Fusion Mass Losses and Tunnels Formed between Touching Nucleons

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When nucleons fuse with neighbors, there is mass loss and great energy emitted. We discuss the great jump in fusion mass lost when four nucleons are fused together compared to three. About 4 times as much mass is lost, but we show how this is largely expected since 4 times as many triangular planes with 'donut holes' are formed vs. for 3 nucleons. Specifically, we show how after 3 Hydrogen-1 atoms fuse to form 1 Helium-3 atom, the mass lost equals twice the mass of a sphere sized to barely fit through the array's donut hole, with an error of about 1 part in 5000. Finally, we discuss implications of all the above and related topics, including supplementing the present neutron-proton based 'binding energy' method with a more revealing electron-proton based one.

1. Introduction

1.1. The Main Motivations for the Paper

To prevent confusion, readers should remember that this paper actually addresses two different fusion subjects.

The first is about trying to understand the reasons for the very different amounts of mass lost during different fusion events, that is when two, three or four nucleons are fused together. And we try to predict those different results with satisfactory accuracy. Regarding that, we note that when 3 nucleons touch, only 1 triangular structure is formed with 1 hole in it, like a donut hole. But in the 4-nucleon case, we have 4 triangular planes and 4 holes.

We hypothesize that those holes serve as tunnels, and invite a flowing action through those tunnels. That flow results in a decrease in the relative pressure between nucleons, a 'Venturi suction' or attraction-like effect. And that is related to Bernoulli's equation. So such major tunnels appear when three or more nucleons touch, and thus those nucleons cling together especially strongly. Therefore, nuclei can be made consisting of <u>more</u> than just one nucleon or two weakly bound ones. And that makes our amazingly diverse world possible! That is indicated in Fig. 1 and Fig. 2.

Where appropriate, for some calculations in this paper we will use some aspects of Bohr's 'liquid drop model' of the nucleus, for example, incompressibility and uniform density.

The other major subject in this paper is this: There is an old method of processing information related to nuclear 'binding energies' that is barely adequate for noting some of the relationships discovered in this paper. And that old method has some flaws. To fully appreciate the closeness of relationships discussed in this paper, and to correct problems inherent in the old binding energies methodology, we will discuss a better one.

Important: The common old binding energy method will be designated here as the "<u>n</u>,<u>p</u>-<u>based</u> <u>binding energy</u> method" -- because it is based on imagining the <u>n</u>eutron and <u>p</u>roton as the basic building blocks. But our newer advocated method will be designated as the "<u>e</u>,<u>p</u>-<u>based</u> <u>binding energy</u> method" -- because it is based on imagining the <u>e</u>lectron and <u>p</u>roton as the basic building blocks of nuclei. Actually, since the 'Bohr Atom' employs one electron orbiting around one proton, the e,p-based binding energy method is equivalent to using one or more Bohr Atoms as building blocks. In fact, historically, that system has been previously and successfully used by the famous textbook writers and accomplished scientists, Sears and Zemansky [1]. I.e., even before this present paper.

A major obvious failure of the old n,p-based binding energy method arises when it is used to calculate binding energies for $_1H^3$ and $_2He^3$, (Hydrogen-3 and Helium-3 isotopes). That old method calculates Hydrogen-3 as having much more binding energy than stable Helium-3. But sadly Hydrogen-3 turns out to be unstable and decays. That misleading calculation occurs because the old binding energy method generally uses the **<u>un</u>**<u>stable</u>, complex neutron as one of the <u>basic</u> building blocks, instead of the more basic and stable electron mass and proton mass.

But using our e,p-based binding energy method, the calculations show Helium-3 with slightly more binding energy than Hydrogen-3. That's good and appropriate because Helium-3 is stable. More details about the calculations are given later.

(Ideally, I wish a different terminology, instead of 'binding energy', had been used from the very beginnings of nuclear science, but we'll leave that alone for now, and return to our first major topic.)

One of the most striking things noticed when one studies physics and nuclear fusion is the huge energy that is emitted when four nucleons fuse together to form the common helium nucleus, ($_2He^4$). Even with only a general science background, much of the public will associate that fusion energy with the powering of the Sun and likely a hydrogen bomb.

Our solar system's <u>mass</u> consists of about 75% hydrogen and 25% helium and less than 1% other nuclei. So we are especially motivated to focus on fusion involving 4 nucleons and fewer nucleons. In fact, in terms of numbers of nuclei (not 'weight'), hydrogen's proton nucleus alone constitutes about 94% of the nuclei in our solar system.

With somewhat more study, one notes the huge jump in emitted energy when four nucleons are fused together vs. only three. That is the approximate quadrupling of output as described in the Abstract above, and is even evident from old common graphs of n,p-based binding energy per nucleon.

That quadrupling is <u>not</u> the expected outcome based on most people's experience with other things. For example, if one touches 2 sticky clay balls together, that results in '1 sticky' contact. Bringing 3 sticky balls together in a triangular pattern causes 3 'sticks', 3 times as many as the previously 1 stick case. And if 4 sticky balls are brought together in a tetrahedral pattern, that causes 6 'sticking points', <u>twice</u> as many as the previously 3. But <u>**not**</u> **four times** as many 'sticks!'

So the quadrupling of energy output in the 4-nucleon fusion case, compared to 3 nucleons, is a surprise at first glance. But on closer examination, we note that when 4 spheres touch in a tetrahedral array, that results in the formation of <u>**4** planes</u>, each consisting of 3 nucleons; unlike just a single triangular array of 3 nucleons forming only 1 plane. So we note the basic geometric shapes and structures involved, and thus the implication that those shapes may relate to the four-fold fusion energy jump and to our modeling.

1.2. (Optional) Comment on Others' Helpful Work

There exist good but rather complicated models and rules for estimating fusion mass losses as more and more nucleons are added to a nucleus to increase its mass, and depending on whether they are protons or neutrons, and other factors. And which proton and neutron combinations will still result in a stable nucleus. Model complexities are not surprising. For example, two protons and a neutron make the rarely occurring Helium-3 isotope that is stable. But two neutrons and a proton make a rarely occurring Hydrogen-3 that is not quite stable. And there doesn't seem to be any stable nuclei with 5 or 8 nucleons.

Despite the challenging task, some scientists have devised rather good and effective models in the 20th Century and early into the next, although models generally involve more than a few rules and are somewhat complicated [2-6}.

The author's supplemental model is very crude and limited in focus. But its focus is especially important. It does not even include charge or spin as considerations. But hopefully, readers will find it is interesting and helpfully thought provoking.

Some of Author's previous papers have shown correlations arising when big spheres surround small spheres in patterns. Volume ratios arose and were noted, and they nearly matched major particle mass ratios in nature. And a slight hint arose that crevice size between three or more equal touching spheres may very loosely correlate with small mass differences among slightly different particles in the same particle class [7-8].

2. Description

2.1. Interpreting Fig. 1

We'll start by discussing Fig. 1, because an aspect of it reveals a surprisingly close equality between a geometric numerical outcome and an empirical outcome as referred to earlier in our Abstract. In Fig. 1 we note the donut hole between the 3 touching nuclei or spheres. That geometry relates closely to e,p-binding energy.

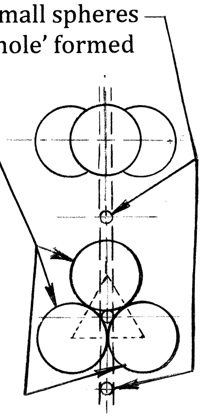

Fig. 1; Three Spheres or Nucleons – in a '<u>1 triangular</u> plane', having about <u>¼ th</u> the binding energy of four nucleons in a tetrahedral array with <u>4 triangular</u> planes.

But before further detailing our binding energy treatment, we unfortunately need to discuss the presently accepted 'atomic mass' standards, and how to use them. Although awkward, the present standards give sufficiently precise published tables of relative masses. And scientists must generally use them to helpfully calculate the mass difference between <u>empirically</u> measured initial masses and the final fused mass, in other words, the 'mass lost', and 'energy emitted'. So we'll also use all that here, and illustrate its use.

Roughly speaking, since the mid 1960s, the standard has been based on first assigning an 'atomic mass' amount to the 12 fused nucleons of carbon plus their 6 'orbiting electrons' (the common atomic carbon isotope $_6C^{12}$). That is assigned 12.000000 u, i.e., 12 units of mass. (Before 1961, the standard was based on the $_8O^{16}$ oxygen isotope and we would refer to that atom's 16.000000 'atomic mass units' ('amu').

The present $_6C^{12}$ standard's 'whole number', 12.000000 u, is now especially nice for carbon, but still results in a somewhat awkward relative mass value for the common hydrogen atom, a proton with orbiting election, namely 1.007825032 u, instead of a 'tidier' 1.000000 u. And the mass of the proton alone, therefore, comes out to almost exactly 1.007276467 u. Fortunately, relative numerical proportions are maintained, despite the shifts, so we can continue to use the table effectively and accurately enough.

Let us now proceed to calculate the e,p-based binding energy for the one $_2He^3$ (Helium-3) atom, made from three $_1H^1$ atoms, and as roughly shown in Fig. 1. (Note, one nice aspect of our methodology is this: We start with a simple system of 3 neutral simplest atoms and end up with a neutral system of one simple atom -- and we don't need to speculate about how deeply one formerly orbiting electron got jammed into the nucleus. Or even if it really formed one true, complete 'neutron' in there.)

The initial ingredients, three hydrogen atoms, equals a total mass of 3.0234751 u. The final fused product, one $_2He^3$ atom, has a mass of 3.0160293 u. The mass difference, and thus mass 'lost', is 0.0074458 u. And that is considered the e,p-based binding energy, i.e., the mass equivalent of energy emitted.

(Optionally, one can divide that 0.0074458 u by the mass of the final fused result, 3.0160293 u, to obtain the .00246874/ 1 ratio shown in Fig. 1.)

Our main model for the above reality includes a slight subtlety, but it only affects the outcome very slightly. We imagine 3 abstract balls of energy in space, perhaps spherical fields or ethereal balls, as equal to the mass equivalent energy of that Helium-3 atom, 3.0160293 u. (We can divide that by 3 to get the average mass equivalent energy of each of those abstract balls.) Twice the mass equivalent energy of a single small ball that would barely fit through that surrounding 3-ball array's donut hole is 0.0074442 u. That geometrical result is about 0.021% less than the 0.0074458 u value of our e,p-based binding energy for the event -- thus an error of only about 1 part in 5000.

(Optionally, one can divide that geometrical result, 0.0074442 u, by the total mass of the final atom, 3.0160293 u, to obtain the other ratio, 0.00246822/ 1, shown in Fig. 1, for comparison.)

Suppose for the final mass of the 3 fused spheres above, we had imagined the value reduced by 2 electron masses to make 2 remotely orbiting electrons. That would have only slightly reduced the size of the donut hole in the slightly reduced size of the 3 surrounding big spheres, thus increasing our error to about 0.06% instead of about 0.02%. That's still a very small error.

Suppose we had asked, instead, "What fits through the initial donut hole in the 3-nucleon array before the array fused, instead of what fits through the donut hole after fusion or an abstract after-fusion representation?" Then we could consider, say, each of the three initial nucleons to be the average of 3 positive protons, but with the mass of one negative electron also added to the mix. Twice the mass of one small sphere that would barely fit through that initial 3-nucleon array's donut hole -- equals 0.00746076 u. That comes out 0.2% higher than the e,p-based binding energy, ref. 0.0074458 u, but that is still very close!

A word of caution about the remarkable closeness achieved, especially for the case of the 'after fusion model' calculations: Of course, the closeness could be 'just a coincidence'. Based on what appears to be the amount of darkened volume in the tunnel region, we might expect that that dark volume might be associated only very roughly with such a mass loss. But suppose the numerical correspondence above is not just a coincidence: Then the donut hole dimensions, its unique 'quantum size', and the somewhat strange quantum propensities in our micro-world -- may actually act to generate quantum-sized increment results in our above-discussed case!

Note this for the first model discussed above (the most abstract model treated somewhat subtly): We extended the incompressibility and uniform density concepts in the Bohr 'Liquid Drop Model' to also apply to our ethereal energy spheres or spherical fields. Our treatments also accepted the rather common theme in physics that sometimes a particle or its energy behaves as if it is not in a simple single place. Examples of that are 'electron double slit diffraction' and in chemical 'resonance bonds'. And in systems with potential energy or where there arises more than one degree of freedom or expression of motion.

2.2. A Better Binding Energy Concept and Fig. 1

Let us now discuss, in more detail, what we have termed, our new e,p-based Binding Energy method, and some of its advantages over the old n,p-based Binding Energy method:

First, we will note the problems that arise when the old **n**,p-based binding energy treatment is used to analyze two slightly different 3-nucleon atoms. The first is the stable Helium-3 atom with ($_2He^3$) nucleus, which the old treatment says consists of two protons and one neutron. And the second is the decay-prone Hydrogen-3 atom with ($_1H^3$) nucleus, which the old treatment says consists of one proton and two neutrons. The old binding energy treatment starts with the following basic ingredients: To make ($_2He^3$), 2 hydrogen atoms and 1 unstable neutron are envisioned as used. And to make ($_1H^3$), 1 hydrogen atom and 2 unstable neutrons are envisioned as used. The binding energy is based on the mass difference between the starting unfused ingredients and the final fused atom's mass.

Thus the old binding energy calculations, using empirical data, result in 'binding energies' for those atoms' nuclei, as follows:

For Helium-3, ($_2He^3$): 0.00**82**857 u.

For Hydrogen-3, ($_1H^3$): 0.00**91**056 u.

Note the substantially **greater** '**binding** energy' value for the **un**stable Hydrogen-3 nucleus compared to the stable Helium-3 nucleus that is thus sadly obtained above.

That is a **disaster** for the commonly used old binding energy method, since the Hydrogen-3 nucleus is unstable and decays (half life about 12 years), but the Helium-3 nucleus is stable. Despite the old method's predictive term, 'greater binding energy' (which implies a greater binding strength should result), the reality is that a significantly weaker bond results for the decay prone ($_1H^3$).

Somewhat relatedly, readers are reminded that when, say, hot liquid tungsten starts cooling and crystalizes, it gives off much greater 'heat of fusion' than other crystalizing metals. And we customarily and correctly associate that much greater heat of fusion with the much higher tensile strength of ordinary tungsten, compared to other metals.

So the empirical instability of ($_1H^3$), despite the old binding energy method assigning it much greater binding energy than stable ($_2He^3$), is contrary to the old method's predictive language and its associated relative numbers. And the method is contrary to practices and outcomes when treating other analogous physics topics, such as heats of fusion. So all that is **not** acceptable. It at least indicates a great need for an alternate binding energy methodology to be made available, an alternate way of handling and interpreting empirical data. (Of course, that's not to say the old method is never helpful – an example of that is given later.)

Now let us see how our advocated e,p-based binding energy method treats those atoms, and obtains better predictive results: Our method's non-fused starting ingredients for making both Helium-3 and Hydrogen-3 are the same, a neutral system of (3) Hydrogen-1 atoms. The difference in mass between that and masses of the final fused atoms are our binding energies, and are as follows:

For Helium-3 nucleus, ($_2He^3$): 0.0074**4**58 u.

For Hydrogen-3 nucleus, ($_1H^3$): 0.0074**2**58 u.

Note our e,p-based binding energy treatment gives a slightly greater binding energy for ($_2He^3$) than for ($_1H^3$). That is very appropriate and good. The implications of the new now greater binding energy for ($_2He^3$) compared to ($_1H^3$) implies literally that ($_2He^3$) is 'bound' together more tightly and is apt to be more stable than the ($_1H^3$). And it is, since the ($_1H^3$) is unstable!

But the fact that the new binding energy of ($_2He^3$) is still not huge nor a lot greater than for ($_1H^3$) means this: That the nucleus of the more common helium isotope ($_2He^4$), that we associate with the tetrahedron array, is likely to be a lot more common than the ($_2He^3$) that we associate with the triangular array. And indeed, that much greater occurrence of Helium-4, is the reality in our solar system and likely for the world.

Our e,p-based binding energy method is, in effect, like making the hydrogen atom a major mass standard for helping to calculate and to judge relative 'mass loss' when various fusions occur. That standard might not be perfect nor beyond improvement, but historically the Bohr Atomic model for the hydrogen atom provided a great basic leap forward. It is understandable using 8th or 9th grade algebra. And no other atom came even close to being so easily treated and still revealing so much. And as said previously, the hydrogen (proton) nucleus is by far the most common nucleus in the universe and does not, itself, incorporate a neutron nor need to.

It is the stable embodiment that serves vastly more often than others as the basic positive charge. And similarly, but oppositely, the electron serves so often as the negative charge.

So why not compare the mass of, say, two simple hydrogen atoms (net charge zero) with the resulting mass of a 'deuterium' atom (net charge also zero)? And then asking the basic question, "How much conventional mass was lost by that 'transition' or replacement?" That is a very self-justified question or analytic tool in its own right, anyway! And similarly for treating atoms with more nucleons by just imagining more Hydrogen-1 atoms used at the start.

It is a great 'systems-before' and 'systems-after' analytic tool, without scientists being 'side-tracked' by the overly compulsive immediate need to know (or think they know) exactly where the 'bound' electron is. We don't need to know exactly where the electron is that gives each system its net electrical neutrality.

Nor do we even have to say, 'the neutron and proton inside the nucleus' vs. 'the neutron and proton outside the nucleus', since the masses in each case are different, anyway, depending upon whether each is 'free' or fused into a bundle. And using similar names for different things (and different masses) tends to lead to unnecessary verbal, conceptual, and philosophical contradictions, too. The problem is due to the overly compulsive propensity to rush in too fast and literally 'over micro-manage' the (micro) system. Or what one thinks is the system.

Consider our preferred alternate method instead: If the electron is orbiting the nucleus, fine. If it's touching the nucleus, fine. If it's somewhere inside the nucleus, fine. Or if at some time it's, so-to-speak, jammed far into the nucleus, that's fine! (All our e,p-based binding energy method needs to know is that the 'beginning system' is electrically net neutral and that the 'final system' is also electrically net neutral.)

Ultimately, the net fusion of several simple Bohr hydrogen atoms to form fused geometric formations, like Helium-4, and even more massive bundles – may increase slightly the 'ether' in our universe. And the reverse action may slightly decrease the amount of ether. Perhaps that is somewhat analogous to the earth's ecosystem: Oceans partly evaporate to give us high humidity; then rain, and that back into the rivers, lakes, and oceans again. (And, hopefully, the greater temperature stability that brings us.)

Our e,p-based binding energy method often gives us a lot of useful information without the problems that often arise when scientists attribute or impose on nature -- their own, perhaps, narrow minded viewpoint or overstretched attributions. Hopefully, we'll first view nature by allowing it to 'do its own thing its own way' -- not necessarily our mentally conceived-of way, and see what we can first glean from that.

We previously applied our new e,p-based binding energy method to atoms with 3 fused nucleons. But when Sears and Zemansky first introduced their e,p-based binding energy, they applied it to 4 fused nucleons, the Helium-4 atom [9]. They wisely imagined for the mass of their starting ingredients, a neutral system of 4 unfused Hydrogen-1 atoms; and for their neutral end product, 1 Helium-4 atom. Then they calculated the mass difference. That gave them the energy emitted, the binding energy.

2.3 Interpreting Fig. 2

We now discuss in more detail -- the common 4-fused nucleons case, often designed 'Helium-4'. See Fig. 2 below:

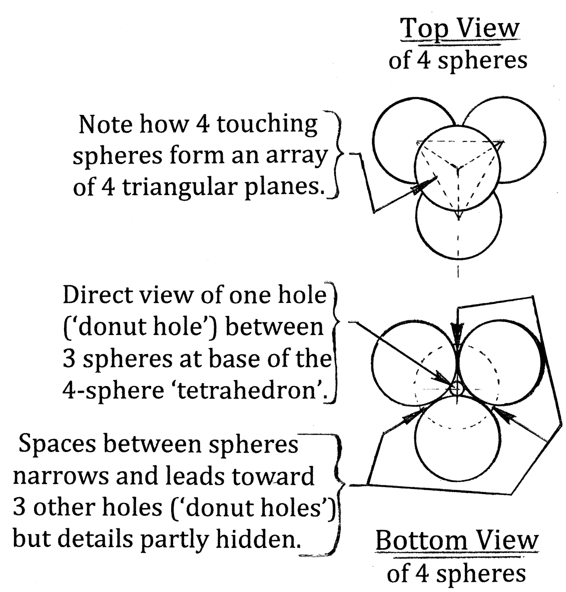

Fig. 2; Four Spheres or Nucleons – in a tetrahedral array of 4 triangular planes. Has about 4 times the binding energy of 3 fused nucleons in a 1 triangular plane.

As previously noted, we can geometrically imagine Helium-4 as resulting from adding a 4th nucleon on top of a 3-nucleon triangular array, thus forming a tetrahedron shaped 4-nucleon array. And as previously noted, we can thus imagine it to consist of 4 triangular planes, each with a donut hole, totaling 4 donut holes. That is to be contrasted with only 3 nucleons, as shown in Fig. 1, forming only 1 triangular plane or array, with only a total of 1 donut hole.

We have previously advocated the logic of likely associating that increase, from 1 donut hole to 4 donut holes, with a roughly 4-fold increase in fusion energy emitted, or fusion mass lost. Empirically, the increase in mass loss comes out a little less than the simple 4-fold jump we envisioned.

Using the standard old n,p-based binding energy method, the increase is interpreted to be from 0.0082857 u to 0.030378 u, about 8.34% less than a full 4-fold jump. But using our e,p-based binding energy method; the increase is interpreted to be from 0.0074458 u to 0.028698 u, and thus only about **3.64%** less than our 4-fold increase envisioned!

We used the wording, 'our 4-fold increase envisioned'. But actually, the somewhat complicated interior cavern (inside our tetrahedron shaped 4 nucleon array) does not really allow us to be as confident about our roughly 4-fold prediction as we might wish. On the one hand, there are aspects about that interior and possible flows, there, that might lead one to predict a somewhat less 'tunnel effect', because of turbulence developing. And since there are 'close quarters' in the interior (instead of the nearly 'open skies' on the exterior), that might also impede the effect.

On the other hand, the internal tunnels seem likely longer, in a sense, than for the simple 3-nucleon case in Fig. 1. And that might increase the tunnel effect. Exact attempted calculations of interior tunnel effects are not given in this paper, but the author is actually somewhat pleasantly surprised that the net empirical result comes out as close to being a '4-fold' increase as it does!

There may be a little 'balancing-out good luck' involved, and perhaps the rather good net result implies that a 'quantum action', by nature, is still somewhat present. But not so overridingly powerful as to dwarf the effects of other factors.

2.4 Interpreting Fig. 3

This author does not here present a detailed, accurate drawing for modeling the nuclear bond between the two nucleons comprising a deuteron. So Fig. 3, below, is just the barest roughest outline of, say, two fused nucleons:

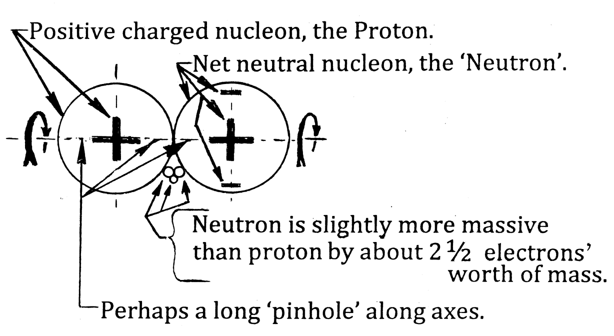

Fig. 3; A Deuteron, two Nucleons, or two Spheres. Any other sketch details totally conjecture, not really known.

Historically, however, quite a few contributors to the 'Proceedings of the Natural Philosophy Alliance' and the journal, 'Galilean Electrodynamics', have presented respectable and thoughtful models. But details of those models are beyond the scope of this paper. Of course, one challenge has been to show and describe the details of what is really going on, that is the cause of such particle behavior -- which scientists have had to concoct the 'charge algorism' to treat efficiently.

Strangely enough, the e,p-based binding energy associated with the relatively weak deuteron's bond does not seem magnitudes greater than energies associated with the electron particle. Nor much greater than the energy associated with point charges separated by a nuclear distance (10^{-15}m). (Even though the neutron and deuteron are considered to have no or trivial dipole moments!)

Interestingly, the energy emitted when just 2 nucleons fuse to form a deuteron is about 2.82 times the (mc^2) energy of one electron mass. (To express that in terms of our e,p-based binding energy, we say this: The binding energy of the deuteron is about 0.00154829 u compared to about 0.00054858 u for a 'free electron'. That comes out to about 2.822 times the energy of the electron.)

But consider that compared to the following related energies: The energy associated with the radius of 'classical electron' (radius = 2.82×10^{-15} m) vs. the energy associated with bringing a 'point' electron 'from infinity' to barely fully inside the surface of a proton (say 1.0×10^{-15} m distance from proton's center). That latter energy is also about 2.82 times the (mc^2) of one electron mass. The likely radius of a proton is about 1.2×10^{-15} m. Those are approximate estimates.

All that is merely an argument for the likelihood that the relatively weak binding between the two nucleons of a deuteron is mostly just 'electric flow' related. That is, related to flows associated with just one or a very few basic units of charge.

Some scientists have also noted the following: Suppose we bring the electron from a 'classical distance' of 2.82×10^{-15} m away from proton -- to the proton's surface, (proton's radius is about 1.2×10^{-15} m). That would constitute adding enough mass equivalent energy to the system to equal the slight difference in mass between a neutron and proton. That energy difference is not much less than the deuteron's e,p-based binding energy.

2.5. More insight into Binding Energy using Deuterons

The deuteron may offer a very special insight into the pros and cons of our simple e,p-based binding energy method and the old n,p-based binding energy method. That is because real experiments have been done to see how much energy is needed to break the deuteron into one neutron and a proton, using a gamma ray.

At first glance, the result and conclusion seem very quick and simple -- too simple. A strong gamma ray, with 'mass equivalent energy' of about 4-1/2 electron masses does the job. Say, we hit 100 deuterons with 100 of those gamma rays. That breaks up each; that 'does the trick' in less than a fraction of a second. So, some scientists might say, "End of test, turn out the lights, go home, and publish the conclusion: The deuteron has 4-1/2 electrons worth of binding energy, a pretty strong bond!" The old binding energy method and its approach seem great, at first glance.

But suppose more diligent experimenters were willing to stay and observe the results for more than 12 minutes, the mean half-life of neutron. They would further note this: After the first deuteron was broken up by the very strong gamma ray, into the proton and neutron, the neutron, itself, broke up into a more basic proton and electron. And gave off about 1-1/2 electron masses' worth of energy back to the experimenter. Imagine the experimenter using that feedback to 'boost' the energy of, say, a next much weaker gamma ray. Say, that next gamma ray, with only 3-electron masses worth of energy initially – gets boosted back up to the 4-1/2 electron masses worth of energy, to split the next deuteron!

And so on, say, for the 99 other deuterons, i.e., saving 1-1/2 electron masses worth of energy per each of those splits. The beauty of the simple e,p-based binding energy method is this: In effect, it gives a weaker net gamma ray energy needed, only 3 electron mass equivalents net worth of gamma ray energy needed for each subsequent deuteron breakup, not 4-1/2 electrons.

So that non-wasted energy or cogeneration 'feedback' result also shows how to do more with less energy. And, as said, that lesser energy need is clearly indicated by our e,p-based binding energy calculation for the deuteron, instead of being obscured by the old n,p-based binding energy calculation.

In general, naturally occurring radioactive elements do not emit neutrons – except in very rare cases of 'spontaneous fission' or when hit by an incident particle. Various naturally occurring radioactive elements typically transform by emitting an electron or by emitting an alpha particle, the nucleus of Helium-4.

2.6. Comments on Binding Energies of more than 4 Nucleons

As the number of nucleons in a bundle increases, a variety of complex subtleties seem to manifest themselves more strongly. So the reader is best referred to the references at the end of this paper for treatment of those subtleties. Still, we will discuss some hopefully helpful analogies, and make some other general comments -- about bigger and bigger nuclei, as follows:

We earlier noted the three major basic ways that nucleons can fuse to form a nucleus: #1) The weak low energy bond between two nucleons like the deuteron in Fig. 3, which we'll term 'electric flow related'. #2) The medium energy or medium strength bond between three nucleons like in Helium-3 in Fig. 1, which is likely related to its having only one donut hole. #3) The high energy or high strength bond like in Helium-4 in Fig. 2, which is likely related to its having four donut holes.

But as we add more nucleons to most other nuclei, we note the following about the jump in bonding strength or energy per nucleon added: The jump is usually a 'hybrid' or mixture of those bonds in the previous paragraph, for example, somewhere between a low and medium energy jump. Or as still more nucleons are added, between a medium and high-energy jump.

That has an analogy in the 'world of chemical bonds' -- where such descriptions arise as 'partial ionic character of a covalent bond'. Or for covalent benzene bonds, a compromise carbon-to-carbon bond length 'with 50% double-bond character'. And so many important chemical bonds exhibit the related so-called 'resonance behavior', somewhat like benzene.

Roughly speaking, in the range of 5 to 8 total nucleons – the binding energy jumps are erratic, averaging in the 'weak electric flow class', but occasionally rising to an almost 'one donut hole' class. From 9 to 12 nucleons, jumps are somewhat beyond the one donut hole class – as if to include a slight 'four-donut hole character' in the mix. From 13 to 16 nucleons – we note slightly smaller binding energy jumps than in the previous range.

Generally after that, as nucleons are further added until about 60 nucleons are accumulated; the 'binding energy jumps' increase, as if to indicate a slightly greater four-donut holes character. But after about 60 nucleons, the magnitude of the jumps becomes less, most likely because of the ever-growing repulsions of the increasing number of positively charged protons in the nucleus.

The lack of any stable 5-nucleon nucleus may partially relate to the following: Plopping the 5th nucleon on top of any one of the four 3-nucleon triangular arrays (comprising Helium-4) – might stop or impede flow involving a pair of the helium's 4 donut holes. And block the former 'port to port' line-of-sight that was partially present. The added flow between a resulting new pair of donut holes would be, at best, very asymmetric relative to previous flows, and in close proximity to them too. Some of that problem might exist even if a 5th nucleon is added anywhere onto the 4-nucleon bundle.

Those problems seem to be much less, for the case of an 8-nucleon bundle, and that seems to have enough appeal. And the 8th nucleon does, in fact, seem to stick on the bundle for nearly a second. But it seems likely that if it and another existing nucleon slide even slightly away from their ideal position, the beginnings of two tetrahedral formations will appear. And perhaps the appeal of two independent 4-nucleon bundles competes with the less competitive single 8-nucleon bundle. So it splits up into two 4-nucleon bundles, i.e., two 'Helium-4' nuclei.

3. Conclusion

In about 1960, Sears and Zemanski introduced an alternate and simpler way of calculating the mass loss associated with nucleon fusion. And thus the energy emitted, or the binding energy of a nucleus. Their illustration started with the net neutral system of (4) Bohr hydrogen atoms, and it finished with those fused to form a net neutral Helium-4 atom. They calculated the mass difference between the former and latter, and thus the large energy emitted. That was, in effect, a, useful, alternative 'binding energy' result. That was because they used electrons and protons as their starting building blocks, instead of the old method that used 2 **un**stable neutrons and 2 hydrogen atoms as the starting building blocks.

We called their new method the 'e,p-based binding energy' method because it uses the **e**lectron and **p**roton (or the Bohr hydrogen atom) as its building blocks, instead of the old n,p-based binding energy method's use of the neutron and proton with orbiting electron.

The new method may be used for calculating the binding energy of the net neutral $_2He^3$ and $_1H^3$ atoms by starting with the net neutral mass of (3) $_1H^1$ Bohr atoms. And the excellent results show a slightly greater e,p-based binding energy for the stable $_2He^3$ nucleus than for the unstable $_1H^3$ nucleus. That contrasts with the old system's confusing and dubious result, which calculates a much greater binding energy (or binding strength) for the **un**stable $_1H^3$ nucleus!

Most of this paper's main themes are, with some effort, even evident using the old binding energy method. But the themes are more readily evident using the newer e,p-based binding energy method.

We have shown that Helium-4 has about 4 times the nuclear binding energy compared to Helium-3. We theorized that that is because a tetrahedral shaped Helium-4 nucleus has 4 times as many triangular planes, each with 1 hole, like in a donut -- compared to Helium-3 with just 1 triangular plane with 1 'donut hole'.

We also showed that the fusion energy emitted after (3) Hydrogen-1 atoms fuse to form a Helium-3 atom is as follows: Twice the energy of one small ball that could barely fit through the donut hole in the array of 3 bigger touching balls. That is, assuming each of those 3 bigger balls has one-third of the energy of the final fused Helium-3 atom. That geometry-based estimate vs. the atom's e,p-based binding energy -- is accurate to a small error of about 1 part in 5000.

There are also other methods in the paper for treating the above fusion and they are more detailed and less abstract. Their predictions give nearly the same result as the above with only slightly greater error. All of our methods use the approximations inherent in the Bohr 'liquid drop model' of the nucleus. That is virtual incompressibility and uniform density, regardless of whether applied to nucleon spheres or 'ethereal spheres of energy'.

It is, of course, quite possible that nucleons are not precisely 'billiard ball' shaped, nor are 3 or 4 of them so arranged as to form perfect triangular or tetrahedral patterns. But perhaps the ethereal fields around them or near them do nearly achieve those ideal forms! More comment on that also given in the paper.

It is hoped that eventually e,p-based binding energies will be calculated for almost all nuclei; that various graphs will be made based on that; and that a lot of nuclear science will be reexamined based on those results. But that is beyond this paper.

It also might be interesting to try to explain the following in simplest terms: Some modern listings give the masses for the free proton, free electron and ground state of the Bohr atom in 'u' units [10]. But that data seems to indicate that the mass of the free proton plus the free electron equals very slightly more than the mass of a Bohr atom. That seems to imply, for some systems, that a motion-related 'relativistic' mass decrease occurs for the electron, instead of an expected increase. But perhaps the data is not quite as precise as hoped, or some alternate explanation.

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