15** contains four waves while the three-wave deflected state shown at **16** represents the 4*p* orbital, the two-wave deflected state shown at **17** represents the 4*d* orbital, and the one-wave deflected state shown at **18** represents the 4*f* orbital.

It is necessary for a proper atomic model to account for the motion and spatial occupancy of all electrons of all energy levels for even the heaviest atoms. This may require accounting for over 100 electrons. Such a building-up system is a unique aspect of this new model. In conventional models, the *s* orbital structure includes two electrons occupying a spherical shell with opposed spins. Nothing here is changed in this new model. Such *s* subshells are constructed in each new shell. Because they are spherically symmetrical and have no preferred orientation, each *s* electron pair or subshell can advantageously be represented simply by a transparent sphere of plastic or similar material.

In building up an atom according to the periodic table and Pauli's Exclusion principle, the second shell accommodates a pair of 2*s* electrons outside of the 1*s* pair of electrons. This pair defines subshell 7*a* of the second shell as shown in FIG. 2. Six more electrons in *p* orbitals **8** must be added, however, in order to complete the second shell. In accordance with the unique properties of this new model, these *p* orbitals do not penetrate the inner shells nor do they extend or overlap one another's domains. As shown in FIG. 3 they are represented by six identical circle ring members **19** defining offset circular orbits, the six of which are arranged along *x*, *y*, *z* axes of the atom in the same way as the electrons of the ellipsoidal charge clouds of the conventional model shown in FIG. 4. It will be noted from FIG. 3 that, as a dimensional characteristic of the model there shown, the diameter of the open circular area between adjacent ring members **19** is less than the diameter of the ring members themselves. This circular area is shown in FIG. 3 by the dotted line **19'**. These six circle rings as shown in FIG. 3 constitute a *p* subshell **20** which may not only be used to represent the 2*p* subshell 7*b* of the atom but may also be used for representing the 3*p* and 4*p* subshells since the only difference between these subshells is in their relative size and the wave cycling of the *p* electrons and for purposes of model shown in FIG. 3, relative size and the representation of the electron waves have been omitted. It is to be understood, however, that appropriate wave paths can be drawn on the circles **19** for purposes of instruction and the like if desirable, and that a series of *p* orbital models like that shown in FIG. 3 can be made with appropriate dimensions when for example it is desired to use the 2*p*, 3*p* and 4*p* subshells at the same time.

In the third completed shell of the atom, the 3*s* subshell **10***a* is shown in FIG. 5 as a sphere completely surrounding the 2*p* subshell 7*b* and positioned at the appropriate distance from the nucleus of the atom whereby three standing waves may exist. The 3*p* subshell **10***b* surrounds the 3*s* subshell at the same effective energy level and as indicated above, it will be composed of six two-wave circular orbits which are arranged on a spherical surface similar to the 2*p* subshell 7*b*. The next subshell which completes the third shell is the 3*d* subshell **10***c* which surrounds the **10***a* and **10***b* subshells at the same effective energy level, and as shown in FIG. 5 by the circle rings **21**, comprises a group of ten *d* electron orbitals. FIG. 2 shows that each of the *d* electrons in the 3*d* subshell will define single standing wave **13**.

In a model of the fourth shell of the atom, the sphere **14***a* shown in FIG. 2 would surround the 3*d* subshell **10***c* of FIG. 5 and be surrounded by the six 4*p* three-wave orbitals **16**, the ten 4*d* two-wave orbitals **17**, and the largest of the subshells, the fourteen 4*f* one-weave orbitals **18**. For purposes of illustration the construction of this latter subshell is shown separately in FIG. 6 where rings **21** are used for representing the fourteen 4*f* orbitals.

In this manner the building process can continue on to account for the total number of electrons required of even the heaviest atoms in the periodic table.

In all of the representations of electronic motion in these new models, one fact should be observed. In none of the orbits is an electron required to move inwardly or outwardly from the nucleus as in the elliptical charge clouds of previous models. Each electron remains at a constant distance from the nucleus and hence, in a constant electrical potential. Only in changes from one state to another would the electrons jump through varying nuclear electrical potentials. Therefore, the model shows that the emission or absorption of energy requires electrical work to be performed by an electron's movement through a potential difference.

Referring again to the four quantum numbers, the *m* or magnetic number is now accounted for by the direction in which the orbits face relative to one another in any of the offset shell groups, and the spin number *s* has in the new model gained a logical reference to the *m* number and it is possible for the first time to visualize with certainty whether spin is in the same or opposite direction as the electron's motion in orbit.

As described above, pairs of *s* electrons follow one another around the nucleus of the atom so that their spin magnetic fields are related one to the other like two permanent magnets fixed in space. Since, however, the electrons in subshells with offset *p*, *d*, and *f* orbitals do not follow one another along the same motion course, their spin fields are smeared with respect to one another and diffused over the entire path of the orbit. In addition to spin magnetic fields, the electrons also possess a separate orbital magnetic moment arising out of the orbital motion of the electrical charges. This orbital magnetic moment is identical to the magnetic field of an electric current loop and lies perpendicular to the plane of the orbit with the north pole on one face and the south pole on the other. Its value is assigned with the 1 quantum number since the quantity of orbital magnetism depends directly on the angular momentum of the orbiting electron.

There is an important relationship between the two types of magnetic field since the electron can arrange its spin in either the same direction or the reverse of its direction of rotation in orbit. This means that spin can either add to, or counter the orbital field. As will be described, below, this mechanism can function as a device for cancelling the magnetic fields under certain conditions.

If the kinetic energy of the electron is great, as it is for the inner shells of the heavier atoms, the orbital magnetic fields are also very great. In the first shell of calcium, for example, the magnetic moment is about 10^{10} gauss per electron, and in the first shell of uranium about 10^{13} gauss. Forces of this magnitude inside the atomic shells must be dispersed in some way. Yet in all of the considerations given to atomic structure in previous models it is nowhere evident that a useful purpose is expected of these forces. In the past there has been much discussion concerning the coupling of the magnetic currents within the atom but no indication of the internal form which this coupling might assume.

According to the teachings of the present invention, a model of the atom showing this magnetic coupling may be constructed by replacing the circle rings of FIGS. 5 and 6, for example, with magnets **22** having the same shape and polar arrangement as the field of current loops. These magnets may be made of ceramic material and are shaped like flat washers polarized on opposite faces. Flat magnetic fields attract one another in two different attitudes. When their polar directions are identically oriented or parallel, they attract face to face, and when their poles are reversed to one another or antiparallel, they attract edge to edge. As shown in FIG. 7, this antiparallel association permits complete freedom in the range

of angles at which any two magnets can associate. The edge to edge association is of special importance for it may be employed in constructing models to represent the magnetic coupling of atomic orbitals. As shown in FIGS. 8–13 it is possible to assemble certain groups of the magnets **22** around a sphere in a mosaic of antiparallel fields to represent the electrons of the different shells and subshells of the atom. In FIGS. 8–13 it will be noted that touching magnets have their magnetic fields disposed in antiparallel relationship in the same manner as shown in FIG. 7.

Each of the magnets of these models may be placed on non-magnetic armatures **23** in order to support their weight and when they are in the proper antiparallel position they cling together. They can be withdrawn individually and when returned, they are seized by the neighboring magnets. Each of the groups is linked together in closed spherical circuits. As completed forms, they define patterns of alternating polarity so that there is no preferred magnetic direction for the represented electron shell. This is in agreement with all experimental evidence which shows that angular momentum and magnetism add to zero for completed shells of electrons.

There is a remarkable correspondence between the numbers of spherical circle groups which can be assembled from magnets and the numbers of electrons in energy levels. If magnets of the same diameter are used in forming any one of the spherical groups of FIGS. 8–13 and the diameter of the open circular area between any four adjacent magnets is smaller than the diameter of one of the magnets, as for example as shown in FIG. 11 at **22'**, only certain groupings are possible. More specifically, it is only possible to form spheres having five, eight, ten, fourteen, eighteen and thirty-two magnets and these are shown respectively in FIGS. 8–13. Other combinations cannot be made with magnets because of the magnetic field relationships presented.

It is to be noted that these numbers correspond closely to the number of electrons present in the first four completed shells and associated subshells of the atom. The notable exception is the group of five magnets shown in FIG. 8 which is the smallest assembly possible. Although this does not represent a completed energy level of the atom, it can be used for representing the sp^2+p hybrid orbitals; and the group possesses the useful property of linking with other groups of five to form hexagon rings with perfect magnetic continuity. An assembly of these groups which contains six of the five-magnet forms would seem to require thirty magnets. It is found however that each two adjacent groups when joined, can share a magnet which is their common face. This cancels six magnets so that a hexagonal ring may be formed with a total of twenty-four magnets and an average of four rather than five to a cell. Such a hexagonal assembly is shown in FIG. 14 and if each magnet is thought of as an electron in orbit the assembly becomes an excellent model of the benzine ring of organic chemistry. For here is a flat hexagonal ring of atoms which can be repeated in an extended pattern like a collection of aromatic ring molecules; and as a model, each carbon atom has the proper number of outer electrons, four, to represent an electrically neutral molecule. This configuration offers a reasonable explanation for the long debated question or organic chemistry regarding the actual structural make-up of the benzine ring which was usually justified in terms of alternating or delocalized bonds in order to account for the proper number of electrons in each carbon atom.

The magnet models shown in FIGS. 9, 12 and 13 contain the sets of numbers for the completed second, third and fourth shells of the atom while the models of FIGS. 10 and 11 contain the sets of numbers for the *d* and *f* orbitals. Absent from the group is the six-circle cubical set which would be expected in order consistently to represent the *p* subshell. Magnetic coupling is prevented in this arrangement because there is no way in which the six faces of a cube can be checkerboarded to permit the association of opposite magnets. The only completely symmetrical organization for this form is an arrangement in which all six magnets face outwardly with the same polar orientation. In terms of magnets, this is a parallel or repelling association. In an atom this orientation of magnetic fields would add to the electrical repulsion between the electrons and force them into a higher energy state. If this happens to take place in an outer shell where the kinetic energies of the electrons are small, it is possible for spin to neutralize the orbital magnetic fields by reversing its orientation. This would tend to cancel the repelling force of the orbital magnetic fields and permit the electrons to approach one another more closely and thus reach a somewhat lower energy state.

The electrons in the inner shells have higher kinetic energies and greater orbital magnetic moments. Because spin is a constant it cannot serve to neutralize these larger orbital fields. According to the teachings of the present invention, it is necessary in constructing magnetic models of the heavier atoms for the *p* electrons of the inner shells to combine with the *s* electrons of those shells in order to form the single magnetic configurations of eight identical orbits as shown in FIG. 9. This is reasonable since the *s* orbitals beyond the first shell have only a provisional chemical stability and do not represent a tightly closed system.

This eight-circle group of FIG. 9 is arranged on a spherical surface along the corner axes of a cube. The four circles whose north poles face outwardly alternate with the four whose south poles are exposed with the two sets describing interlocking regular tetrahedra. Although the octet of the inert gases is generally believed to comprise an *s* subshell and a *p* subshell, there is some controversy regarding this. Linus Pauling and others have discussed the possibility that *s* and *p* shells are a single entity like two interlocking tetrahedra. The model of FIG. 9 supports this latter view of a single octet shell and in addition, may be used to show such structures as the H_2O molecule with the two lower forwardly facing discs representing the two hydrogen atoms bonded to the oxygen atom at 109° 28'.

In assembling the models of FIGS. 9–13, the armatures **23** may be connected to a suitable framework **24** adapted to be disposed in the interior of the spheres. FIG. 15 shows such a structure for mounting the model of FIG. 9 in which eight magnets **22** are to be assembled. As there shown the framework **24** has secured thereto at proper points the eight armatures **23** upon which the magnets **22** are to be placed. In the support shown in FIG. 15, the bottom armature is magnetically connected to a suitable magnetic turntable **25** driven by a motor **26**. In this way, the lower magnet of the model as shown in FIG. 15 becomes the driving disc for the remaining magnets which are placed on their respective armatures for free rotation; and when the driving disc or magnet is actuated, the entire set of magnets will rotate with all north poles turning in one rotational sense and all south poles in reverse as indicated by the arrows in FIG. 9. This causes no change in the relationship of the magnetic fields since the north and south poles remain constant to one another. The magnets simply act like a set of gears, spherically arranged and in frictional contact. This phenomenon, which can be attributed to binary systems, that is, the pairing of the magnets shows an important principle. For what is observed here, in mechanical form, has its exact counterpart in electricity where two orbits or electrical loops must have counter-rotating charges in order to give rise to antiparallel fields.

In addition to the individual models shown in FIGS. 8–13, it is within the teachings of the present invention to translate the groups of the models in space, cell upon cell like polyhedra and to combine various types of models into a composite model with no loss of magnetic or gearing continuity. For example, FIG. 16 shows an assem-

bly comprising four fourteen-circle magnetic groups arranged in a square. This system can be translated in space with the polarities of the adjacent groups providing the proper magnetic linkage from cell to cell. By turning one magnet of a group, an endless assembly can be made to turn like an infinite system of gears and in all the various forms a structural order of great intricacy can be seen. For example, a complex model can be constructed for representing various crystalline lattices composed of electron networks magnetically arranged and bound by nuclear charge centers.

The above description includes a number of examples of models and the manner in which they may be assembled and used to represent various atomic forms; however, it is to be understood that various changes may be made without departing from the spirit of the invention as set forth in the following claims.

What is claimed is:

1. A model for atomic forms comprising a plurality of substantially identical circular disc magnets polarized on opposite faces and arranged in a group defining the boundary of a sphere with each magnet making edge contact with at least two other magnets and having its outwardly exposed surface of a polarity opposite that of each contacting magnet.

2. A model for atomic forms as set forth in claim 1 in which the diameter of the open circular area between any adjacent magnets is less than the diameter of said magnets.

3. A model for atomic forms comprising a plurality of concentrically arranged spheres for representing the different energy levels of an atom with each represented energy level including at least one sphere comprising a plurality of circular members having predetermined equal diameters and arranged in a group to define that sphere with the periphery of each member engaging the periphery of each adjacent member and lying in separate planes on that sphere offset from planes extending through the center of the model.

4. A model for atomic forms as set forth in claim 3 in which the diameter of the open circular area between adjacent circular members defining any sphere is less than the predetermined diameter of the members of that sphere.

5. A model for atomic forms as set forth in claim 4 in which the circular members are disc magnets polarized on opposite faces and arranged with each magnet making edge contact with at least two other magnets and having its outwardly exposed surface of a polarity opposite that of each contacting magnet.

6. A model comprising a frame member, a plurality of support rods extending outwardly from a common point in said frame, substantially identical circular members having predetermined equal diameters rotatably mounted on said support rods about said frame with each member extending in a plane at right angles to the longitudinal axis of its support rod, said rods being positioned on said frame whereby said circular members define a sphere with each member making edge contact with at least two other members and with the diameter of the open circular areas between any adjacent magnets being less than the predetermined diameter of said magnets, and means for rotating one of said members.

7. A model comprising a frame member, a plurality of support rods extending outwardly from a common point in said frame, substantially identical circular disc magnets polarized on opposite faces and having predetermined equal diameters rotatably mounted on said support rods about said frame with each magnet extending in a plane at right angles to the longitudinal axis of its support rod, said rods being positioned on said frame whereby said magnets define a sphere with each magnet making edge contact with at least two other magnets and with each magnet having its outwardly exposed surface of a polarity opposite that of each contactiing magnet, and means for rotating one of said magnets.

8. A model as set forth in claim 7 in which the diameter of the open circular area between any adjacent magnets is less than the predetermined diameter of said magnets.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,276,148 October 4, 1966

Kenneth D. Snelson

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 1, line 15, for "electron's" read -- electrons' --; line 22, for "minature" read -- miniature --; column 2, line 12, for "De Broglie" read -- de Broglie --; line 45, for "anular" read -- angular --; column 3, line 18, for "1" read -- $\underline{1}$ --; line 25, the formula should appear as shown below instead of as in the patent:

$$-\underline{1}, -\underline{1}+1 \ldots 0 \ldots +\underline{1},$$

column 4, line 63, for "have" read -- having --; column 5, line 2, after "f", in italics, strike out the comma; same line for "subshell" read -- subshell. --; column 7, line 72, for "weave" read -- wave -- column 8, line 6, for "an" read -- any --; line 38, for "1" read -- $\underline{1}$ --.

Signed and sealed this 29th day of August 1967.

(SEAL)
Attest:

ERNEST W. SWIDER
Attesting Officer

EDWARD J. BRENNER
Commissioner of Patents