Appendix A-2

The Atomic Nuclei

Having now the model of the neutron as a combination of a proton and an electron into a new type of *Spherical-Center-of-Oscillation* oscillating as a resultant of its separate components' *Spherical-Centers-of-Oscillation*, a similar model is now available for the atomic nuclei. In fact, such a model is essential. The "bunch of grapes" and related concepts of the nucleus with its 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 *Propagated Outward Flow* (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 protons. The mass deficiency of atomic nuclei is hypothesized as the means of nuclear binding, but an acceptable mechanism is needed.

   To meet that requirement a force, the "strong nuclear force" is further 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 those problems are overcome by the *Spherical-Centers-of-Oscillation* nuclear model. The nucleus is a new unitary particle, the resultant of the natural oscillations of its component simple *Spherical-Centers-of-Oscillation* particles [protons and electrons] 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. The nucleus is a single unitary particle with its *Propagated Outward Flow* natural field. It is a single *Spherical-Center-of-Complex-Oscillation*.

2- There is no need for nuclear binding energy, no need for a force to hold component particles together. The nucleus is one (complex) *Spherical-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. Only the neutron components' oscillations are part of the overall atom's nucleus components' oscillations.

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. How could each particle and its anti-particle get together in a "bunch of grapes" configuration? But the single unitary *Spherical-Center-of-Oscillation* model readily accommodates the mechanism of mutual annihilation presented in Appendix C, *Why No Immediate Mutual Annihilation*.

As will shortly be developed, the *Spherical-Center-of-Oscillation* model accounts for: all of the various nuclei, their masses, their stability or instability, radioactivity and its mean lifetime before decay. It also correlates directly with the origin of the universe. The nuclear model is a complex *Spherical-Center-of-Oscillation* the combination of its co-located component *Spherical-Centers-of-Oscillation.*

Those components are quantity A of protons and quantity $[A-Z]$ of 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 per Appendix A-1, *The Neutron*. The fundamental "building block" particles are the proton and the electron. The neutron is more properly viewed as the nucleus of the atom of $Z = 0, A = 1$.

Developing the *Spherical-Center-of-Oscillation* atomic nuclear model in detail proceeds as follows.

THE NUCLEAR SPECIES MODEL

The problem in developing the details of the general nuclear model is: how do multiple protons or multiple electrons, alone, combine into a super *Spherical-Center-of-Oscillation* or as part of one ?

In the case of the neutron the combining of the two component co-located *Spherical-Centers-of-Oscillation*, a proton and an electron, consisted of the direct addition of the two oscillations, 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.

To develop a corresponding general expression for atomic nuclei requires dealing with multiple protons [all of the same frequency] and multiple electrons [all of the same frequency] .

The principal factors determining the form of the model must be the proper representation of Z and A so that the nuclear electric charge and Coulomb effect are correct (for Z) and so that the atomic mass number (A) is the nearest integer to the actual exact mass. As developed in Section 3, *The Action of Matter - Coulomb's Law* the Z must be the average value of the oscillation. Neither the frequency nor the amplitude of the oscillatory part of the oscillation can affect 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. 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.

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 *A-2-1*, below.

$$\text{(A-2-1)}\quad \begin{aligned} &U\left[M\ \text{protons}\right]=U_c\cdot\left[M-\mathrm{Cos}(2\pi\cdot[M\cdot f_p]\cdot t)\right] \\ &U\left[M\ \text{electrons}\right]=-U_c\cdot\left[M-\mathrm{Cos}(2\pi\cdot[M\cdot f_e]\cdot t)\right] \end{aligned}$$

Then, the structure of an atomic nucleus would be

$$\text{(A-2-2)}\quad \begin{aligned} U\left[{}_Z\mathrm{Sym}^A\right] &= A\ \text{protons} + [N=A-Z]\ \text{electrons} \\ &= U_c\cdot\left[A-\mathrm{Cos}(2\pi\cdot[A\cdot f_p]\cdot t)\right] + \left[-U_c\cdot\left[N-\mathrm{Cos}(2\pi\cdot[N\cdot f_e]\cdot t)\right]\right] \\ &= U_c\cdot\left[Z-\mathrm{Cos}(2\pi\cdot A\cdot f_p\cdot t)+\mathrm{Cos}(2\pi\cdot N\cdot f_e\cdot t)\right] \end{aligned}$$

where the "Sym" of ${}_Z\mathrm{Sym}^A$ means the element *symbol*, the one or two letter abbreviation for the element name.

With regard to the nuclear species formulation of the above equation *A-2-2*:

1- The formulation reduces to the form for a neutron per equation *A-1-1* when the parameter values are $A = 1$, $Z = 0$.

2- The formulation yields the proper overall average value of the wave form, $Z\cdot U_C$, which corresponds to the net positive charge of the nuclear *Spherical-Center-of-Oscillation*.

3- As is necessary for the electric charge $[Z]$ of the nucleus to be independent of the mass $[A]$ of the nucleus the amplitude of the oscillatory portion of the expression (the amplitude of each of the two oscillatory terms of equation *A-2-2*) is the same for all nuclear species and not a function of A or Z.

The resulting conclusion from this is:

The amplitude of the Spherical-Center-of-Oscillation, U_C*, is a universal constant 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.)*

Figures A-2-2 through A-2-4 on the following pages depict the wave forms per equation $A\text{-}2\text{-}2$ 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 A-2-1, 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.

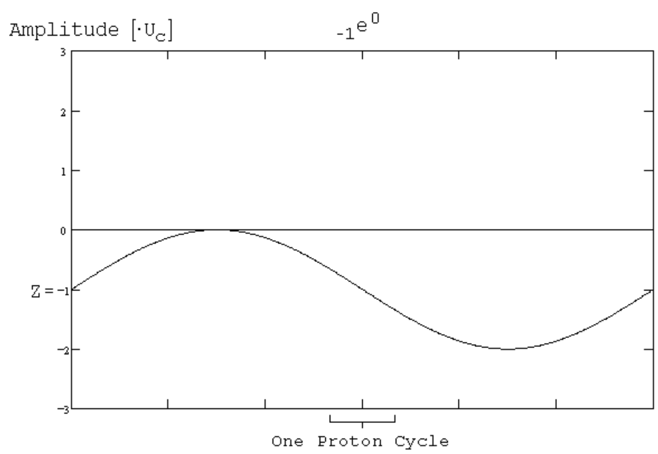


Figure A-2-1(a), The Electron Wave Form

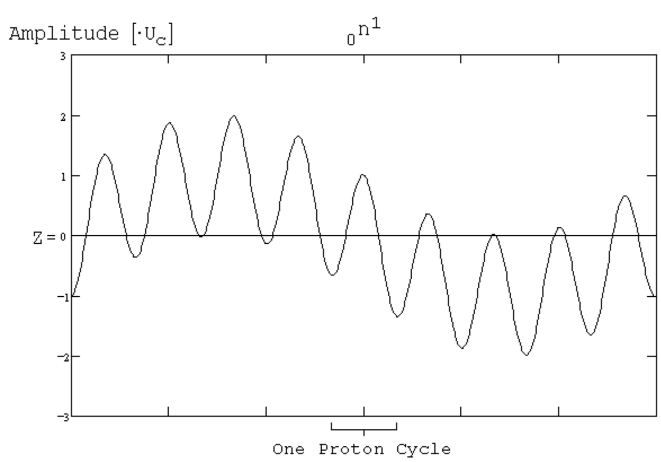


Figure A-2-1(b), The Neutron Wave Form

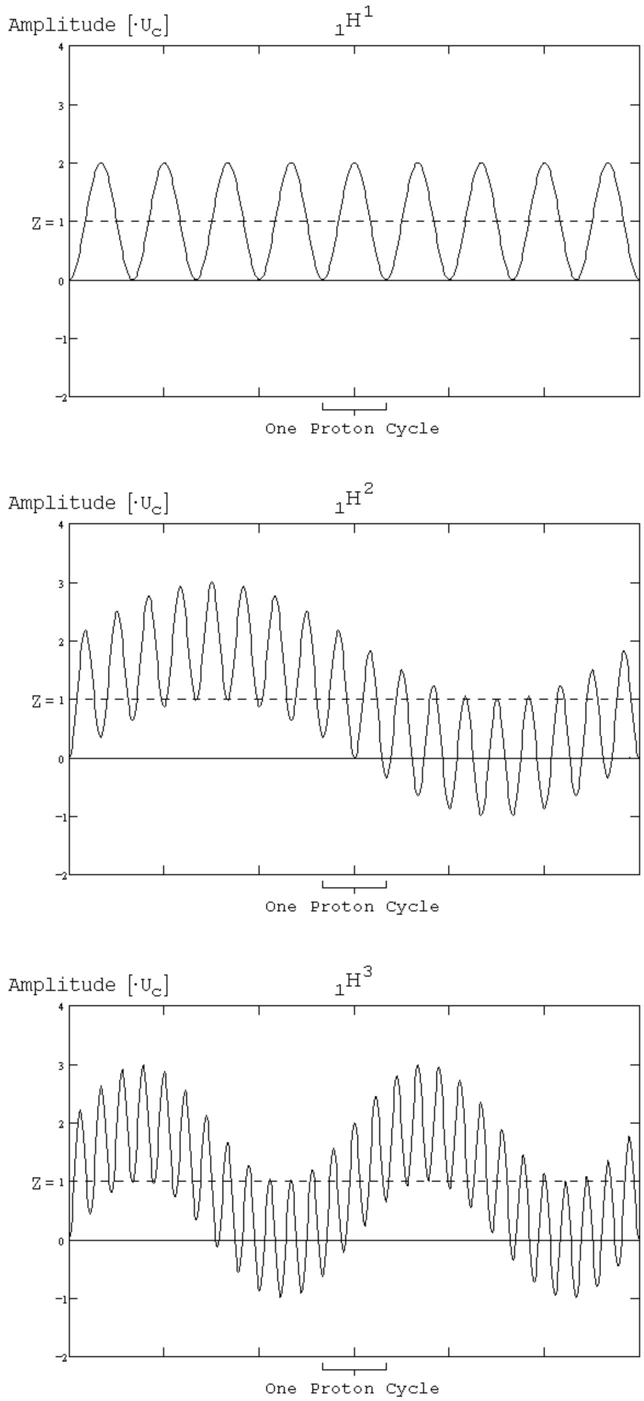


Figure A-2-2, The Hydrogen Wave Forms

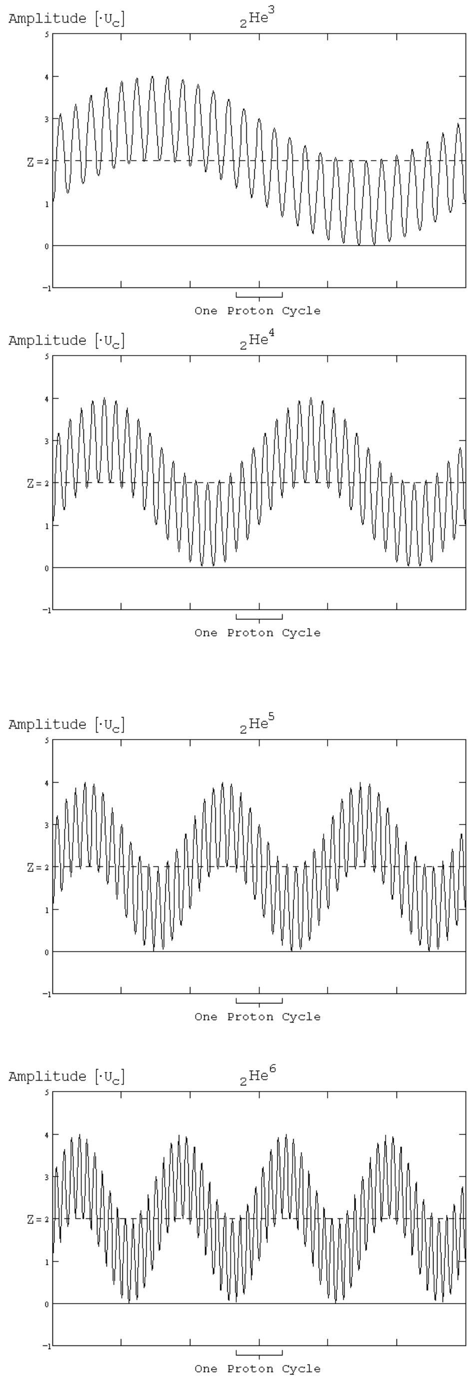


Figure A-2-3, The Helium Wave Forms

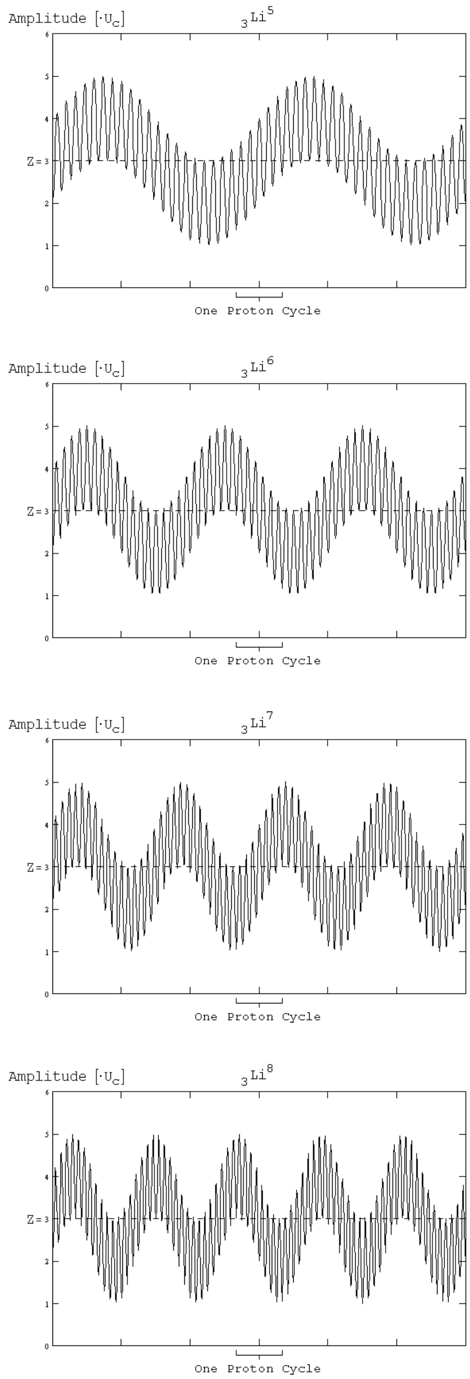


Figure A-2-4,The Lithium Wave Forms

FURTHER DEVELOPMENT OF THE NUCLEAR SPECIES MODEL

In extrapolating the model of the neutron developed in the preceding Appendix A-1 to the family of all the nuclear species, the mathematical description of the neutron model has been treated, but not the remainder, the formation of the neutron from its component proton and electron mutually accelerating toward each other, uniting into a new *Spherical-Center-of-Oscillation*.

Of course, unlike the case of the neutron, the components of an atomic nucleus, protons and electrons, cannot naturally and unaided come together to form a nucleus. The description of these atomic 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 a procedure for determining what are the characteristics of the resulting nucleus.

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 was the case with the "Big Bang".

In Section 2 under the sub-title "The Form of Matter as Generated by the Big Bang" the Big Bang is described as follows:

> "Judging by its result, the "Cosmic Egg" was not unlike an immense atom, a very unstable immense atom [as are all of the atomic species of atomic number exceeding 83 which the cosmic egg would have immensely exceeded]. Its "Big Bang" was a kind of explosive nuclear decay. Such decays follow chains:
>
> - From a heavy and complex composition,
> - Through many various stages of multiple less heavy less complex products,
>
> . . . . .
>
> - Until ultimately they arrive at many multiple stable forms [and some long half-life still slowly decaying forms].
>
> Some of those decay chains ended in stable species heavier than Hydrogen, heavier than the proton. Those appear to us as the various stable atomic species of the Periodic Table of the Elements."

The other way for some of the complex atomic nuclei to form 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 their mutual repulsion. This is thought to occur in stars where the product is later spread to the universe by the star exploding as a super nova.

As in the case of the neutron, escape velocity masses are a factor in all of the atomic nuclei. The point when two *opposite* charged particles mutually attracting each other, *i.e.* the case of the neutron, achieve their mutual escape velocity is just before they collide. But, when two *like* charged particles such as two protons, rushing away from each other in mutual repulsion, achieve their escape velocity is at their maximum separation (infinite distance). For them to stay together and to not so rush apart, they must lose their mutual escape velocity kinetic energies.

Evaluation of those cases in the manner as was done for the neutron becomes an inordinately complex problem. 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 simplest case of 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.

The following is not a description of how a deuteron comes to be. Rather it is an analysis of the considerations that must be satisfied for it to exist regardless of how it came to be.

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. Figure A-2-5, below, illustrates the 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 which is in the center by default, where it equally attracts each of the protons.

Legend:

$\succ\!\!-\!\!\prec$ Proton — Electron Coulomb Attraction (as in the case of a simple neutron)

$\longleftrightarrow$ Proton — Proton Coulomb Repulsion

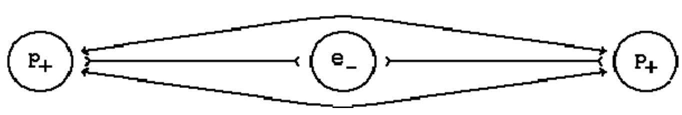


Figure A-2-5

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 would 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 are the same, all of it appearing in kinetic energy of the protons.

Thus for this part of the interaction the deuteron should have a mass excess equal to twice the mass excess of the neutron,

(A-2-3) $2 \cdot [839.854\ \mu\text{-amu}]$ or $0.001,679,708$ amu.

The Deuterium nucleus' mass deviation from the mass of its component particles is calculated in the same way as was done for the neutron at equation D-2, as follows.

(A-2-4)
$$\begin{aligned}\Delta m_{De} &= \left[m_{De,atom} - m_{De,orbital\ electron} \right]_{rest} - \left[2 \cdot m_p + m_e \right]_{rest} \\ &= 2.014,101,779 - 0.000,548,579,903 \ldots \\ &\quad \ldots -2 \cdot [1.007,276,470 + 0.000,548,579,903] \\ &= -0.001,548,319 \ \text{amu}\end{aligned}$$

This negative numerical result is to be expected. Unlike the neutron, the deuteron must have a mass deficiency, which is always found when the nucleus contains 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 *A-2-5*, below, which can only be due to the interaction of the two protons.

```
(A-2-5)  +1,679.708 μ-amu proton-electron mass increase Equation A-2-3
       - -1,548.319 μ-amu deuteron net mass decrease of Equation A-2-4
         ----------
         +3,228.027 μ-amu required proton-proton mass decrease
```

Theoretical Formation of a Deuteron From Its Components

The combination of the proton - electron Coulomb attraction and the proton - proton Coulomb repulsion produces the resulting deuteron net mass. That decrease is equal to the energy that the two component protons lose to become part of the nucleus as partially offset by the mass excess developed between the electron and each of the protons.

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 A-2-6, starting on the second following page, is a partial 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.

Just as 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 present data is 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 atomic masses of Table A-2-6 are those of that 1983 evaluation. All of the data are rest masses.

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, and the *mass deficiency* and the *separation energy*, defined in equations *A-2-6* and *A-2-7*, below.

```
(A-2-6)                  Mass Deficiency
        Mass          Mass of        Mass of       Atomic
        Defic-   =    Nuclear    +   Orbital   -    Mass
        iency        Components     Electrons    (Per Table)

       [Here for mass deficiency the "Nuclear Components" are
          Protons and neutrons.]
```

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 A-2-7, below.

(A-2-7) <u>Separation Energy</u>

```
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.]
```

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 a particle or wave 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 and the neutron can have, at least in theory, a family of separation energies for different decay products. The separation energy listed in Table A-2-6 is the largest one for that atom, which corresponds in general to the most probable decay, which is the decay listed in the table.

Examination of the *mass deficiency* data in Table A-2-6 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 A-2-6 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, 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.

Table A-2-6
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 A-2-6 (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 A-2-6 (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 *E-6* and *E-7* definitions of separation energy and mass deficiency to the data in "The 1983 Atomic Mass Evaluation".

Those nuclear species 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 ${}_8O^{17}$.

The particle emission process, *radioactivity*, does not always immediately occur. Rather it is delayed in various amounts and occurs at an overall exponential rate. It is treated in Appendix A-3, *Radioactivity*.

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 STABLE AND UNSTABLE RANGES OF NUCLEAR SPECIES

As indicated greatly exaggerated in Figure A-2-7, below, 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]` as in Figure A-2-8, next page, then only the deviations from linearity are plotted, the changes in curvature which range from small to large to small again.

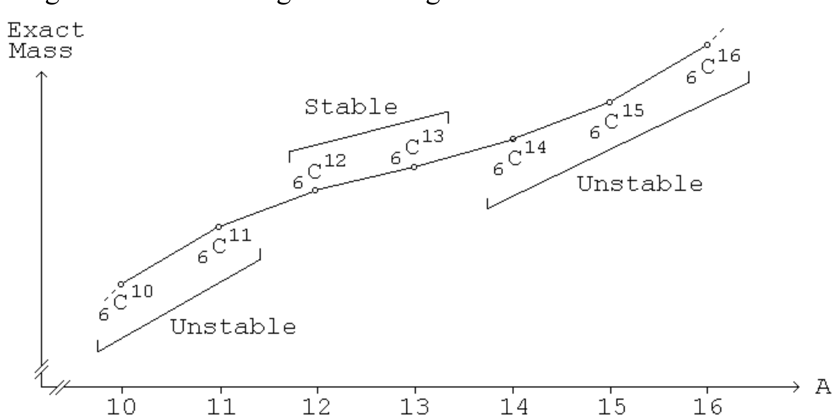


Figure A-2-7

"S-shaped" Curvature in Isotope Nuclear Mass Variations (Exaggerated)

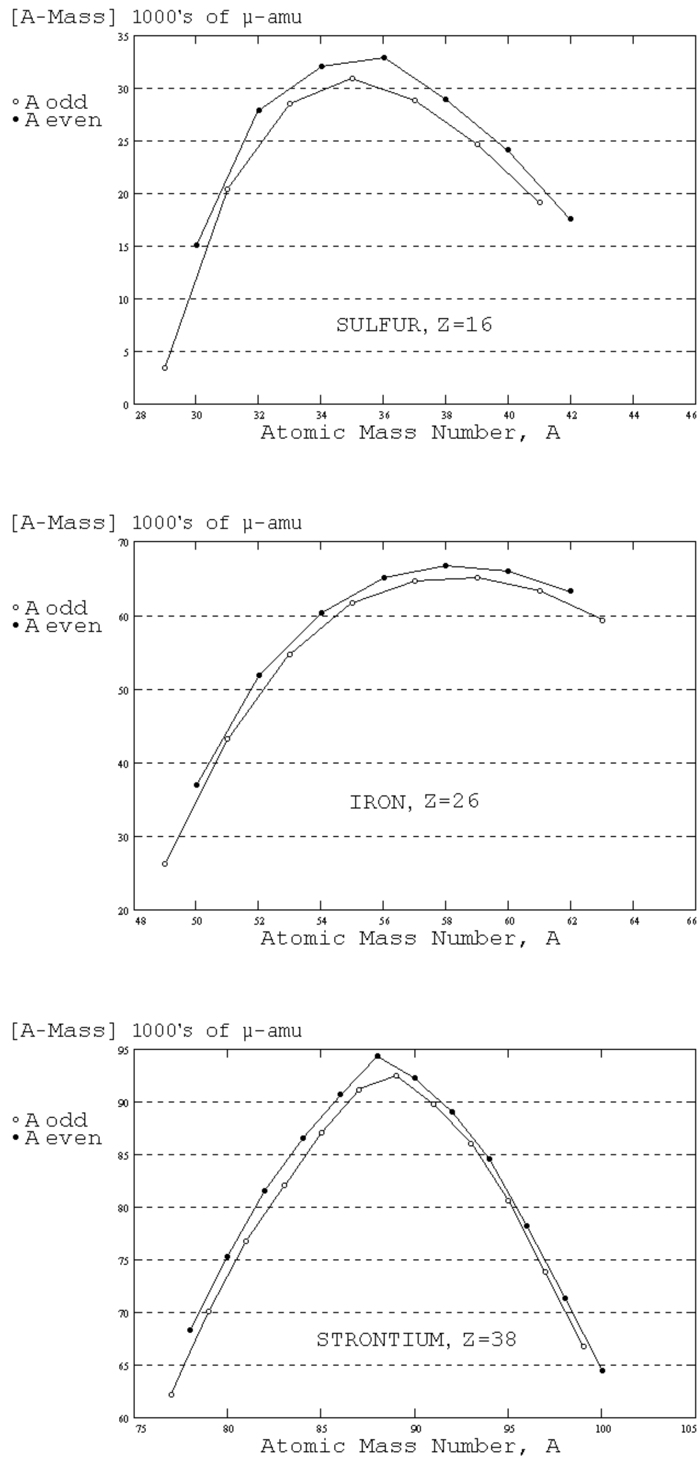
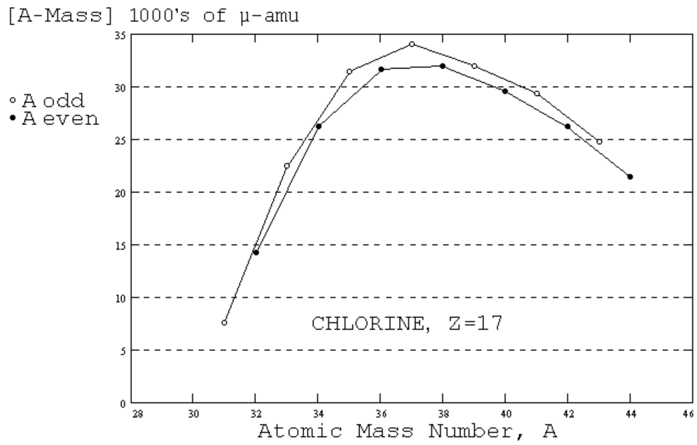
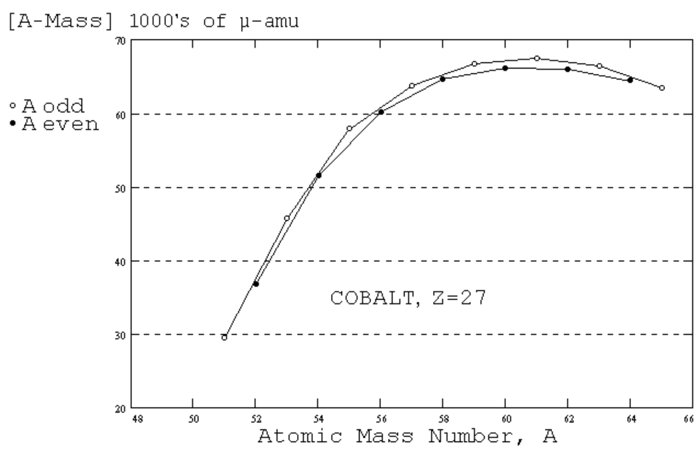


Figure A-2-8, Page 1





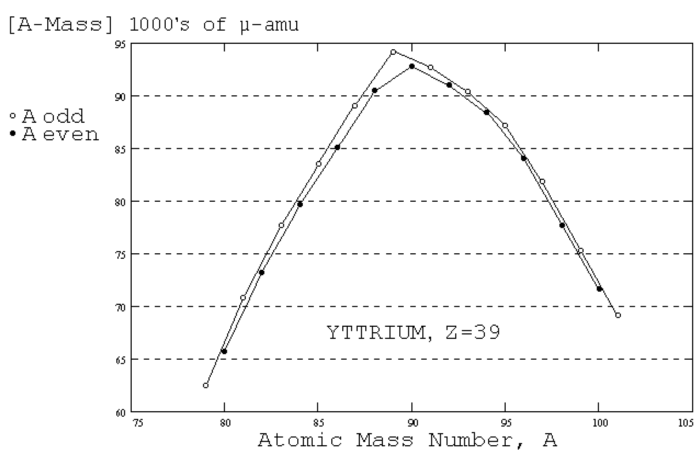


Figure A-2-8, Page 2

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.

THE "SERIES" PATTERN IN THE NUCLEAR SPECIES

The data of Table A-2-6, 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 A-2-8.

Traditionally N is the number of neutrons in the nucleus, but in terms of *Spherical-Centers-of-Oscillation* and the nuclear model of Equation $A\text{-}2\text{-}2$, N is the number of electrons entering into the formation of the nucleus [in effect forming neutrons with some of the protons]. 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 A-2-9, below.

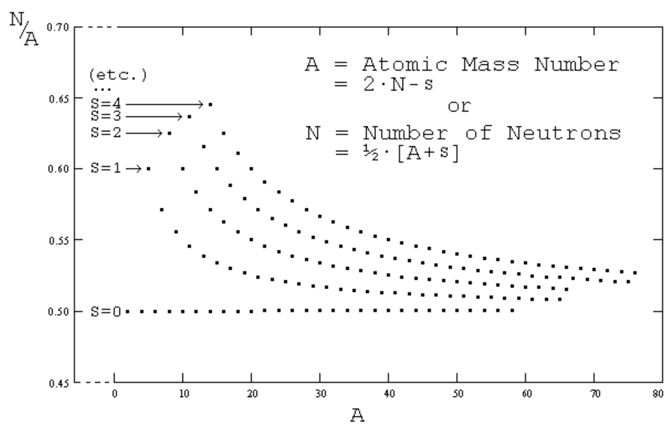


Figure A-2-9

The nuclei appear in *series* according to the relative amounts of the particles, more precisely according to

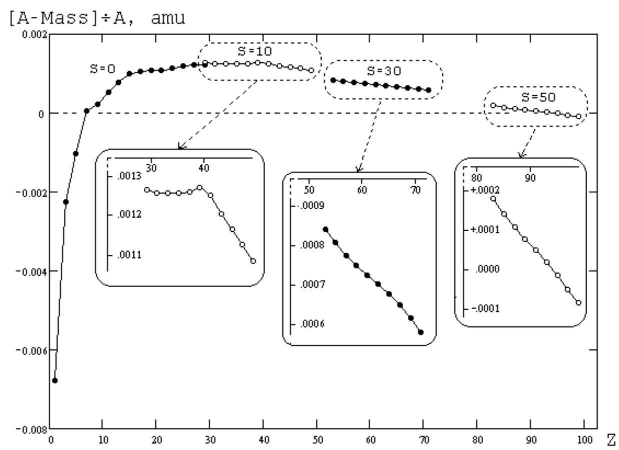
$$(A\text{-}2\text{-}8) \qquad A = 2 \cdot N - s$$

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

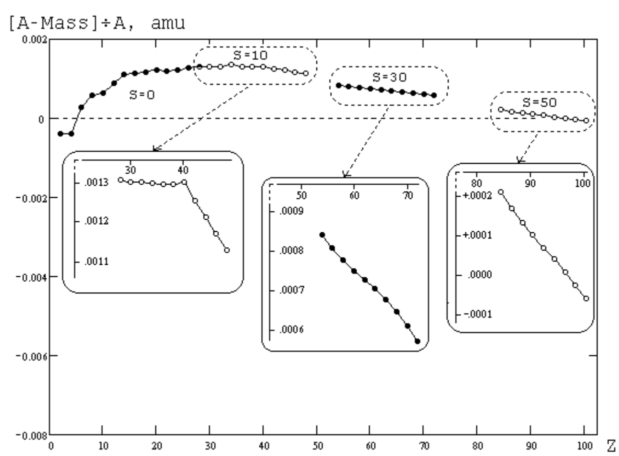
However, Figure A-2-9 is in terms of the integers, A and N, not exact masses. That a set of integers produces an orderly pattern does not necessarily mean that the actual exact masses are orderly. It is a systematic pattern of nuclear structure and exact nuclear masses that must be found. The curves of Figure A-2-8 show such a pattern to exist within families of nuclei of the same Z, but one must exist for all of the nuclei collectively.

Turning now to a comparative examination of the masses of various nuclei within an *s-series* per equation *A-2-8*, 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 A-2-8, the related quantity being *[A - mass]*. That same quantity will now be employed again except slightly modified. For Figure A-2-8 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 $[A - mass]/_A$. 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 A-2-10, below.



(a) Odd Z's
Figure A-2-10



(b) Even Z's
Figure A-2-10

The middle s *series* show the "*S-shaped*" curve of Figure A-2-7. It is present less pronounced in the high s *series* because the changes from species to next higher species are fractionally smaller, that is for large A and large N the ratio $N/_A$ is very little different from the ratio $[N+1]/_{[A+1]}$. It appears interrupted at low s *series*.

> These data indicate that there is a simple and regular mode of behavior, structure or process that operates effectively for middle and 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.

THE LOW Z LOW S EFFECT - POLYTOPES

To analyze the process operating at low Z or on low s *series*, Figure A-2-12 on the next two pages investigates the same changes as did Figure A-2-10, 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 $\mathbf{Z = 4, 8,}$ **and** $\mathbf{20}$. See Figure A-2-12 then return here.

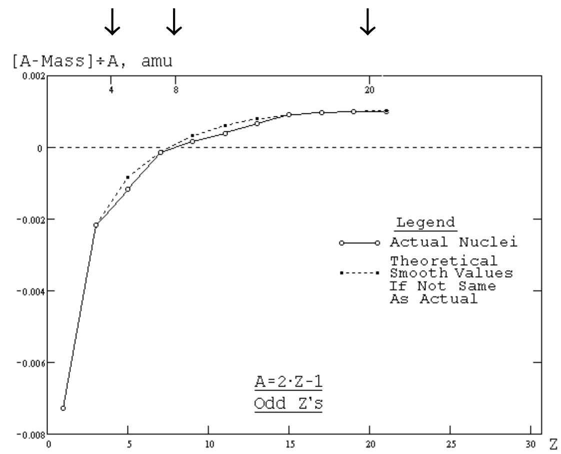
To understand the effect operating here a brief digression into a relatively slightly attended area of mathematics is necessary. The subject area is that of *polytopes*. A polytope is a geometric figure in $[n]$ dimensions having as its boundary a number of geometric figures in $[n - 1]$ dimensions.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

A three - dimensional polytope is a *polyhedron*. Its boundary is 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, listed in Table A-2-11 below. (They are sometimes referred to as the *Platonic Solids* because Plato was the first to recognize and study them).

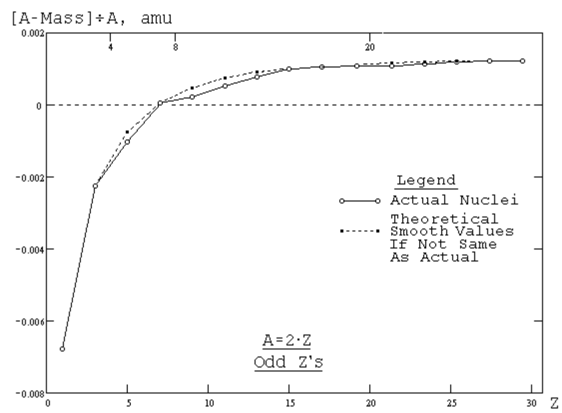
Name	Face	Nr Of Faces	Surface Area	Volume	Radius of Inscribed Sphere
Tetrahedron	Equilateral Triangle	4**	$1.73 \cdot a^2$	$0.12 \cdot a^3$	$0.20 \cdot a$
Cube	Square	6	$6.00 \cdot a^2$	$1.00 \cdot a^3$	$0.50 \cdot a$
Octahedron	Equilateral Triangle	8**	$3.46 \cdot a^2$	$0.47 \cdot a^3$	$0.41 \cdot a$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

Table A-2-11
The Regular Polyhedrons

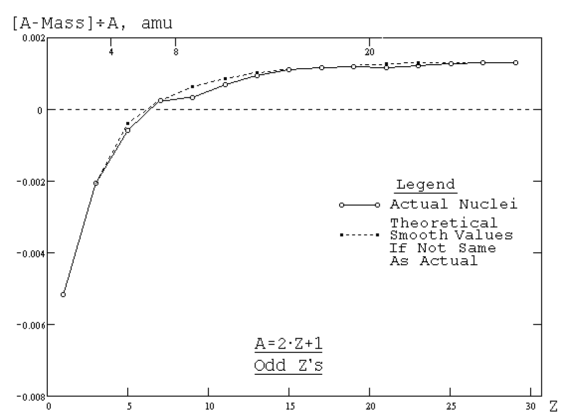
The appearance in the above table of the same three key numbers: **4, 8, and 20**, that turn up in the graphs of Figure A-2-12 is immediately noticeable. Furthermore, the polyhedrons at which those numbers appear are the three regular polyhedrons that have as face the equilateral triangle, the most simple regular polygon. But, of most significance is that those three cases have relatively the smallest overall sizes, are the most compact.



(a) Series s = -1

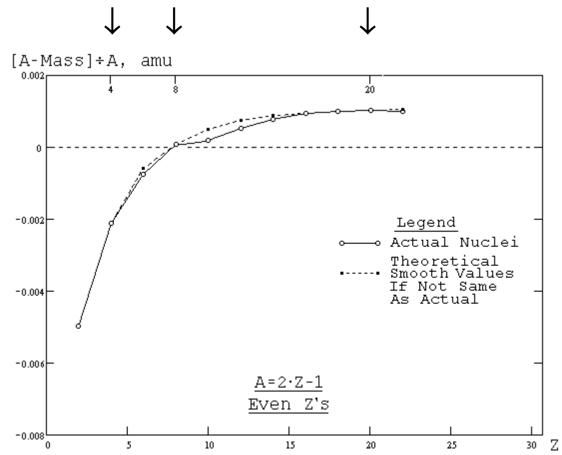


(b) Series s = 0

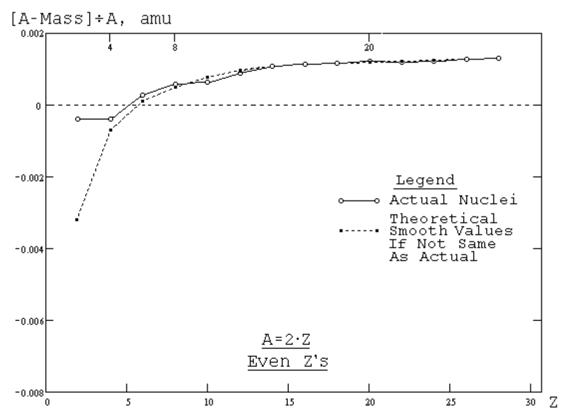


(c) Series s = +1

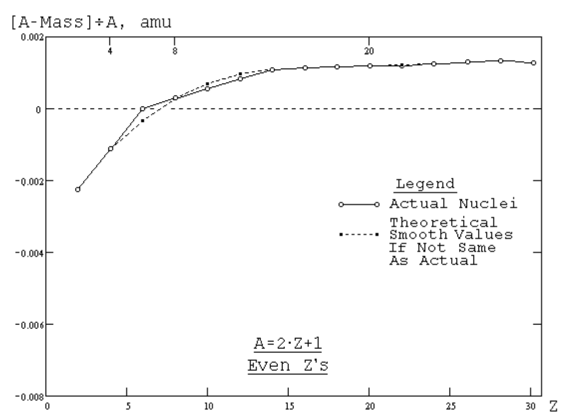
Figure A-2-12 Odd



(a) Series s = -1



(b) Series s = 0



(c) Series s = +1
Figure A-2-12 Even

That those three cases have relatively the smallest overall sizes, are the most compact, is apparent from the relative volumes, relative surface areas and relative inscribed spheres indicated in Figure A-2-11. Figure A-2-13, below, depicts these five polyhedrons to the same scale, that is the same edge length, "a" in Table A-2-11. The relative compactness of the three equilateral-triangle-faced polyhedrons is apparent.

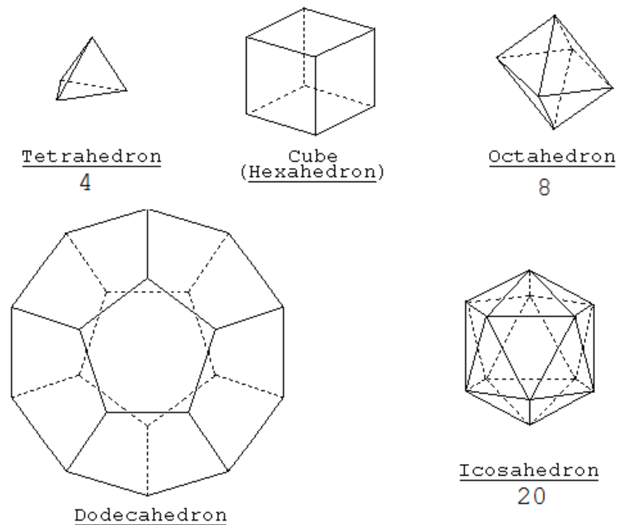


Figure A-2-13
The Regular Polyhedrons [The Platonic Solids]

The relationship between these solid geometric forms and 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 from the otherwise smooth variation [dashed line] 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: a number, N, of electrons and a larger number, A, of protons.

The nucleus being the resultant of A protons and $[N = A-Z]$ electrons, the amount of negative charge to be assembled is less than the positive. Consequently, it can be deemed that the assembly is first of the N electrons into a core around which the A protons are then assembled.

(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', *Spherical-Centers-of-Oscillation*, merge.

(3) That configuration in space before the merging is geometrically equivalent to the sphere inscribed inside a regular polyhedron. 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.

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. 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 they lose for their merging into a new nuclear supercenter to take place. Compactness of the natural configuration of the like charge particles assembling into a nuclear supercenter corresponds directly to the mass decrease exhibited by that nuclear type.

In the graphs of Figure A-2-12, the vertical axis is $[A - Mass]/_A$. 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.

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.

That is the significance of the points at $Z = 4, 8,$ and 20 in the curves of Figure A-2-12. Some several pages previously, after Figures A-2-10 it was stated that:

> "These data indicate that there is a simple and regular mode of behavior, structure or process that operates effectively for middle and 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.

It must be emphasized that there is no contention that the nuclear species 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 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 yields the minimum mass / energy case.

There are no regular polyhedrons of an odd number of faces. The consequence of this geometric condition is that the odd Z nuclear species 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.

How The Stable Nuclei Came To Be Assembled

While some of the presently existing atomic nuclei were manufactured in stars, the vast majority of all of the atomic nuclei in the universe are products of the Big Bang. Its initial instant was the equivalent of a pair [particle and antiparticle] of single, very unstable, immense atomic nuclei.

Its "Big Bang" was an explosive nuclear decay from its heavy complex composition through many various stages of multiple less heavy less complex products until ultimately some arrived at stable forms while others, still unstable, decayed further. Some are still present today as long half-life slowly decaying forms.

Whether a particular case was stable, that is optimally compact to a mass minimum per the S-shape or fell into the unstable category, was a matter of mere chance. The S-shape selected the stable ones.

Those decay chains that ended in stable species appear to us as the various stable atomic species of the Periodic Table of the Elements."

The Cause of the S-Shape

The characteristic *S-shape*, the shape that makes for the stable isotopes amid a sea of unstable ones, 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 mass increase of $840\ \mu\text{-}amu$ per neutron 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.
>
> 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 if 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 if 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 A-2-14, below. The Figure is schematic, not precisely quantitative, and only intended to indicate the general form and tendency of the effects.

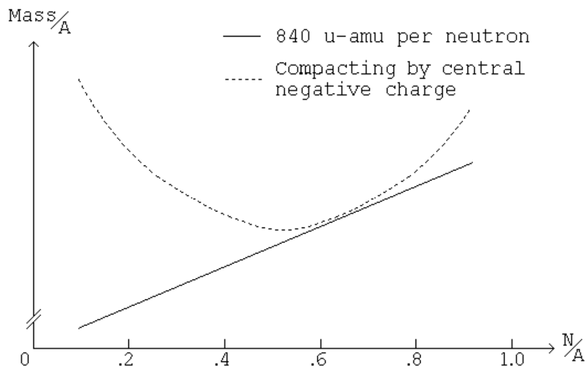


Figure A-2-14

CONCLUSION

The atomic nuclei are each a complex supercenter, a single unitary particle, a *Spherical-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 A-2-2. 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 A-2-2 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 A-2-2 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 A-2-2 would be per equation A-2-9, below.

(A-2-9)

$$A \cdot f_p = \sum_{i=1}^{A} [i^{th} f_p] = \sum_{i=1}^{A} [i^{th} m_p] \cdot \frac{c^2}{h}$$

$$N \cdot f_e = \sum_{i=1}^{N=A-Z} [i^{th} f_e] = \sum_{i=1}^{N=A-Z} [i^{th} m_e] \cdot \frac{c^2}{h}$$

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.

Those of the emerging decay products of the Big Bang that by chance arrived at a maximally compact N/A ratio became our stable elements.