SECTION 17

A Model for the Universe (7) -- The Atomic Nucleus and The Nuclear Species

Having now at hand the model of the neutron as a combination of a proton and an electron into a new type of center-of-oscillation, a complex center oscillating as a resultant of its components, a similar model is now available for the atomic nuclei. In fact, such a model is essential. The "bunch of grapes" concept of the nucleus with its components, distinct protons and neutrons, simply will not work.

The problems with the "bunch of grapes" concept, whether the "grapes" (protons and neutrons) are closely packed or are a loose assembly in motion relative to each other, are as follows.

(1) The U-wave field (the electric field) of individual protons is partially blocked by the other particles in the nucleus (protons and neutrons). It is not possible to find a configuration of protons and neutrons as distinct entities, collectively constituting an atomic nucleus, where the full net positive electric field of the protons is present in all directions simultaneously. Yet, of course, the full field simultaneously in all directions is required, if only for the sake of the orbital electron structure.

(2) In the "bunch of grapes" model there is the need for nuclear binding energy to overcome the tendency of the nucleus to fly apart because of the mutual repulsion of the positive charges in the nucleus. The *mass deficiency* of atomic nuclei has been hypothesized as the cause of nuclear binding, but an acceptable mechanism is needed. To meet that requirement traditional 20th Century physics has hypothesized a force that operates only over the very short distances within a nucleus, is very strong within the nucleus, and is due to "exchange forces", that is the exchange of particles called mesons between the nuclear components.

The hypothesis is not entirely convincing, however, and has not been proven. Furthermore, as will shortly be seen, there is very little correlation between the amount of mass deficiency and the relative stability of a nucleus.

(3) The fact that a free neutron, one not part of an atomic nucleus, decays into a proton and an electron with a modest mean lifetime before decay but that the neutron is entirely stable when a component of a stable atomic nucleus is unexplained and would appear to be unexplainable in the "bunch of grapes" model.

All of the above difficulties are overcome by the Universal Physics nuclear model as presented in this section. The nucleus is a new unitary particle, realized as a new center-of-oscillation, a complex center oscillating as a resultant of the natural oscillations of its component simple centers-of-oscillation / particles analogous to the structure of the neutron. That structure of atomic nuclei, that model, performs as follows.

> (1) It naturally exhibits the correct electric field in all directions at all times. There are no component particles to get in the way. There are no components at all. The nucleus is a particle with its natural field, a single center-of-(complex) oscillation.
>
> (2) There is no need for nuclear binding energy at all, no need for a force to hold component particles together. The nucleus is one (complex) center-of-oscillation not mutually repelling multiple particles.
>
> (3) Within the nucleus the neutron does not exist as a separate particle. There is no neutron, as such, within the nucleus at all so, of course, there is no regular decay of a nuclear neutron in a stable nucleus.

There are other advantages to this nuclear model. It is difficult to envision matter-antimatter annihilation of an atomic nucleus and its antimatter counterpart in other nuclear models, but this Universal Physics model readily correlates with the mechanism of mutual annihilation presented above for simple particles. As will shortly be developed, the model will be shown to account for all of: the various nuclei, their masses, their stability or instability, radioactivity and its mean lifetime before decay, and so forth. It will also be shown to correlate directly with the origin of the universe.

The nuclear model is that of a complex center-of-oscillation the result of the co-location of its component centers-of-oscillation. Those components are A protons and $[A-Z]$ electrons, not the traditional Z protons and $N = [A-Z]$ neutrons. The neutron is itself a combination particle, the combining of one proton and one electron into a new, complex center-of-oscillation. The fundamental "building block" particles are the proton and the electron. The neutron is more properly viewed as the nucleus of the atom of $Z = 0$ and $A = 1$.

It is now necessary to develop that model in detail:

- The way in which the co-located centers combine,
- The mathematical description of the nucleus (analogous to equation 16-3 for the neutron),
- The correlation of the model and the characteristics of the actual nuclear species, nuclear types.

THE NUCLEAR SPECIES MODEL

The problem in developing the details of this general nuclear model is as follows.

In the case of the neutron the combining of the two component co-located centers-of-oscillation, a proton and an electron, into a new supercenter consisted of the direct addition of the two oscillations, of the two wave forms. Because the frequencies of the two component wave forms were different the relative phase of the two was not of consequence and the two frequencies *beat* together producing the neutron wave form.

(The general principle of addition of wave forms must be valid because it is upon that principle that the maintenance of conservation by $+U$ and $-U$ offsetting each other depends.)

To develop a corresponding general expression for atomic nuclei requires dealing with multiple protons and multiple electrons. So, the question is: how do (would) multiple protons or multiple electrons, alone, combine into a supercenter or as part of one ?

Of course, multiple protons and multiple electrons can only exist in combination with each other in an atomic nucleus the structure being too unstable otherwise. Furthermore, in such a structure, that is in an atomic nucleus' supercenter, the protons and electrons (and the implied neutrons) are not present as such. There is only the resulting supercenter. However, the question as to what is the theoretical form of multiple protons and multiple electrons in a nucleus is a necessary step in developing their combination into such a supercenter.

Each of the individuals in a set of protons or a set of electrons would have the same rest frequency, f_p or f_e. A frequency difference would be due only to the relativistic effect of their having different speeds. A phase difference would be due to their having different locations. However, as was pointed out in the case of the mutual annihilation of a particle and its anti-particle, in order to combine the two must be co-located over at least a brief period of time. For that to be so both the frequency and the phase of the two combining protons (theoretically combining as such) or the two combining electrons would be the same because their locations and velocities would have to be the same for them to be co-located.

The principal factors determining the form of an initial model must be the proper representation of Z and A so that the nuclear electric charge and Coulomb effect are correct (Z) and so that the apparent mass reflects at least the approximately correct value according to the atomic mass number (A). With regard to Z, Z corresponds to, is, the average value of a particle's oscillation. Neither the frequency nor the amplitude of the oscillatory part of the oscillation affects the value of Z.

With regard to A, for several reasons one would expect that a "double proton" would have a frequency of twice the normal single proton's frequency. First, of course, is that a double proton would be expected to have approximately twice the mass of a single proton. Since it has already been found that mass is proportional to frequency the double mass would seem to call for a doubling of the frequency.

In addition, if one reviews the development of the neutron's focusing action relative to that of a proton in Section *16 - A Model for the Universe (6) - The Neutron, Newton's Laws* (Figure 16-16(a) in particular), it can be noted that if the neutron's electron component frequency is increased then the number of different proton-form cycles per electron cycle decreases and their gradients increase. If that process were carried on to the point of the electron frequency equaling that of the proton then there would be only one form cycle and it would have twice the proton gradients. In other words it would be a double frequency proton.

One would then expect that a double proton would have the wave form of a single proton except that its average value would be double (its Z would be $Z = 2$), and its oscillation frequency would be doubled. In general by this reasoning, a particle that is M multiples of a fundamental particle such as a proton or an electron would have M times the average value and M times the frequency of the basic particle as in equation 17-1, below.

$$(17\text{-}1)\qquad U\left[M\cdot {}_{1}p^{1}\right] = U_c\cdot\left[M - \mathrm{Cos}\left[2\pi\cdot[M\cdot f_p]\cdot t\right]\right]$$

$$U\left[M\cdot {}_{-1}e^{0}\right] = -U_c\cdot\left[M - \mathrm{Cos}\left[2\pi\cdot[M\cdot f_e]\cdot t\right]\right]$$

Then, the structure of an atomic nucleus would be

$$(17\text{-}2)\qquad U\left[{}_{Z}Sym^{A}\right] = \left[A \text{ protons} + [N = A-Z] \text{ electrons}\right]$$

$$= U_c\cdot\left[A - \mathrm{Cos}[2\pi\cdot A\cdot f_p\cdot t] + -\left[N - \mathrm{Cos}[2\pi\cdot N\cdot f_e\cdot t]\right]\right]$$

$$= U_c\cdot\left[Z - \mathrm{Cos}[2\pi\cdot A\cdot f_p\cdot t] + \mathrm{Cos}[2\pi\cdot N\cdot f_e\cdot t]\right]$$

(The "Sym" of ${}_{Z}Sym^{A}$ means the element symbol, the one or two letter abbreviation for the element name per Table 17-6, further below.)

At this point some observations and / or reservations arise with regard to the nuclear species formulation of the above equation 17-2.

(1) The formulation reduces to the form for a neutron per equation 16-3 when the parameter values are $A = 1$, $Z = 0$ as it should, of course.

(2) The formulation must yield the proper overall average value of the wave form, $Z\cdot U_c$, which corresponds to the net positive charge of the nuclear supercenter. Because equation 17-2 contains no exponentiated cosines, only cosines of multiples of f_p and f_e, the average value of the oscillatory part of equation 17-2 is zero and the correct Z results from the non-oscillatory part.

(3) The oscillatory part of the wave form might, at first thought, be expected to have an amplitude proportional to the mass, that is proportional to A.

Amplitude performs in several different rolls in the overall functioning of a supercenter-of-oscillation and both the average amplitude and the amplitude of the oscillatory part must be treated. As already pointed out, the *average* amplitude must correspond to the value of Z for the supercenter. That is essential if the supercenter is to function properly according to Coulomb's Law, exhibiting the correct nuclear positive charge, electric field and U-wave field.

Furthermore, it is the average amplitude, only, that determines the magnitude of the Newton's Law response to a Coulomb interaction. It is the portion of the average amplitude of the incoming waves that is focused onto the encountered center's singularity and replaces part of the average amplitude that the encountered center would otherwise propagate that determines the Newton's Laws actions that result. That is because the Newton's Law effect is the long term time average of the instantaneous moment by moment action taking place. (Even over as brief a time as a trillionth of a second a proton oscillation goes through on the order of 10^{11} cycles.)

Of course, the overall Coulomb - Newton interaction is one integrated interaction. It is only we humans who must think about and describe it in terms of components: the (Coulomb) force and the resulting (Newton) acceleration, the two mediated by the effect that we call inertial mass.

Since the *average value* of the *oscillatory part* of the overall oscillation must be zero it follows that its peak to peak amplitude has no direct effect on those Coulomb - Newton interactions, on the mass. In that sense the oscillatory amplitude may be whatever it may wish to be. However, if for the same frequency the amplitude of the oscillation is increased, then the gradient, the primary focusing parameter, increases in direct proportion. Increasing the focusing power decreases the mass. Thus, for example, a doubling of the oscillation amplitude would cause a doubling of the focusing gradient and a consequent reduction of the mass by a factor of four.

That is clearly all wrong. If one were to feel that the oscillation amplitude should vary with the mass one would be thinking of greater, not smaller, amplitude for a greater mass. But, it is clear from the prior paragraph that the oscillation amplitude cannot be larger as A becomes larger and if it were to vary with the mass, with the value of A, it would have to vary inversely, so as to reduce the gradient and the focusing power. In any case, mass has been found to be directly proportional to frequency and the frequency varies according to A in equation 17-2.

Thus the amplitude of the oscillatory portion of the oscillation (the amplitude of each of the two oscillatory terms of equation 17-2) must be the same for all nuclear species and not a function of A or Z.

The inevitable resulting conclusion from this is:

The amplitude of the oscillation is a universal constant, U_c, *the same constant quantity that is the cause of the fundamental electric charge,* q, *being a constant.* (U_c *and* q *are essentially the same thing.)*

In extrapolating the model of the neutron, developed in the preceding section, to the family of all the nuclear species in general, the mathematical description portion of the neutron model has been treated, but not the remainder of the model. That remainder is the formation of the neutron from its component proton and electron mutually accelerating toward each other, relativistically increasing in mass, and uniting into a new center-of-oscillation in which the frequencies, f_p and f_e, in equation 16-3 are those corresponding to the larger relativistic masses of the two component particles (as Lamb Shift adjusted) not their rest masses. The development required to treat those effects begins after the figures below.

Figures 17-2 through 17-4 on the following pages depict the wave forms per equation 17-2 of the principal isotopes of the first three elements, $Z = 1$ to 3, Hydrogen, Helium, and Lithium. The neutron, being in effect the element $Z = 0$ is depicted to the same scale in Figure 17-1, below. The electron oscillation is included in that figure for comparison purposes.

The graphs use a ratio of f_p/f_e of $9/1$ rather than the much larger actual value, which is on the order of the rest value, $1,836.152,701$. The $9/1$ ratio permits indicating the general variation of the wave form in a moderate amount of space. At the actual f_p/f_e ratio the wave form change from f_p cycle to f_p cycle is much more gradual than in the figures.

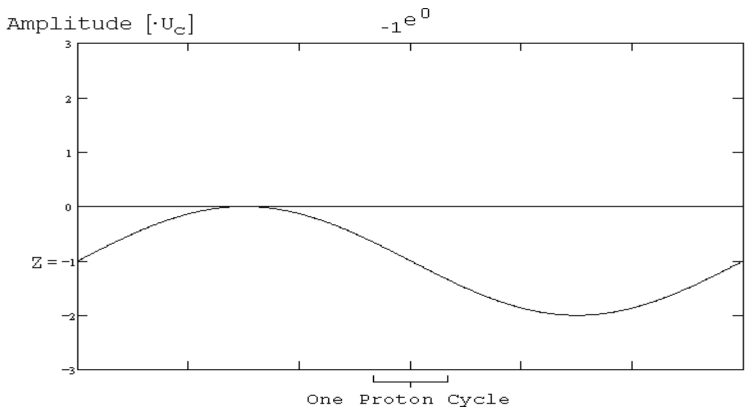


Figure 17-1(a), The Electron Wave Form

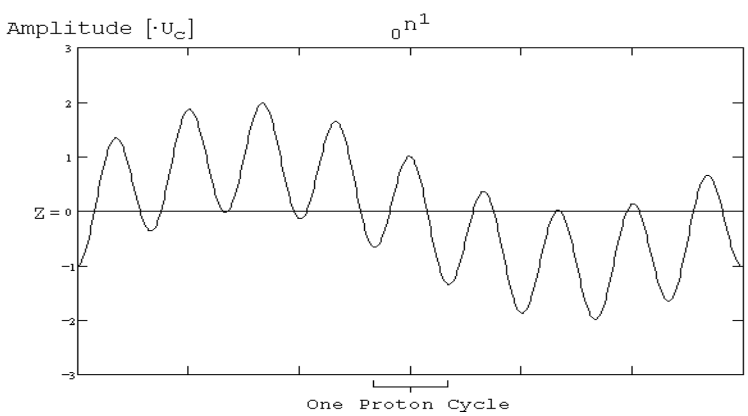


Figure 17-1(b), The Neutron Wave Form

Figure 17-2, The Hydrogen Wave Forms

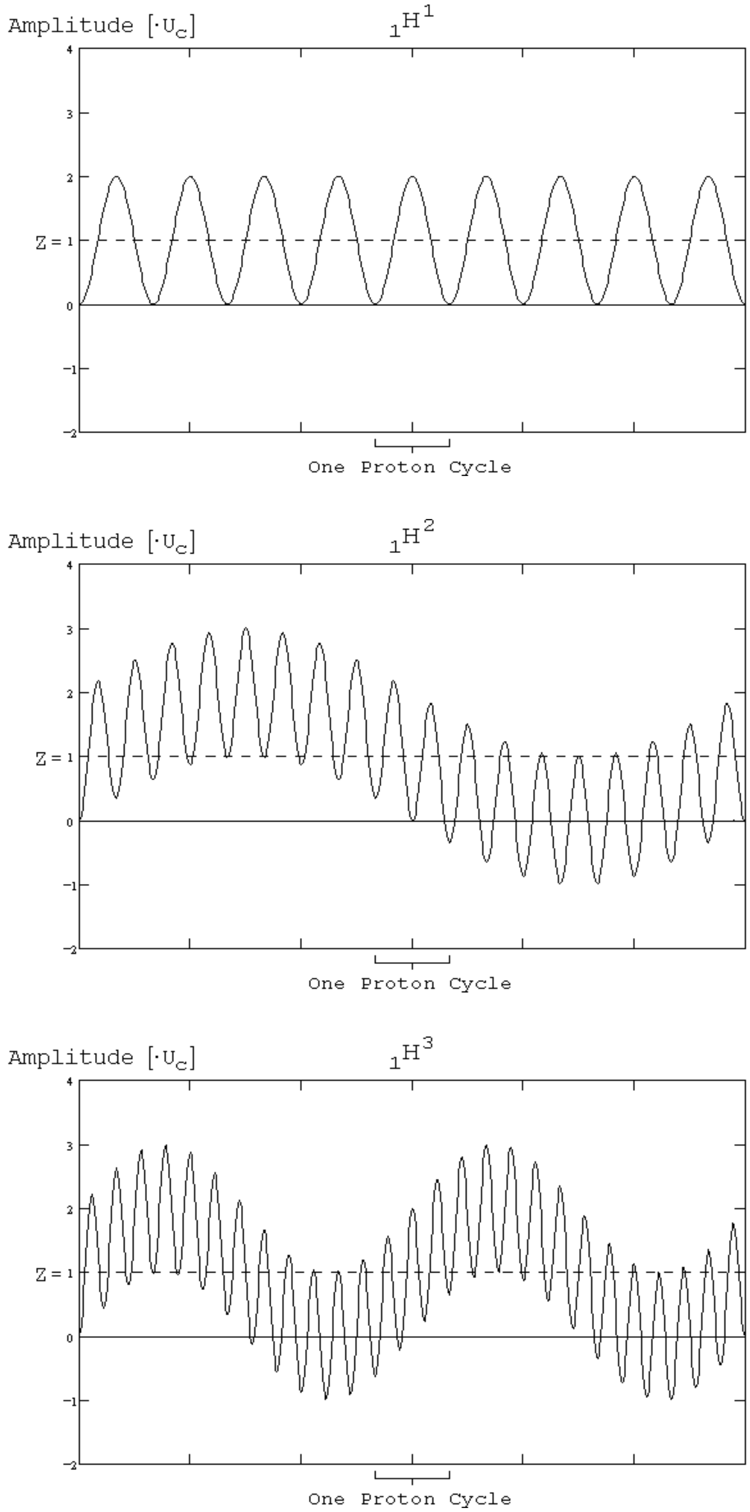


Figure 17-3, The Helium Wave Forms

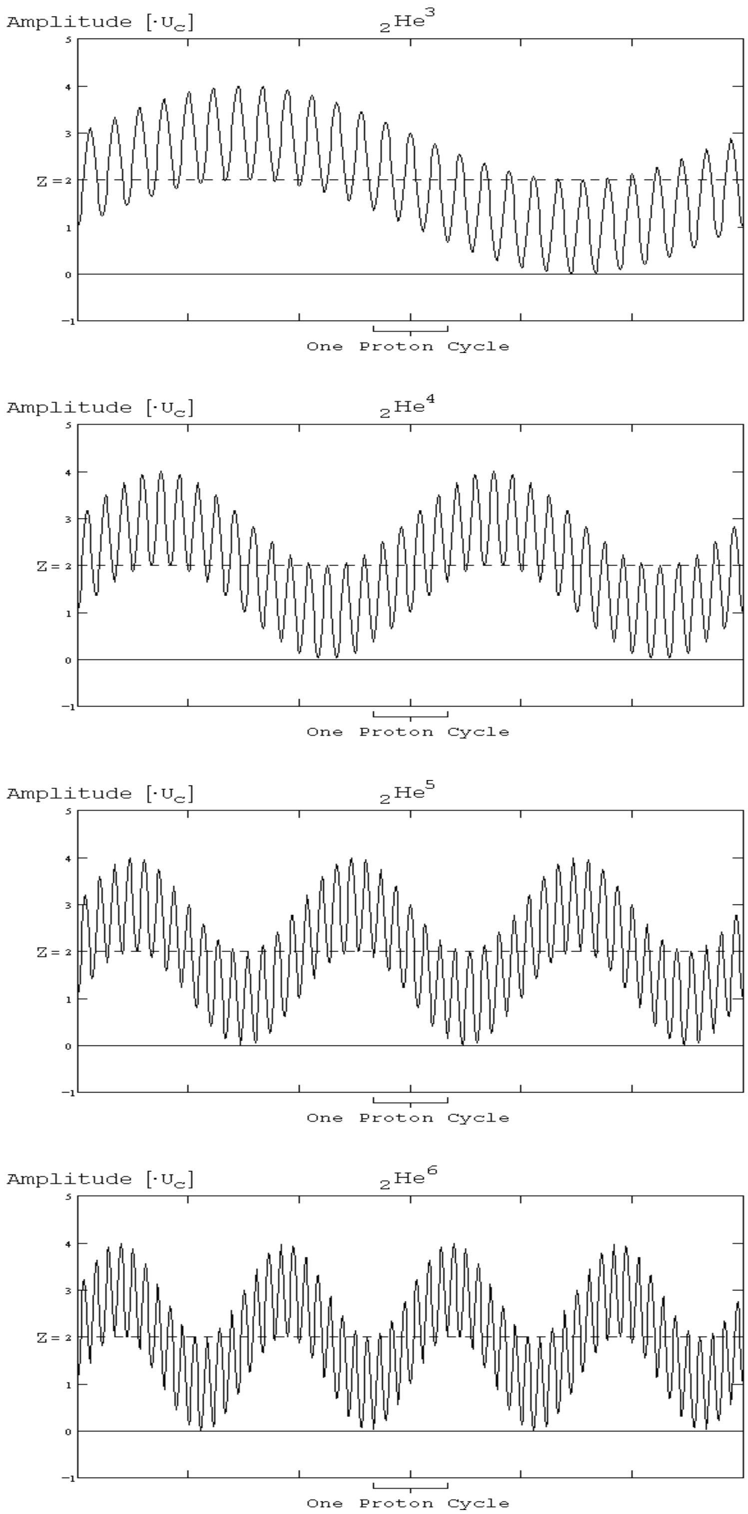
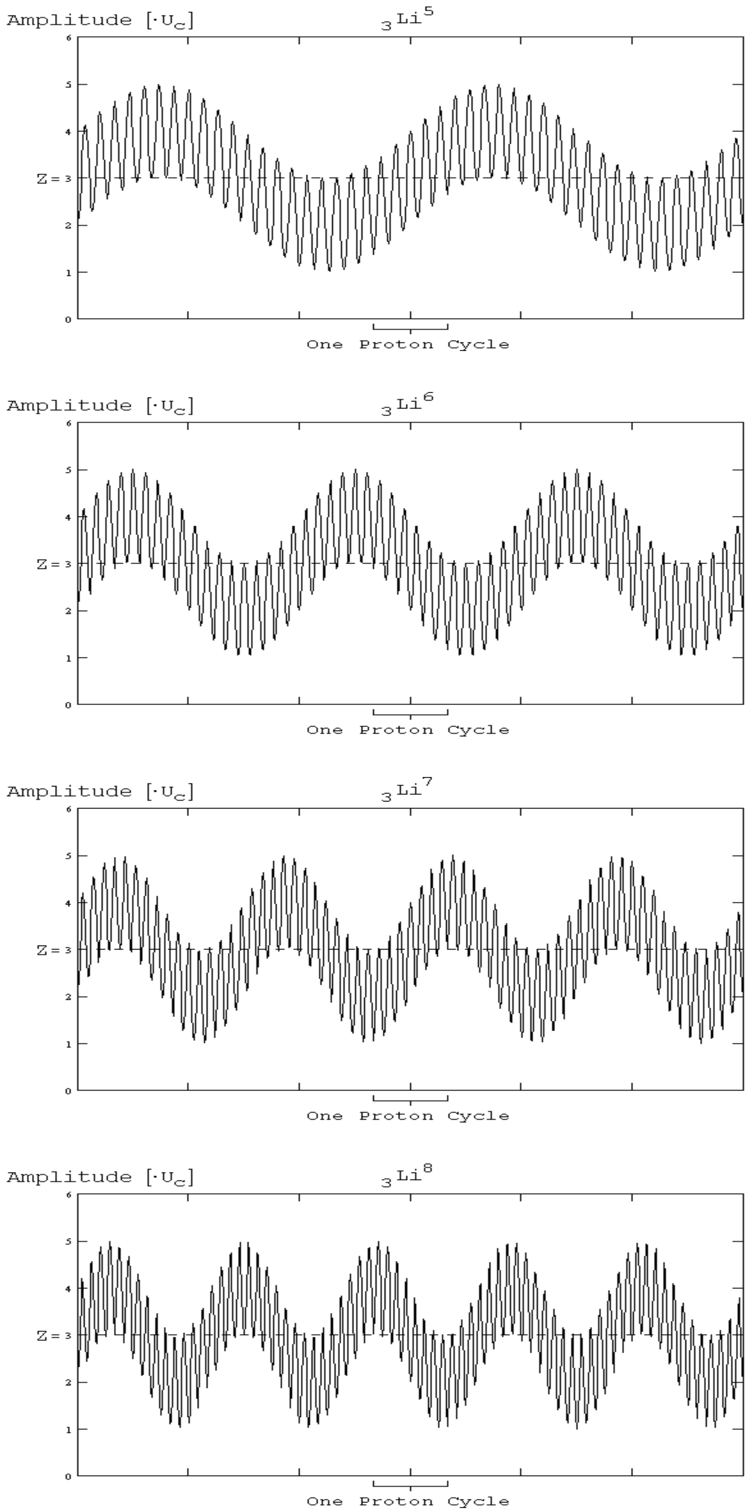


Figure 17-4, Lithium Wave Forms



Further Development of the Nuclear Species Model

The above figures illustrate the general form of the oscillations of the supercenters for various nuclear types but, there is another component to the problem of the nuclear structure and its model. In the case of the neutron it was found toward the end of section *16 - A Model for the Universe (6) - The Neutron, Newton's Laws*, equations 16-51 through 16-56, that the wave form in itself produces the effect that the neutron mass is the sum of the wave form component proton and electron masses. It was also found that the deviation of the actual neutron mass from the simple sum of the components' rest masses was because it is the components' escape velocity kinetic masses that enter into forming the particle.

The neutron is correctly described by its wave form equation provided that the frequencies, f_p and f_e, are those corresponding to the relativistically enhanced masses of the component particles. That is, the neutron is as if composed of a proton having a rest mass equal to its escape velocity kinetic mass plus a corresponding electron.

The equation and wave forms for the family of nuclear types, of which the neutron is one member, that is per equation 17-2, result in the particular nucleus being the sum of its A protons and $N = A - Z$ electrons. The specific particular nuclear mass of any one nuclear type must result from its components entering into it at masses other than their pure rest masses, just as is the case for the neutron.

It should be expected, then, that escape velocity masses be a factor in all of the atomic nuclei, the neutron and those that are more complex than the neutron. Evaluation of those cases in the manner as was performed for the neutron becomes an inordinately complex problem, however. The escape velocity calculations, which involve relativistically calculating the potential energy relationships among the particles, and the resulting velocities that they take on become quite complex when more than two particles are involved. Deuterium illustrates the multi-body escape velocity difficulty.

After the neutron, ${}_0n^1$, and the Hydrogen nucleus ${}_1H^1$, the next most complex nucleus is that of the Hydrogen isotope, Deuterium, ${}_1H^2$, the nucleus of the Deuterium atom, which is also referred to as the *deuteron*. That nucleus has traditionally been deemed to consist of one proton and one neutron. In this Universal Physics nuclear model the deuteron consists of the combination of two protons and one electron. Those two protons mutually repel each other. Between the electron and each of the protons there is attraction. Thus the escape velocity kinetic energy configuration is complex.

Figure 17-5(a), below, illustrates the electrostatically likely Deuterium nucleus component particles' configuration for their approach to merger into a deuteron. Their mutual repulsion places the two protons on opposite sides of the electron, as far from each other as they can be. The electron is then in the center by default, where it equally attracts each of the protons.

If the mutual repulsion between the two protons is ignored for the moment, then the same escape velocity kinetic energy as was found in the case of the formation of a neutron should be developed between each of the protons and the single electron. The velocity situation will be different from that in the neutron case because the electron, being simultaneously and equally attracted in exactly opposite directions experiences no net acceleration. But the energies should be the same, all of it appearing in kinetic energy of the protons. Thus, if the interaction between the two protons is ignored for the moment, the deuteron should have a mass excess equal to twice the mass excess of the neutron, $2 \times 839.854\ \mu\text{-amu}$ or $0.001{,}679{,}708$ *amu*.

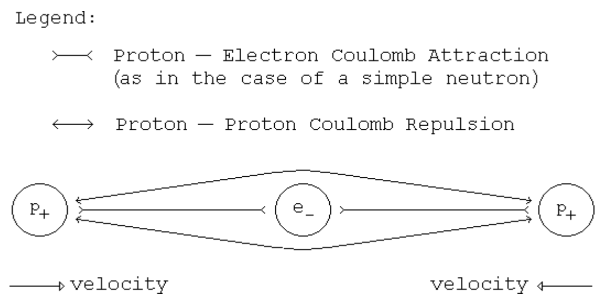


Figure 17-5(a)
Theoretical Formation of a Deuteron From Its Components

The Deuterium nucleus' kinetic mass deviation from the mass of its component particles is calculated in the same way as was done for the neutron at equation 16-49, as follows. (The Deuterium atom's orbital electron binding energy is too small to be of significance here.) (This mass difference is different from that developed just following Table 16-1. That table, using the traditional 20th Century physics procedure, takes the component nuclear particles to be protons and neutrons. Those neutrons include a mass excess of $839.854\ \mu\text{-amu}$. Here the components are the "pure" particles, protons and electrons, which themselves have no mass deficiency nor excess.)

$$
\begin{aligned}
(17\text{-}3)\quad m_{De,\Delta} &= m_{\text{Deuterium Nucleus}} - m_{\text{component particles}} \\
&= \left[m_{\text{De atom}} - m_{e,\text{orbit}}\right]_{\text{rest}} - \left[2 \cdot m_p + m_e\right]_{\text{rest}} \\
&= [2.014{,}101{,}779 - 0.000{,}548{,}579{,}903] - \cdots \\
&\qquad \cdots - [2 \cdot 1.007{,}276{,}470 + 0.000{,}548{,}579{,}903] \\
&= -0.001{,}548{,}319 \text{ amu}
\end{aligned}
$$

This negative numerical result is to be expected. Unlike the neutron, the deuteron has a mass deficiency, which is always found when the nucleus contains (according to the traditional model) multiple particles needing to be held together. In this Deuterium case the mass of the atomic nucleus has a net mass decrease in the amount per equation 17-4, below, which can only be due to the interaction of the two protons.

$$
\begin{array}{lrll}
(17\text{-}4) & +1{,}679.708 & \mu\text{-amu} & \text{proton-electron mass increase} \\
- & \underline{-1{,}548.319} & \mu\text{-amu} & \text{deuteron net mass decrease} \\
 & +3{,}228.027 & \mu\text{-amu} & \text{total required mass decrease} \\
 & & & \text{to be supplied by the protons}
\end{array}
$$

The algebraic sign of this effect is correct for the interaction of two like charged particles, two protons. When two *opposite* charged particles achieve their mutual escape velocity is just before they collide. But, when two *like* charged particles such as the two protons in the deuteron, rushing away from each other in mutual repulsion, achieve their escape velocity is at their maximum separation (infinite distance). To cause them to stay together and to not so rush apart, that much energy (their mutual escape velocity kinetic energies) must be removed from them.

The magnitude of the potential energy between the two protons is inversely proportional to the distance separating them just as in the case of a proton and an electron. In the case of the deuteron that separation distance is twice the distance separating the electron from either proton (per the above Figure 17-5(a)). Thus the potential energy between the two protons should be of magnitude half the potential energy between the electron and either proton or *419.927 μ-amu*. We have then:

(17-5)	-3,228.027	μ-amu	required mass decrease
	-419.927	μ-amu	decrease due to the usual Coulomb effect of the protons
	-2,808.100	μ-amu	to be accounted for

This calculation neglects the Lamb Shift effect on the interaction between the two protons. From Figure 16-22 with the value $^r/\rho = 4$ (twice that for the neutron) the Lamb Shift is on the order of *20%* and in addition is in the wrong direction to resolve the above missing mass decrease.

The three-component deuteron has a *net mass decrease* equal in magnitude to almost twice the two-component neutron's *mass excess*. No traditional scenario of behavior of the deuteron's component two protons and one electron would seem to lead to that result. However an additional effect is operative in the configuration of the Deuterium nucleus: Coulomb focusing. The electron center-of-oscillation, located exactly between the centers of the two protons, is in ideal position to focus an increased portion of the propagation from each proton onto the other proton as illustrated in Figure 17-10(b), below.

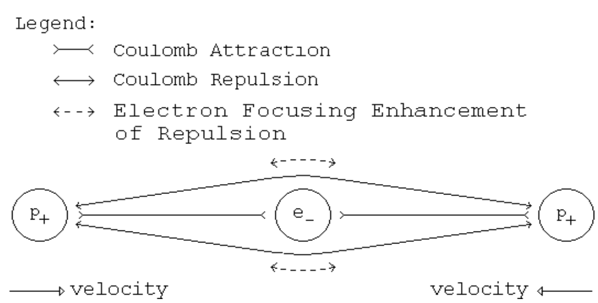


Figure 17-5(b)
Theoretical Formation of a Deuteron - Electron Focusing Action

That focusing action increases the amount of the electric field of each of the two protons that interacts with the other -- in effect produces results as if the protons' charges were larger. As a result the force of mutual repulsion and the potential energy between them are greater and the amount of energy / mass that they must lose to be able to combine is greater.

The effect of extra Coulomb focusing, due to the electron components, on the Coulomb effect potential energy between the *proton components of each of the nuclear types (all of which have Z more component protons than electrons) produces their mass decrease.*

The combination of the proton - electron Coulomb attraction and the simultaneous, focusing enhanced, proton - proton Coulomb repulsion produces the resulting deuteron net mass decrease. That decrease is equal to the energy that the two component protons must lose to become part of the nucleus as partially offset by the mass excess developed between the electron and each of the protons. Each of the proton components in the wave form, equation 17-2, are at an f_p that is less than the proton rest frequency in an amount corresponding to half the deuteron net mass decrease. The electron component frequency is the true electron rest frequency in this deuteron case.

Of course, unlike the case of the neutron, the components of an atomic nucleus cannot come together to form the nucleus naturally and unaided. There are only two ways that such a nucleus can come into existence. One is through the process of radioactive decay of a more complex nucleus, which is treated in the next section. The other is for the set of components, or more likely some two less complex nuclei, to be accelerated toward each other with so much energy that they merge in spite of the mutual repulsion. At the moment of merger not only would the new nucleus be formed, but in addition the excess mass would be given off in some combination of small particles and photons.

The description of these nuclei in terms of their component protons and electrons assembling in a particular manner is not to say that that action actually occurs in that way. Rather, it is the procedure for determining what the characteristics of the resulting nucleus must be: it must have a net mass decrease that corresponds to that which is required by the theoretical scenario of combination because that is the minimum mass / energy case.

However, there is much more to the overall development of this nuclear model. That further development requires a detailed analysis of the various nuclear types and a matching of the nuclear model to that data.

NUCLEAR DATA ANALYSIS

Table 17-6, starting on the second following page, is a partial list compilation of all atoms known, stable and unstable. (The table is a partial list plus a reference to the source data for a complete compilation.) In the table the atoms are grouped by atomic number, Z, with Z listed in ascending order and with all atoms having the same Z listed in ascending order of their atomic mass number, A. In addition to listing for each atom its symbol, name, Z, A, and mass, the table also indicates whether the atom is stable or not, the particle emitted if the atom is unstable, the mass deficiency and the *separation energy* (explained below).

Just as presented earlier for the fundamental physical constants, whose values are published by CODATA, the best set of internationally accepted masses of the various atoms are up-dated and published as more accurate measurements become available. The last such publication was *The 1983 Atomic Mass Evaluation* by The National Institute of Nuclear Physics and High-Energy Physics, Amsterdam; University of Technology, Delft, The Netherlands; and Laboratoire Rene Bernas du CSNSM, Orsay, France. The atomic masses of Table 17-6 are those of that 1983 evaluation.

The mass deficiency, which was referred to earlier in this section, is given by equation 17-6, below. (Of course, throughout this discussion of the atomic, nuclear, particle or whatever masses it is rest masses that are intended. Relativistic mass increases occur based solely on velocity. Atomic nuclear structure is independent of that effect.)

```
(17-6)   Mass          Mass of         Mass of        Atomic
         Defic- =     Nuclear    +   Orbital    -    Mass
         -iency     Components     Electrons     (Per Table)

         The "Nuclear Components" are:
           Protons and neutrons for mass deficiency.
           Protons and electrons for mass  decrease.
        (The electrons' orbital binding energy is
         so small, on the order of 0.000,000,01
         amu, as to be negligible here.)
```

The *separation energy* deals with the possibility of decay of a nuclear type. It is the mass of the nucleus before decay less the mass of the decay products as equation 17-7, below.

```
(17-7)  Separation  =  Mass of nucleus before
         Energy          decay

                    +  One electron mass if the decay
                       is by the nucleus capturing an
                       electron

                    -  Mass of resulting nucleus

                    -  Mass of particle(s) emitted

        (The nuclear mass is in each case the
         atomic mass per the table less the mass of
         the Z orbital electrons.  Again, the
         electrons' orbital binding energy is
         negligible here.)

        (Electron capture occurs when an electron
         of the inner-most orbit falls into the
         nucleus, is captured by it.)
```

If the *separation energy* is positive then the initial component(s) have enough mass to make up the final components plus some extra mass to appear as energy of motion of the final components or as E-M radiation. If the *separation energy* is negative then the decay cannot take place because there is not enough mass to make up the final components and conservation would be violated. Therefore, positive *separation energy* means instability and negative *separation energy* means stability.

In a practical sense the positive *separation energy* must be large enough to supply the escape velocity of the product particles, just as was the case for the neutron. Otherwise a decay would be followed by an immediate recombination and be, in effect, no decay at all.

Any nuclear species except Hydrogen can have, at least in theory, a family of Separation Energies for different decay products. The separation energy listed in Table 17-6 is the largest one for that atom, which corresponds in general to the most probable decay, which is the decay listed in the table.

Table 17-6
The Natural Atomic Species and Masses

		Z	A	Measured Atomic Mass amu	Emission if any	Mass Defic'y μ-amu	Separ'n Energy μ-amu
n	Neutron	0	1	1.008,664,904	-Beta	-840	840
H	Hydrogen	1	1	1.007,825,035		0	(-)
			2	2.014,101,779		3,228	(-)
			3	3.016,049,27	-Beta	9,106	20
He	Helium	2	3	3.016,029,31		9,965	(-)
			4	4.002,603,24		32,056	(-)
			5	5.012,220	Neutron	29,425	952
			6	6.018,886,0	-Beta	31,424	3,765
Li	Lithium	3	5	5.012,540	Proton	28,265	3,209
			6	6.015,121,4		34,348	(-)
			7	7.016,003		42,132	(-)
			8	8.022,485,6	-Beta	44,314	17,180
			9	9.026,789,0	-Beta	48,676	14,607
Be	Beryllium	4	6	6.019,725	Proton	28,905	457
			7	7.016,928,3	Elec Capt	40,367	2,022
			8	8.005,305,12	Alpha	60,655	2,842
			9	9.012,182,2		62,443	(-)
			10	10.013,534,1	-Beta	69,756	597
			11	11.021,658	-Beta	70,297	12,353
B	Boron	5	8	8.024,605,8	+Beta	40,514	19,301
			9	9.013,328,8	Proton	60,456	1,296
			10	10.012,936,9		69,513	(-)
			11	11.009,305,4		81,809	(-)
			12	12.014,352,6	-Beta	85,427	14,353
			13	13.017,802	-Beta	90,642	14,447
C	Carbon	6	10	10.016,856,4	+Beta	64,754	3,322
			11	11.011,433,3	+Beta	78,842	2,128
			12	12.000,000,000		98,940	(-)
			13	13.003,354,826		104,250	(-)
			14	14.003,241,982	-Beta	113,028	168
			15	15.010,599,2	-Beta	114,335	10,490
			16	16.014,701	-Beta	118,898	9,601
N	Nitrogen	7	12	12.018,613,0	+Beta	79,487	18,613
			13	13.005,738,60	+Beta	101,026	2,384
			14	14.003,074,002		112,356	(-)
			15	15.000,108,97		123,986	(-)
			16	16.005,099,9	-Beta	127,660	10,185
			17	17.008,450	-Beta	132,974	9,319

Table 17-6 (continued)

		Z	A	Measured Atomic Mass amu	Emission if any	Mass Defic'y μ-amu	Separ'n Energy μ-amu
O	Oxygen	8	14	14.008,595,33	+Beta	105,994	5,521
			15	15.003,065,4	+Beta	120,189	2,956
			16	15.994,914,63		143,724	(-)
			17	16.999,131,2		148,172	(-)
			18	17.999,160,3		156,808	(-)
			19	19.003,577	-Beta	154,337	5,174
			20	20.004,075,5	-Beta	162,504	4,094
F	Fluorine	9	16	16.011,466	+Beta	119,614	16,551
			17	17.002,095,05	+Beta	137,650	2,964
			18	18.000,937,4	+Beta	147,472	1,777
			19	18.998,403,22		166,230	(-)
			20	19.999,981,39	-Beta	165,758	7,546
			21	20.999,948	-Beta	174,456	6,105
Ne	Neon	10	18	18.005,710	+Beta	141,860	4,773
			19	19.001,879,7	+Beta	154,355	3,476
			20	19.992,435,6		180,862	(-)
			21	20.993,842,8		188,120	(-)
			22	21.991,383,1		199,245	(-)
			23	22.994,465,4	-Beta	196,429	4,698
			24	23.993,613	-Beta	205,946	2,652
Na	Sodium	11	20	20.007,344	+Beta	156,716	14,908
			21	20.997,650,5	+Beta	175,074	3,808
			22	21.994,434,1	+Beta	186,955	3,051
			23	22.989,767,7		209,525	(-)
			24	23.990,961,4	-Beta	207,758	5,919
			25	24.989,953	-Beta	217,431	4,216
			26	25.992,586	-Beta	223,463	9,992
Mg	Magnes-sium	12	22	21.999,574,3	Proton	180,975	5,689
			23	22.994,124,4	+Beta	195,090	4,357
			24	23.985,042,3		222,915	(-)
			25	24.985,737,4		230,885	(-)
			26	25.982,593,7		242,6	(-)
			27	26.984,341,2	-Beta	239,533	2,803
			28	27.983,876,8	-Beta	248,662	1,967
Al	Aluminum	13	24	23.999,941	+Beta	197,099	14,899
			25	24.990,429,0	+Beta	215,275	4,692
			26	25.986,892,2	+Beta	227,477	4,299
			27	26.981,538,6		252,414	(-)
			28	27.981,910,2	-Beta	249,789	4,983
			29	28.980,446	-Beta	259,918	3,951
			30	29.982,940	-Beta	266,089	9,170

Table 17-6 (continued)

	Z	A	Measured Atomic Mass amu	Emission if any	Mass Defic'y µ-amu	Separ'n Energy µ-amu
Si Silicon	14	26	25.992,330,00	+Beta	221,200	5,438
		27	26.986,703,90	+Beta	235,491	5,165
		28	27.976,927,10		253,932	(-)
		29	28.976,494,90		274,787	(-)
		30	29.973,770,10		274,419	(-)
		31	30.975,362,10	-Beta	281,492	1,600
		32	31.974,148,30	-Beta	291,371	241
P Phospho-rus	15	28	27.992,313,00	+Beta	237,707	15,386
		29	28.981,803,00	+Beta	256,881	5,308
		30	29.978,306,70	+Beta	269,043	4,537
		31	30.973,762,00		294,850	(-)
		32	31.973,906,80	-Beta	290,772	1,836
		33	32.971,725,20	-Beta	301,619	267
		34	33.973,636,20	-Beta	308,373	5,770
S Sulfur	16	30	29.984,903,00	+Beta	261,606	6,596
		31	30.979,554,30	+Beta	275,620	5,792
		32	31.972,070,70		291,769	(-)
		33	32.971,458,43		314,483	(-)
		34	33.967,866,65		313,302	(-)
		35	34.969,031,83	-Beta	320,802	179
		36	35.967,080,62		331,418	(-)
		37	36.971,125,54	-Beta	336,038	5,223
		38	37.971,162,00	-Beta	344,667	3,151

(etc.)

1 µ-amu = 0.000,001 amu
read as "micro-amu"

This table begins a list of the known atomic species. By "known" is meant that a sufficient amount of the isotope has been isolated to enable a measurement of its atomic mass with some reasonable accuracy. The omitted isotopes follow the same patterns as those included.

The data is derived from:

> "The 1983 Atomic Mass Evaluation" by The National Institute of Nuclear Physics and High-Energy Physics, Amsterdam; University of Technology, Delft, The Netherlands; and Laboratoire Rene Bernas du CSNSM, Orsay, France.

The table can be extended to its finish by applying the equations 17-9 and 17-10 definitions of separation energy and mass deficiency to the data in "The 1983 Atomic Mass Evaluation".

End of Table 17-6

Examination of the mass deficiency data in Table 17-6 discloses insufficient correlation with the various atoms' nuclear stability or instability. Mass deficiency tends generally to increase with atomic number, Z, and atomic mass number, A, but there is no value of mass deficiency that separates stable and unstable nuclei.

It would probably be more appropriate to work in terms of the mass deficiency per nuclear particle $[^{MD}/A]$ or per nuclear proton $[^{MD}/Z]$ since it would presumably require more binding energy to bind more protons while neutrons (neutralized protons) are not so much part of the problem. But neither of those values show sufficient correlation to specifically relate them to nuclear stability or instability. Nuclear stability / instability correlates with mass deficiency in only a broad and general sense.

The data in Table 17-6 make clear that, without yet asking for a reason (which is presented below), *separation energy* is the touchstone of nuclear stability. For each Z there is a number of nuclear species, called isotopes, of successively larger A. They differ among each other only by the number of neutrons in the nucleus. The number of protons is the same for the same Z. For any Z the isotopes of "medium values of A" are stable. They have negative *separation energy*; that is, the total mass / energy of the nucleus is not large enough to make up any set of decay products whatsoever.

Those of smaller A have positive *separation energy* and emit a particle which in most cases ($+Beta$, a positron) changes the species to being species $[Z-1]$ at the same A, a step toward being a species "of medium A" for the new, lower Z that it has become. (In some cases a different particle is emitted but the tendency to change toward a species where the A is "medium" is always the case.) For example, unstable species $_7N^{12}$ emits a $+Beta$ and becomes stable species $_6C^{12}$.

Likewise, the species of relatively large A for their Z also have positive *separation energy*. They in most cases emit a particle ($-Beta$, an electron) which changes the species to being species $[Z+1]$ at the same A, a step toward being a species "of medium A" for the new higher Z that it has become. For example, unstable species $_7N^{17}$ emits a -Beta and becomes stable species $_8O^{17}$.

So to speak, all atomic nuclei are unstable; however, there are no products to which those with negative *separation energy* can decay; they are forced into stability by the requirements of conservation of mass / energy. Those with positive *separation energy* can and do decay and the process, the nature of the particle emitted, is such as to move them toward being stable species.

(The process, called *radioactivity*, does not always immediately occur. Rather it is delayed in various amounts and occurs at an overall exponential rate. The process is treated in section *18 - A Model for the Universe (9) - Radioactivity*.)

Why is this so ? It is the pattern of the nuclear masses that creates this situation. As indicated greatly exaggerated in Figure 17-7 on the following page, it is the way that the mass varies from isotope to isotope that results in a narrow range of nuclei with negative *separation energy* and consequent stability, the nuclei on either side of that range having positive *separation energy* and consequent instability. For a given Z the masses of the isotopes are not exactly some constant number times A; rather they vary from such a straight line relationship, only very slightly, in an S-shaped curve fashion.

This curvature in the variation of mass, which is so important and significant, is too small to be observed in a practical unexaggerated plot. If, instead, the plot is of *[A - Exact Nuclear Mass (amu)]* versus A then only the deviations from linearity are plotted, the changes in curvature which range from small to large to small again. Figure 17-7 is an artificial depiction in which a set of isotopes is depicted with exaggeration and modification in order to illustrate the point. Figure 17-8, on the next two pages, is a precise and accurate plot of that curvature change for selected nuclear species.

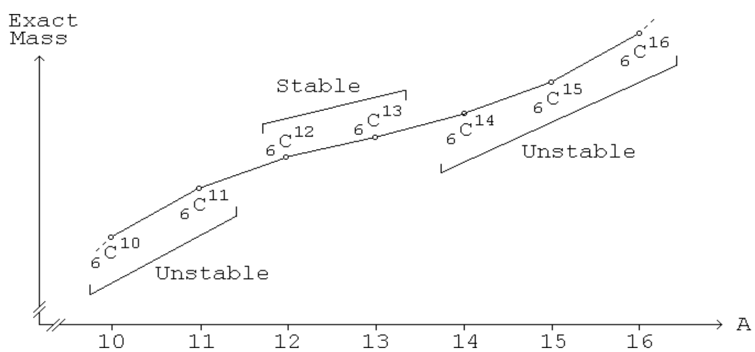


Figure 17-7
Curvature in Isotope Nuclear Mass Variations (Exaggerated)

The curves of Figure 17-8, in addition to demonstrating the curvature of the change in mass from isotope to isotope, disclose two other important phenomena:

> (1) There is a distinction in mass variation pattern between isotopes of odd A and those of even A. Two separate curves appear for each Z, each species, one curve for the odd A isotopes and another for the even A ones.
>
> (2) There is a distinction in the mass variation of odd and even Z species. In odd Z species the odd A isotopes are the upper curve in each plot. For the even Z species the odd A isotopes are the lower curve.

These two data combined would indicate that the distinction is one primarily related to the number of neutrons in the nucleus, whether odd or even. That is, since the number of neutrons in a nucleus is $[A-Z]$, then if both A and Z are odd or both A and Z are even the number of neutrons will be even. If one of A and Z is odd and the other is even the number of neutrons will be odd. Since the vertical axis in the plots is proportional to the nuclear species's actual mass the curves indicate that nuclei of even N are slightly less massive.

These variations in the nuclear species masses are relatively small. Broadly speaking the masses are all very near to A, which varies linearly. Yet these small mass variations account for the entire family of stable isotopes that give us our world and its characteristics. Clearly it is of crucial importance for a model of nature to model and account for the exact nuclear species masses.

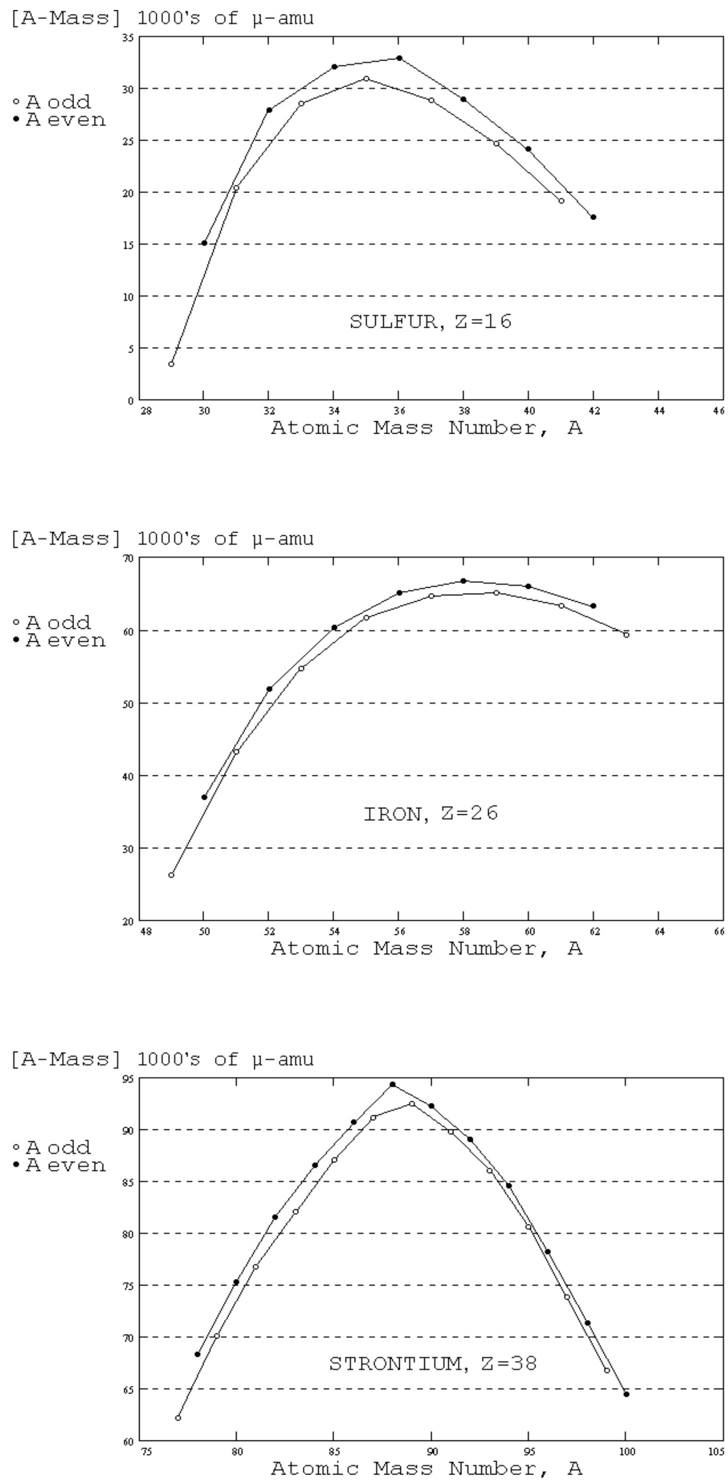


Figure 17-8, Page 1

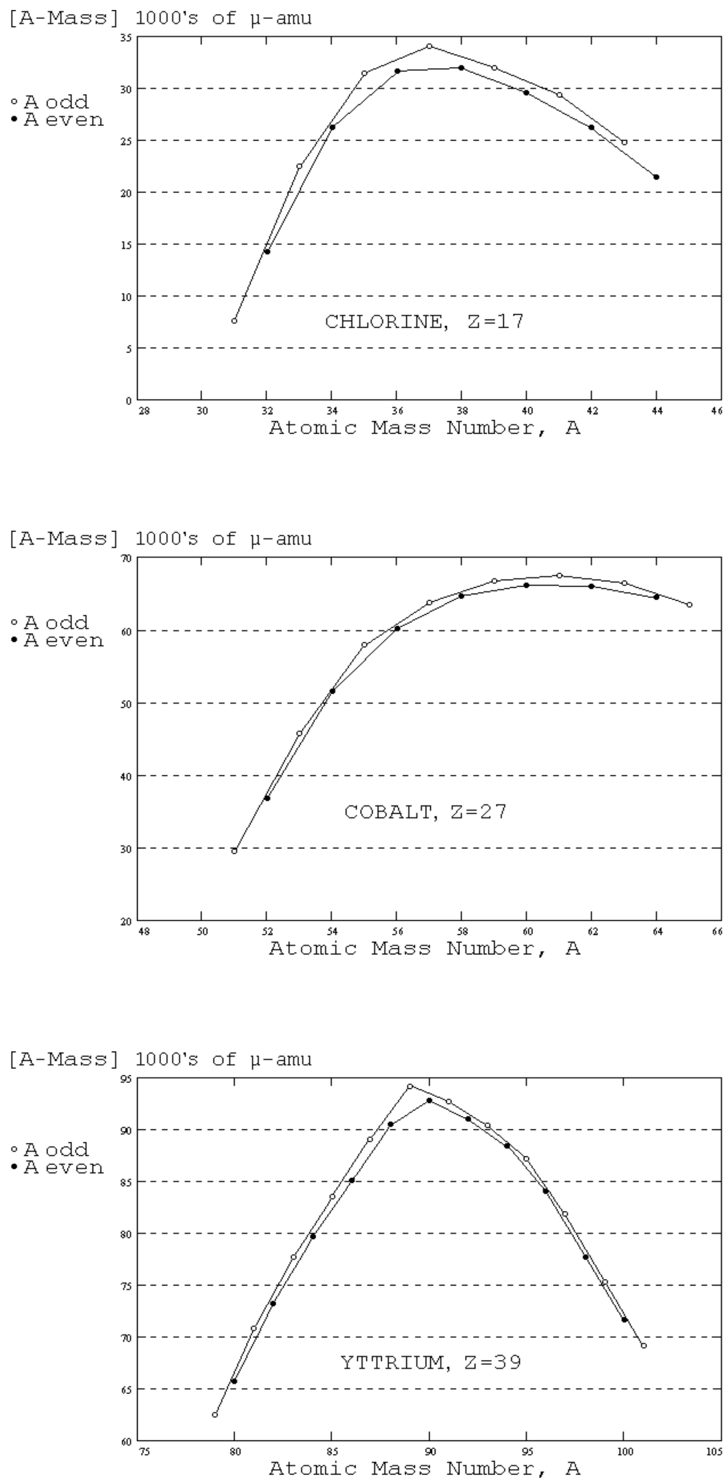


Figure 17-8, Page 2

The data of Table 17-6, the masses and the mass deficiencies, appear to be random and chaotic in their minor variations, the very variations that are crucial to accounting for the behavior of matter. But, since nature is orderly, there must be an underlying pattern or patterns that account for the exact actual masses, which are themselves the cause of the overall pattern of stable and unstable species. It is those patterns that must be found and modeled. Their presence is confirmed by the regularity of the curves of Figure 17-8.

Defining N as the number of neutrons in a nucleus where $N = A-Z$, it was pointed out in conjunction with Figure 16-2 that the ratio $^N/_A$ is always equal to or a moderate amount larger than 0.5 for the stable nuclei, the sole exceptions being the $_1H^1$ Hydrogen and $_2He^3$ Helium Three nuclei which do not have enough components to meet the rule. If a plot is made to show the trend of $^N/_A$ versus A a pattern emerges in the entire family of nuclear species as shown in Figure 17-9, below.

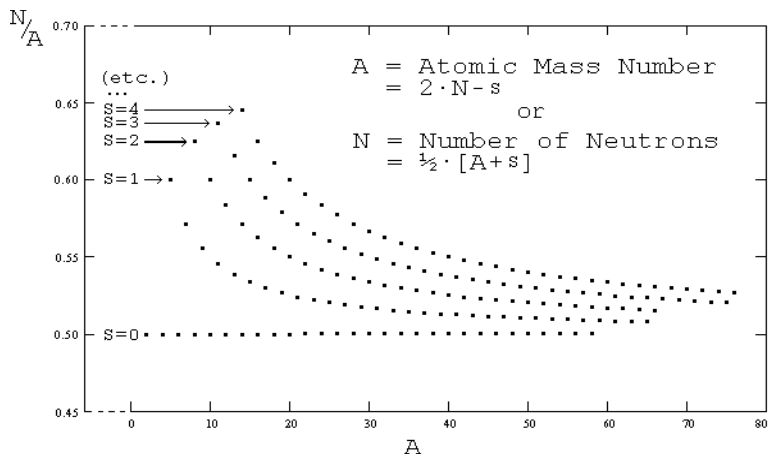


Figure 17-9

The seemingly fairly random pattern of the atomic nuclear species now becomes orderly based only on the ratio of the neutron number to the atomic mass number, $^N/_A$. The nuclei appear in series according to the relative amounts of the particles, more precisely according to

$$(17\text{-}8)\quad A = 2\cdot N - s$$

where s is an index, a series number for each of the series. This suggests an underlying structural pattern to the assembly of the various atomic nuclei.

However, Figure 17-9 is in terms of the integers, A and N, not exact masses. That a set of integers produces an orderly pattern does not necessarily mean that the actual exact masses are orderly. It is a systematic pattern of nuclear structure and exact nuclear masses that must be found. The curves of Figure 17-8 show such a pattern to exist within families of nuclei of the same Z, but it must exist for all of the nuclei collectively.

The structural pattern of equation 17-8 is further presented in Table 17-10 on the following three pages. The nuclear species are arranged in the figure according to the series s, found above. (The additional species implied by the extension of each row in the table are theoretically possible but are too unstable to obtain or measure.)

Table 17-10
Chart of the Nuclei

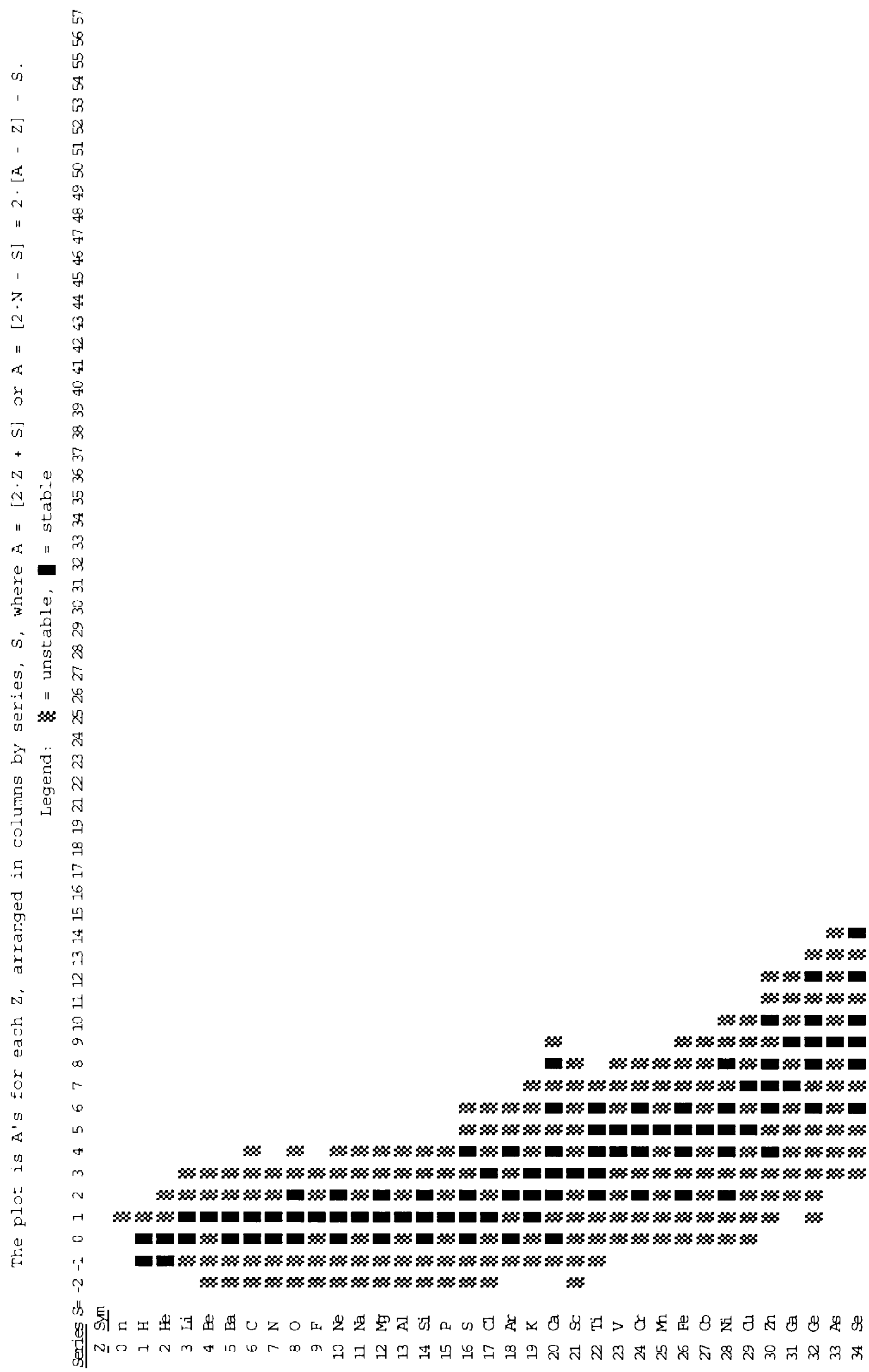


Table 17-10 (Continued)

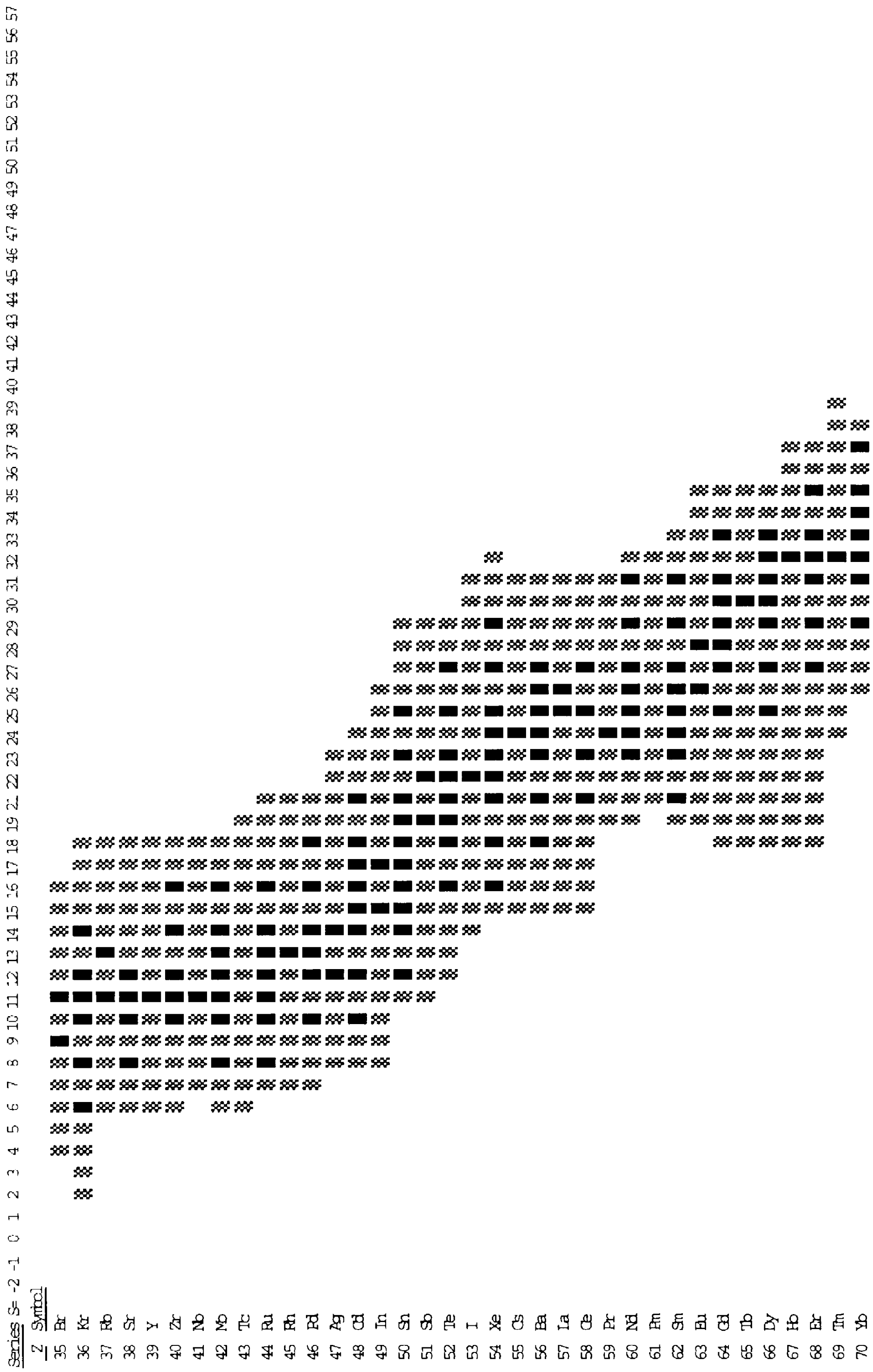


Table 17-10 (Continued)

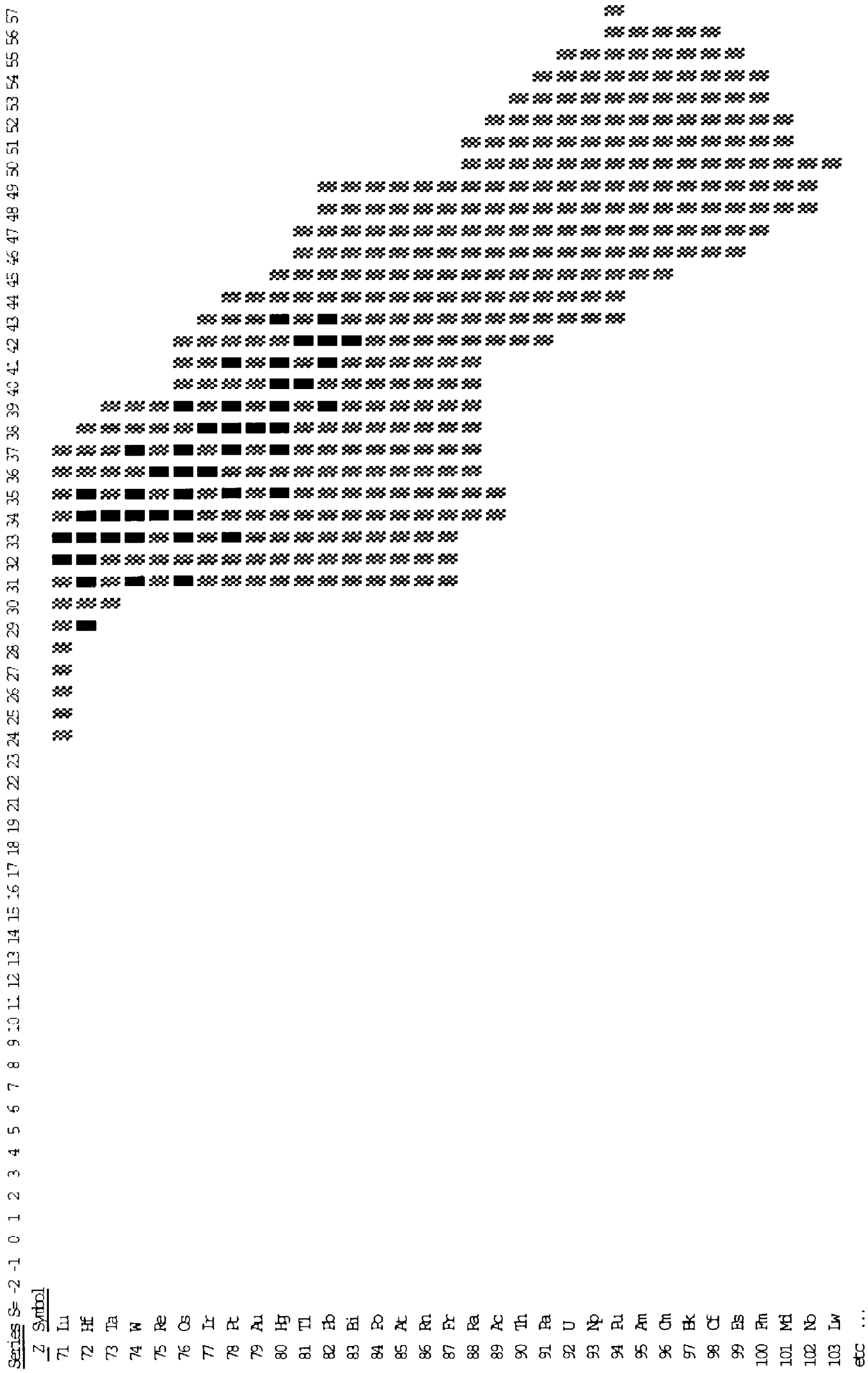


Table 17-6 lists the nuclear species according to Z and by A for each Z. The ordering could just as well by according to A and then by Z for each A. If that is done the same results as presented so far are obtained: behavior analogous to Figures 17-7 and 17-8 and the discussion so far presented.

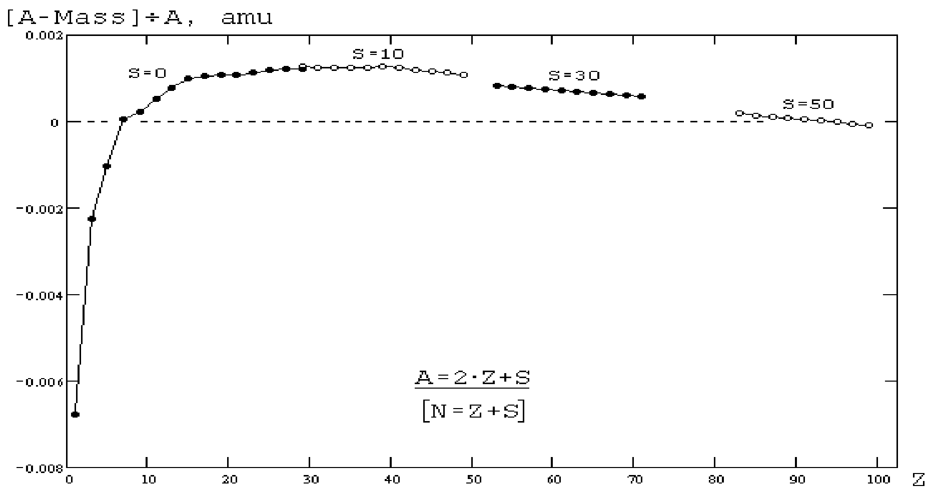
Before proceeding with further analysis some additional observations on the data already presented should be made.

> If one examines Table 17-6 from Oxygen on an odd / even pattern to the stability of the nuclear species appears. Odd Z species have, with almost no exceptions, two or fewer stable nuclei compared to even Z species, which have three or more stable nuclei. The pattern is true of all of the nuclear species except those before Oxygen, where the variety of possible nuclei is limited by the small Z, and those after Bismuth, which are completely unstable for reasons developed later.
>
> In examining Table 17-6 for "almost stable nuclei", that is unstable species differing from stable species by one unit of A (by one neutron), the positive separation energy that enables the instability is usually moderate, in the range from near zero to on the order of a few thousand μ-*amu*, that is a few thousand $amu \cdot 10^{-6}$. Thus a difference of on the order of a few thousand μ-*amu* in overall mass could make the difference between stability and instability for a marginal case nuclear type.
>
> Now, referring to the examples of Figure 17-8, the vertical axis is in units of *1000's of* μ*-amu.* For example, taking Sulfur ${}_{16}S^{35}$, *[A - mass] = 0.030,968 = 30.968 1,000's of* μ*-amu.* In the figure the mass differences between the upper and lower curves for the various species are typically in the range of a few thousand μ-*amu*, an amount sufficient to make the difference between stability and instability for the "almost stable nuclei".
>
> In other words, that some nuclear species have a significantly greater number of stable nuclei than others at nearly the same Z, as demonstrated in Figure 17-10, becomes more understandable in terms of the masses for "almost stable species" differing by an amount comparable in magnitude to their separation energies so that they might easily fall on one side or the other of the stable / unstable boundary.

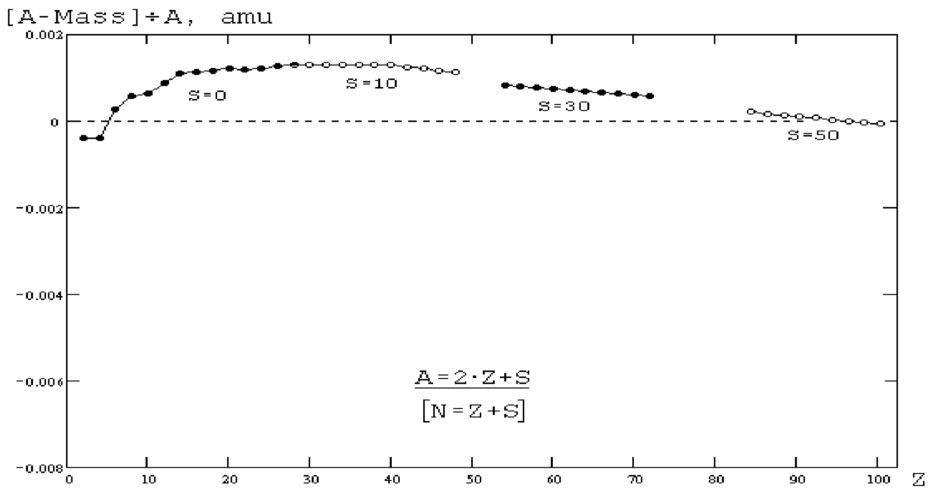
Turning now to a comparative examination of the masses of various nuclei within an *s-series* per equation 17-8, analysis is difficult because the search is for patterns of behavior in very minor variations in relatively large quantities. If the overall masses are analytically compared the relatively large total masses prevent observation of the minor mass variations. A procedure to get around that problem is to find a directly related smaller number to analyze.

Such a procedure was used in Figures 17-8, the related quantity being *[A - mass]*. That same quantity will now be employed again except slightly modified. For Figure 17-8 the range of values of the masses depicted in one graph was quite limited. Now a much greater mass range is to be treated. In order to reduce the size of graph required for a given precision or resolution in the graph, the related quantity plotted will now be $[A - mass] \div A$.

Because it has already been found that there is a significant distinction between odd and even Z species the two will be analyzed separately. The resulting analysis of selected typical *s-series* of nuclear species is presented in Figure 17-11, below.



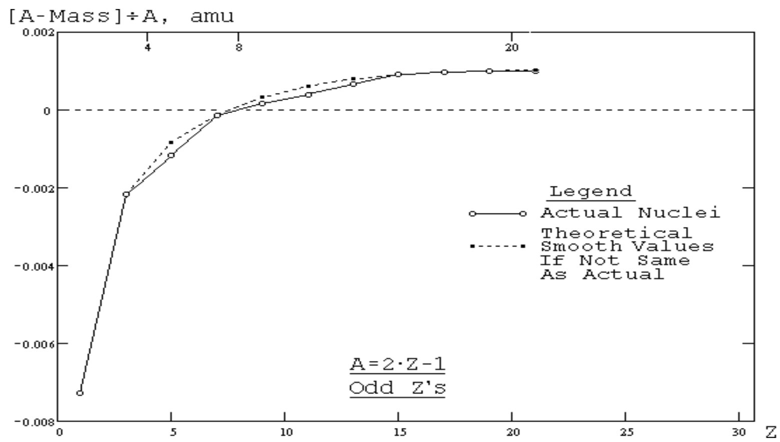
(a) Odd Z's



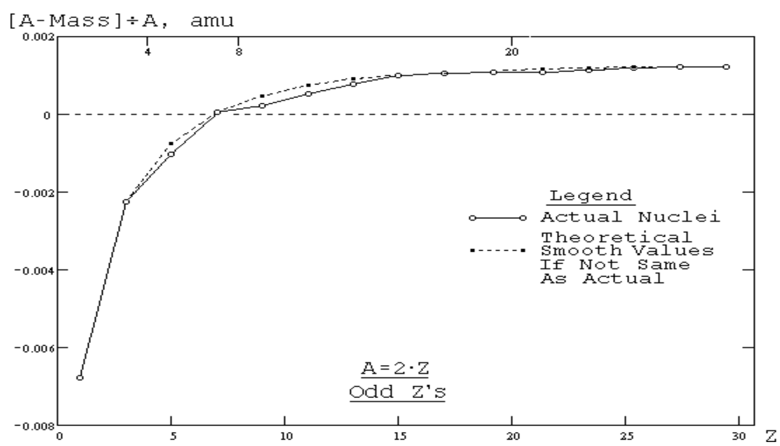
(b) Even Z's
Figure 17-11

These data would appear to indicate that there is a simple and regular mode of behavior, structure or process that operates effectively for high Z or high s series, that the variations from nuclear type to type are smooth and regular there. That mode apppears to also operate for low Z, low s series, but is apparently there partially overwhelmed by some other effect not so far detected and taken into account.

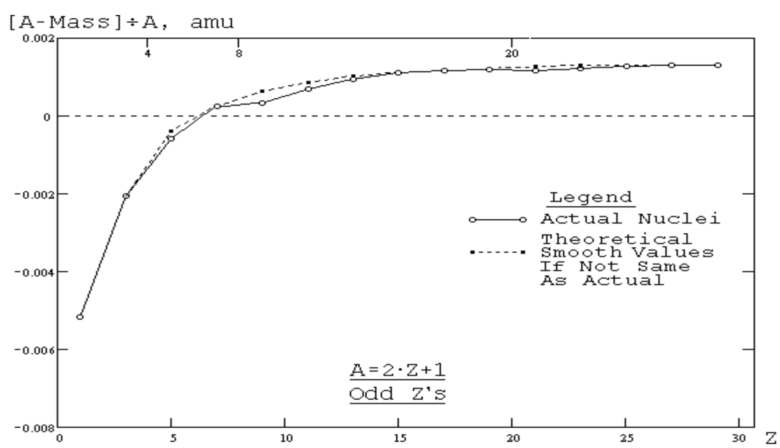
To analyze the process operating at low Z or on low s series, Figure 17-12 investigates the same changes as did Figure 17-11, but now for several adjacent low s series: $s = -1, 0,$ and $+1$. The outstanding characteristics of these data, as plotted, is that regular dips or valleys in the graphs occur at values of Z just following each of $Z = 4, 8,$ and 20.



(a) Series s = -1

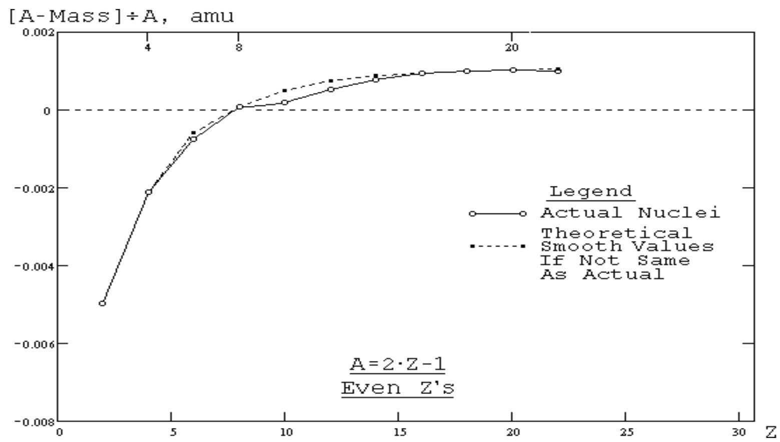


(b) Series s = 0

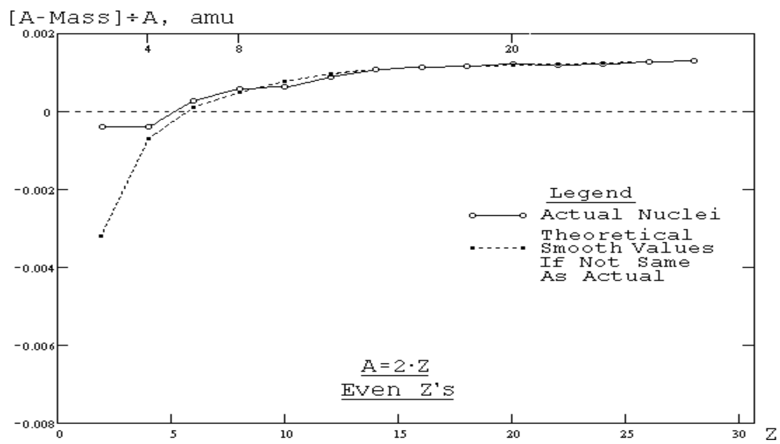


(c) Series s = +1

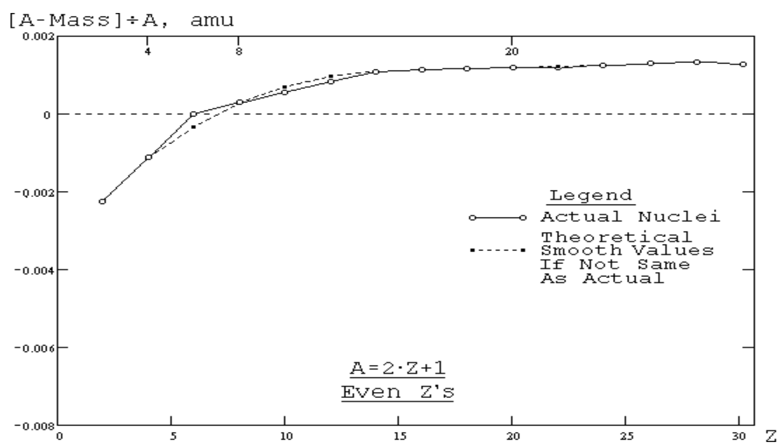
Figure 17-12 Odd



(a) Series s = -1



(b) Series s = 0



(c) Series s = +1

Figure 17-12 Even

In order to understand the effect operating here a brief digression into a relatively slightly attended area of mathematics is necessary. The subject area is that of *polytopes*. A polytope is a geometric figure in *[n]* dimensions having as its boundary a number of geometric figures in *[n - 1]* dimensions. If the boundary figures are all identical then the polytope is *regular*, and it is regular polytopes that are of interest here.

A one - dimensional polytope is a simple straight line having as its boundary its zero - dimensional end points (and being not of much interest as a polytope). A two - dimensional polytope is a (flat) polygon, having one - dimensional straight lines as its boundary, examples of regular polygons being the equilateral triangle, the square, and so forth. A three - dimensional polytope is a *polyhedron*. Its boundary is a set of flat *faces* that are polygons. Some common polyhedrons are the pyramid and the cube.

It turns out that the regular polyhedrons are central to atomic nuclear structure. There are only five regular polyhedrons that can exist (they are sometimes referred to as the *Platonic Solids* because Plato was the first to recognize and study them) and these are listed in Table 17-13 below.

Name	Face	Nr Of Faces	Surface Area	Volume	Radius of Inscribed Sphere
Tetrahedron	Equilateral Triangle	4**	$1.73 \cdot a^2$	$0.12 \cdot a^3$	$0.20 \cdot a$
Cube	Square	6	$6.00 \cdot a^2$	$1.00 \cdot a^3$	$0.50 \cdot a$
Octahedron	Equilateral Triangle	8**	$3.46 \cdot a^2$	$0.47 \cdot a^3$	$0.41 \cdot a$
Dodecahedron	Regular Pentagon	12	$20.65 \cdot a^2$	$7.66 \cdot a^3$	$1.11 \cdot a$
Icosahedron	Equilateral Triangle	20**	$8.66 \cdot a^2$	$2.18 \cdot a^3$	$0.75 \cdot a$

Where "a" is the length of an edge, one straight line segment of a face's boundary.

The values shown are two decimal places of irrational numbers except for the cube.

Table 17-13
The Regular Polyhedrons

The appearance in the above table of the same three key numbers: 4, 8, and 20, that turned up in the graphs of Figure 17-12 is immediately noticeable. Furthermore, the polyhedrons at which those numbers appear are the three regular polyhedrons that have the equilateral triangle, the most simple regular polygon, as face. But, of most significance is that those three cases have relatively the smallest overall sizes, are the most compact. That is apparent from the relative volumes, relative surface areas and relative inscribed spheres indicated in Figure 17-13. Figure 17-14 on the following page depicts these five polyhedrons to the same scale, that is the same edge length, *"a"* in the above table. The relative compactness of the three equilateral triangle faced polyhedrons is apparent.

The relationship between these solid geometric forms and the atomic nuclear structure, which relationship would appear to be indicated by the correlation of the number of faces of the three most compact of the five regular polyhedrons with the regular dips in the mass curves of the low Z, low s, atomic species, is as follows.

(1) The theoretical assembly of an atomic nucleus from its component particles involves the assembling together of a number of like charges: first a number, N, of electrons and then a larger number, A, of protons.

(2) In such an assembling of like charges, for example the electrons, the like charges all mutually repel each other with the Coulomb force. Consequently, they automatically space at equal separation distances in the form of a sphere in space. Assembling them into a nucleus is a case of reducing the size of that sphere to the point where the individual particles, centers-of-oscillation, merge.

(3) That configuration in space before the merging is geometrically equivalent to the sphere inscribed inside a regular polyhedron -- at least when the number of merging particles is one of the five cases of Table 17-13. The center of each face of the polyhedron corresponds to the location of the charges. The inscribed sphere touches each face at just that point.

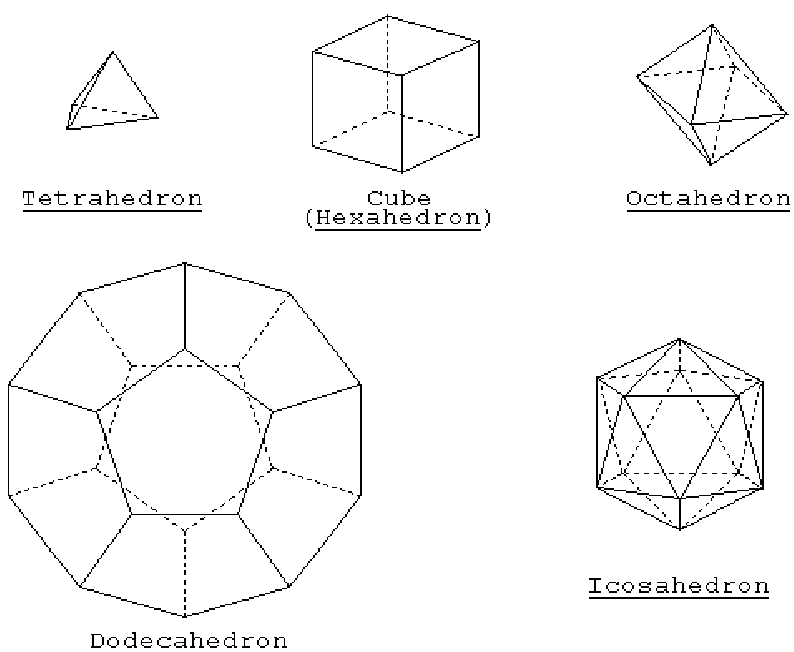


Figure 17-14
The Regular Polyhedrons

When the number of merging particles does not correspond to the number of faces in one of the five regular polyhedrons the configuration of the mutually repelling particles is still according to a polyhedron having its number of faces equal to the number of like charge particles that are merging. However, the polyhedron is not regular and that means that the particles are unable to space equally. The best that they can do is arrive at some more or less stable balanced mixture of separation distances that vary around the average value.

The resulting corresponding polyhedron is a quasi-regular form having polygons of various numbers of sides as its faces. It is not as compact as would be the case if it were regular, however. Its inscribed sphere does not touch all of its faces, only the nearest ones, and that means that some of the charges are radially farther from the center than others.

If the polyhedron corresponding to the assembling charges is regular then the radial distance of each of the charges from the center is the same. The figure is more compact. And, if the polyhedron is of the type having equilateral triangles for its faces, that is a polyhedron of $4, 8,$ or 20 faces, representing an assembly of $4, 8,$ or 20 like charges, then the radial distance of each charge from the center is a minimum, the configuration is maximally compact.

The more compactly these like charges can fit together the greater will be the potential energy between them and, consequently, the greater will be the energy which must be removed from them for their merging into a new nuclear supercenter to take place. <u>Compactness</u> of the natural configuration of the like charge particles assembling into a nuclear supercenter corresponds directly to the <u>mass decrease</u> exhibited by that nuclear type.

In the graphs of Figure 17-12, the vertical axis is $[A - Mass] \div A$. Therefore, smaller mass (greater mass decrease) produces higher points on the curves, larger mass (smaller mass decrease) produces dips in the curve. The high points on the curves correspond to greater compactness of the assembly configuration. The dips correspond to less compact cases.

Now in the assembling of N electrons and A protons, the N electrons and a corresponding N out of the total of A protons offset each other. Their merger of mutual attraction occurs naturally and readily. Only the excess Z protons remaining have the above described configuration problems as they are being assembled into a nuclear supercenter. Thus results the significant points in the curves of Figure 17-12 at $Z = 4, 8,$ and 20.

Consider the Figure 17-12 Odd curves in the region near $Z = 8$.

> The $Z = 7$ case, if viewed as $Z = 8$ with an excess proton (one not neutralized by an electron but instead taking a position according to the polyhedron) having been removed, is then at least as compact as for $Z = 8$ and actually can be a little more compact because of the missing proton. However the value of A (which $= 2 \cdot Z + s$) is reduced by two units and the net $[A - Mass] \div A$ (which $= 1 - {}^{Mass}/A$) is somewhat less than that for $Z = 8$. The type plots on the graph as on the main trend a little lower than where $Z = 8$ would fall.
>
> The $Z = 9$ case, if viewed as $Z = 8$ with one excess proton added, certainly must be less compact than $Z = 8$. Being so it has less overall mass decrease than for $Z = 8$, greater total mass and is a lower point on the curve, off of the smooth trend.

The $Z = 10$ and successively higher Z cases exhibit behavior similar to $Z = 9$ gradually tapering off as the general moderating effect of increasing A and distance from the special $Z = 8$ case increases.

At $Z = 20$ the general cycle repeats except moderated by the much larger value of A .

Considering the Figure 17-12 Even cases the behavior is even more pronounced at $Z = 8$ and 20 because the even $Z's$ produce data points exactly at those key numbers. Below $Z = 8$ the same effects are operating but with modified results because of the even values of Z.

First, at $Z = 6$ the case of the regular polyhedron the cube enters in. It is less relatively compact than the polyhedrons having equilateral triangles for faces, but it is more relatively compact than the cases of $Z = 7$ or $Z = 5.$

In addition, at $Z = 2$ is another maximally compact case. There can be no polyhedron with only two faces, but the configuration is nevertheless as compact as theoretically conceivable, more compact even than the tetrahedron.

The special cases of $_2He^4$ and $_4Be^8$ experience the maximal compactness of $Z = 2$ and 4 combined with low values of A, which tend to make the effects more pronounced. This is especially so for the $s = 0$ cases. There, for Helium and Beryllium, all three of $A,$ $Z,$ and N correspond to maximally compact cases: $2,$ $4,$ and 8.

The last point is of some significance. It must be emphasized that there is no contention that the nuclear specie actually materially form via the simultaneous combining of N electrons and A protons. There is no mechanism available to produce such an effect except within intensely hot stars, and even there the combinations effected must be of two particles at a time. The coincidence of simultaneity required for combining a greater number of particles at a time is prohibitive. The effect of assembly configuration that has been presented stems from that the net resulting atomic nucleus, those nuclei as they must materially exist, must have masses as if they had been so constituted. That method, that procedure, yields the minimum mass / energy case.

Consequently, it can to some extent be deemed that the assembly is first of the N electrons into a core around which the A protons are then assembled. In that view, the values of N and of A matching or deviating from the regular polyhedrons would also enter into the mass decrease and net mass of the various nuclear types. While the effect is apparently not as great as is that of the value of Z, it would particularly add to the accounting for the relatively extreme cases of the $_2He^4$ and $_4Be^8$ nuclear masses.

Another interesting and useful result develops from the effect of polyhedral geometry on the assembly structure of nuclear species. Table 17-13 includes as regular polyhedrons only cases with an even number of faces. There are no regular polyhedrons possible having an odd number of faces. That is quite reasonable in that it would instinctively appear to be more difficult to obtain uniformity of spacing and maximal compactness with an odd number of participants. The consequence of this geometric condition is that the odd Z

nuclear specie are slightly less compact, have slightly less reduced mass, have slightly greater relative overall masses, and are somewhat less stable or exhibit fewer stable isotopes than their even Z counterparts. It also accounts for the behavior noted a number of pages earlier, with regard to Figures 17-8, that *even N* types are slightly less massive (that is have slightly larger mass decrease) than *odd N* types.

Some several pages previously, immediately after Figures 17-11 it was stated that:

> "These data would appear to indicate that there is a simple and regular mode of behavior, structure or process that operates effectively for high Z or high s series, that the variations from nuclear type to type are smooth and regular there. That mode appears to also operate for low Z, low s series, but is apparently there partially overwhelmed by some other effect not so far detected and taken into account."

That behavior is the assembly configuration effect analyzed and developed above and now "detected and taken into account". Without that phenomenon the variation in mass from nuclear type to type would be completely smooth and regular.

To further investigate the last contention Figures 17-15(a) and (b), below, amplify the $s = 10, 30,$ and 50 series presented earlier. The series $s = 30$ and 50 are quite smooth and regular, even substantially amplified. They exhibit the characteristic s-type shape described earlier in conjunction with Figure 17-7, the characteristic that makes a small number of isotopes in the range $N = {}^{A}/2$ or a little more stable while all of the other isotopes are unstable. The $s = 10$ series exhibits a minor kink (minor on the original unamplified curve relative to the rest of the curve) just at (for Z *even*) and just before (for Z *odd*) the $Z = 40$ position.

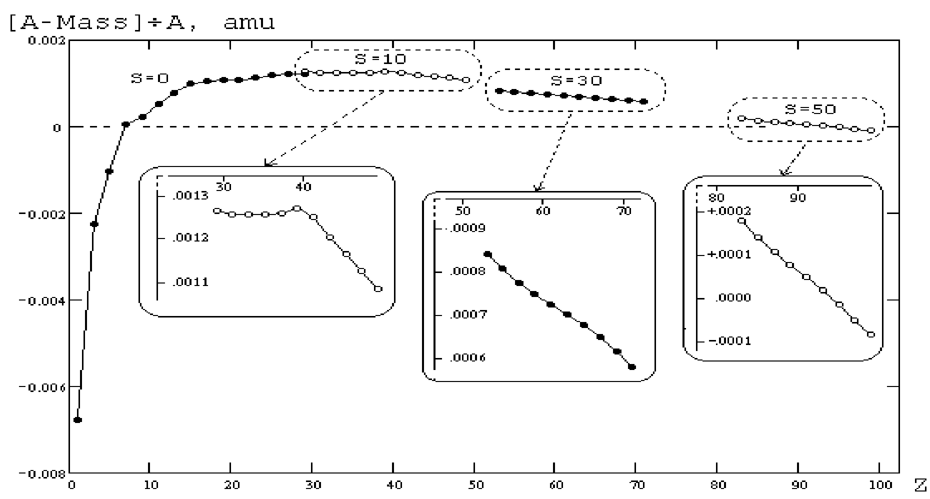


Figure 17-15(a) Odd Z's

The minor kink in the $s = 10$ series is due to the polyhedral case of the dodecahedron. If each of the 20 faces of a dodecahedron is divided in half a quasi-regular *40 - faced* polyhedron results. While it is not as compact as a pure regular polyhedron it is significantly more compact than most values of *Z* can achieve. It is quite near to being a pure regular polyhedron. Its effect is a "minor kink" partly because it is not purely regular and partly because it occurs at a relatively large value of *A*, which tends to moderate the assembly configuration effect.

While a similar effect might then be expected at $Z = 16$ due to the octahedron, such an effect is of much less significance. Dividing each of the *8* faces of an octahedron in half is a much greater distortion of the polyhedron than is dividing each of the *20* faces of the dodecahedron.

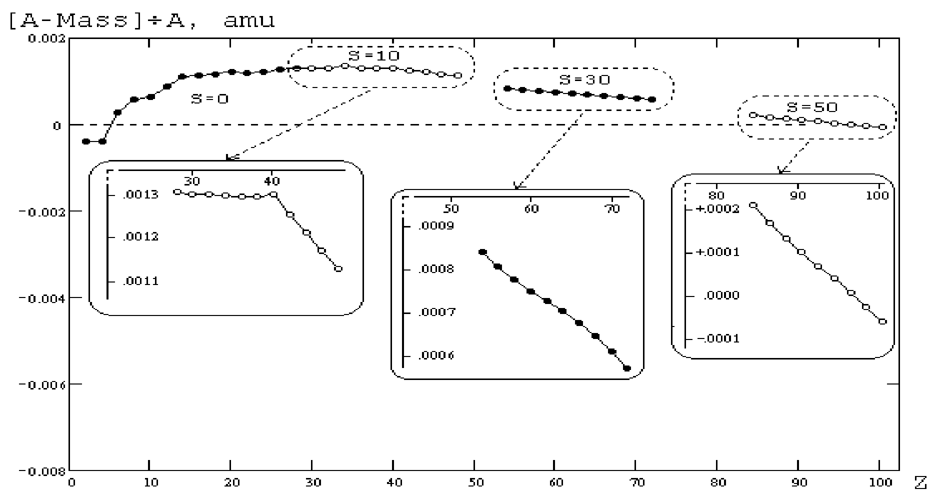


Figure 17-15(b) Even Z's

The characteristic s-type shape, the shape that makes for the stable isotopes amid a sea of unstable ones and, therefore, on which our existence depends, comes about as follows.

> On the one hand, as the number of electrons in the composition of a nuclear supercenter becomes greater the number of neutrons becomes greater and, consequently the number of multiples of the 840 μ-amu per neutron mass increase applied to the nuclear type.
>
> On the other hand, as the number of electrons in the composition of a nuclear supercenter becomes greater the central negative charge attracting the positive protons as a group becomes larger and tends to produce a more compact overall result.
>
> Thus the first tendency is to increase the nuclear mass and the second is to decrease the nuclear mass, both as the N/A ratio increases.

If the ratio is very small, that is there are few or no electrons in the nuclear composition, then the compactness is quite poor, what with the attempting to combine the mutually repelling protons unaided by a central negative charge. If the ratio is quite large, that is the nuclear composition is almost all net neutrons, then the neutron mass excesses overwhelm any small mass decrease due to the few un-neutralized protons, even though they are well compacted. Only in the range of balance of these two tendencies can a mass minimum be achieved. That occurs at and a little above $^N/_A = 0.5$ as indicated in Figure 17-16, below. The Figure is schematic, not precisely quantitative, and only intended to indicate the general form and tendency of the effects.

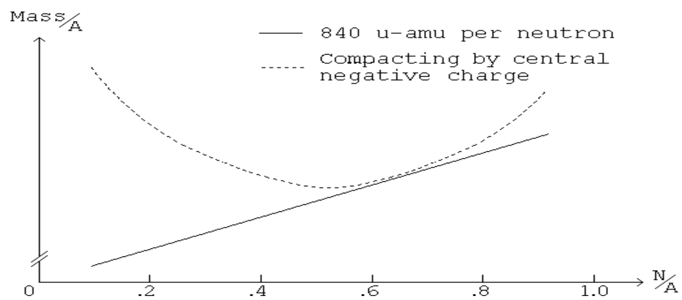


Figure 17-16

One other observation concerning the data so far presented should be made. Figure 17-10 indicates that for elements of Z higher than 83, for Bismuth, $_{83}Bi$, there are no stable nuclei at all. The reason for this relates directly to the curvature discussed relative to Figure 17-7 and the effect of relative uniformity. Large nuclei vary little in relative composition from isotope to isotope. That is, for large A and large N the ratio $^N/_A$ is very little different from the ratio $^{[N+1]}/_{[A+1]}$.

As a result the curvature illustrated in Figure 17-7, and which effect accounts for a region of negative separation energy and stability amid unstable surroundings for the lighter species, lessens to the point of ineffectiveness for the heavier species. Apparently the turning point is at Bismuth. The amplified depictions of nuclear series in Figures 17-15 show this effect in that the curvature is quite slight for $s = 50$ compared to that for $s = 30$.

CONCLUSION

The atomic nuclei are each a complex supercenter, a single particle, a center-of-oscillation oscillating as the sum of the oscillations of its components, N electrons and A protons, the oscillation being as presented in equation 17-2. The neutron, also, is an atomic nucleus, that of $Z = 0$, not a nuclear component

However, the frequencies in that oscillation are not merely N multiples of the electron rest frequency and A multiples of the proton rest frequency. Rather they are determined by a complex action derived from the theoretical assembly of the nucleus as if from the component particles approaching each other.

The frequency content of equation 17-2 must correspond directly and exactly with the mass of the nucleus just as the two frequencies in the neutron oscillation wave form correspond directly with the neutron mass. For a nuclear type that matches a regular polyhedron so that the assembling charges can be perfectly equidistant, the frequency of the equation 17-2 component corresponding to those particles would be A or N multiples of the frequency corresponding to the energy of one of those equidistant and, therefore, equal energy particles.

For the more common case in which the assembling particles are unable to be perfectly equidistant because of the prohibitions of the spherical geometry, the non-matching to a regular polyhedron, the frequency content of equation 17-2 would be A or N multiples of the frequency corresponding to the average energy of the set of particles. Or, there might be several different frequency oscillation components, one for each of the several different energies of the non-equidistant particles, the sum of the multiples of each of the components adding up to A or N as appropriate.

The result is that the precise mass of any particular nuclear type depends on the ratio of the number of negatively charged components to the number of positively charged ones and how compactly those charges can arrange themselves overall. The mass of the resulting nucleus is the minimum energy / mass configuration of the charges. The dependency on configurational compactness is attested not only by the natural physical logic of the action but also by the congruence of the especial cases at $Z = 4, 8,$ and 20 with the geometry of the regular polyhedrons.

The nuclei do not actually come into being by such an assembly, however. Rather they are formed by one of two means. One is the combining of pairs of smaller nuclei and/or nuclear components under circumstances where there is sufficient energy to overcome the natural Coulomb repulsion. That most commonly would take place in the interior of stars; however, it has also been performed in the laboratory to some extent.

The other method of formation of a new atomic nucleus is by the radioactive decay of an existing heavier nucleus. The matter of the radioactive decay behavior of nuclear supercenters is treated in the next section.