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Nuclear systematics:
IV. Asymmetry between matter and anti-matter

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The dominance of matter over anti-matter in the universe is at obvious variance with the widely assumed symmetry between matter and anti-matter[1]. Systematic properties of nuclear matter reveal an asymmetry between positrons and electrons in β-decay and offer a possible explanation for the paucity of anti-matter in nature. Measurements are proposed to test for symmetry between matter and anti-matter.

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Introduction

Systematic properties of known nuclides indicate that n-p interactions are attractive but the n-n and p-p interactions are repulsive and symmetric except for Coulomb effects[2-4]. A recent paper suggests that nucleon interactions may be understood in terms of the Casimir free energy between nuclear particles in a sea of electrons and positrons[5]. This model of the nucleus and systematic properties of nuclides are used here to look for an explanation of the high abundance of matter relative to anti-matter in the universe. Parts of this paper were presented at the 2003 American Physical Society meeting in Philadelphia, PA[6] and the 33rd Annual Mid-west Regional Astrophysics Conference in Kansas City, MO[7].

Nuclear Systematics

Systematic properties of matter are shown on the right side of Figure 1 in a plot of the average potential energy per nucleon, M/A, versus charge density, Z/A, for the 2,850 known nuclides[8]. Anti-matter is represented on the left side of Figure 1 by an assumed reflection of matter through an imagined plane of symmetry at Z/A = 0. If this symmetry is valid[1], then why does the universe consist mostly of material on the right, rather than the left, side of Figure 1?

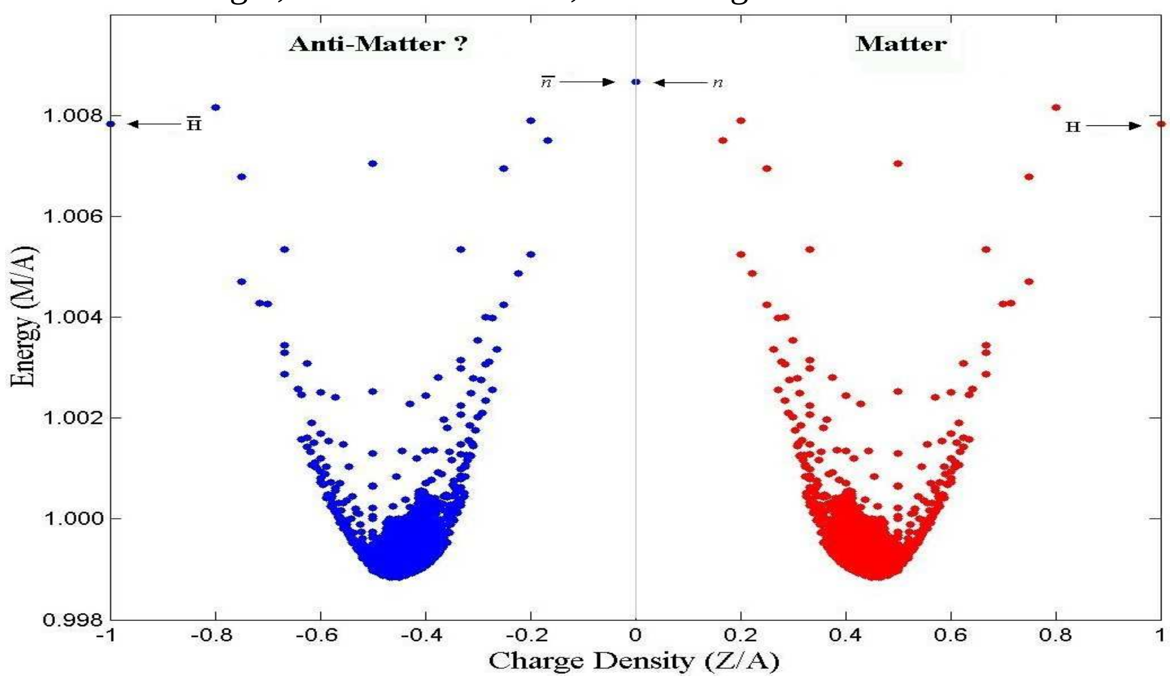

Figure 1. Matter on the right is represented by 2,850 data points of nuclides from the latest edition of *Nuclear Wallet Cards*[8]. Anti-matter, on the left, is represented by a reflection of matter through an imagined plane of symmetry at Z/A = 0. This concept of symmetry between matter and anti-matter arose from observations of β^+-emission by proton rich nuclides and subsequent annihilation of the electron-positron pair.

The key to the origin of this asymmetry may be discernible on the right side of Figure 1 when the nuclei of *matter*, containing a sea of electrons and positrons[5], spontaneously emit one or the other.

The positron provided the first experimental evidence of Dirac's prediction in 1931 that "*a hole, if there were one, would be an entirely new kind of particle, unknown to experimental physics, having the same mass, and opposite charge of the electron.*" [Quinn[1], p. 31]. In general, positron emission is observed when the charge density, Z/A, is high. This is illustrated in Figure 2 for the emission of positrons, β^+, and electrons, β^-, from isobars[8] at A = 13. Regions of β^+-emission and β^--emission are approximately symmetric about ^{13}C, the isobar at A = 13 with the most stable charge density, Z/A = 6/13.

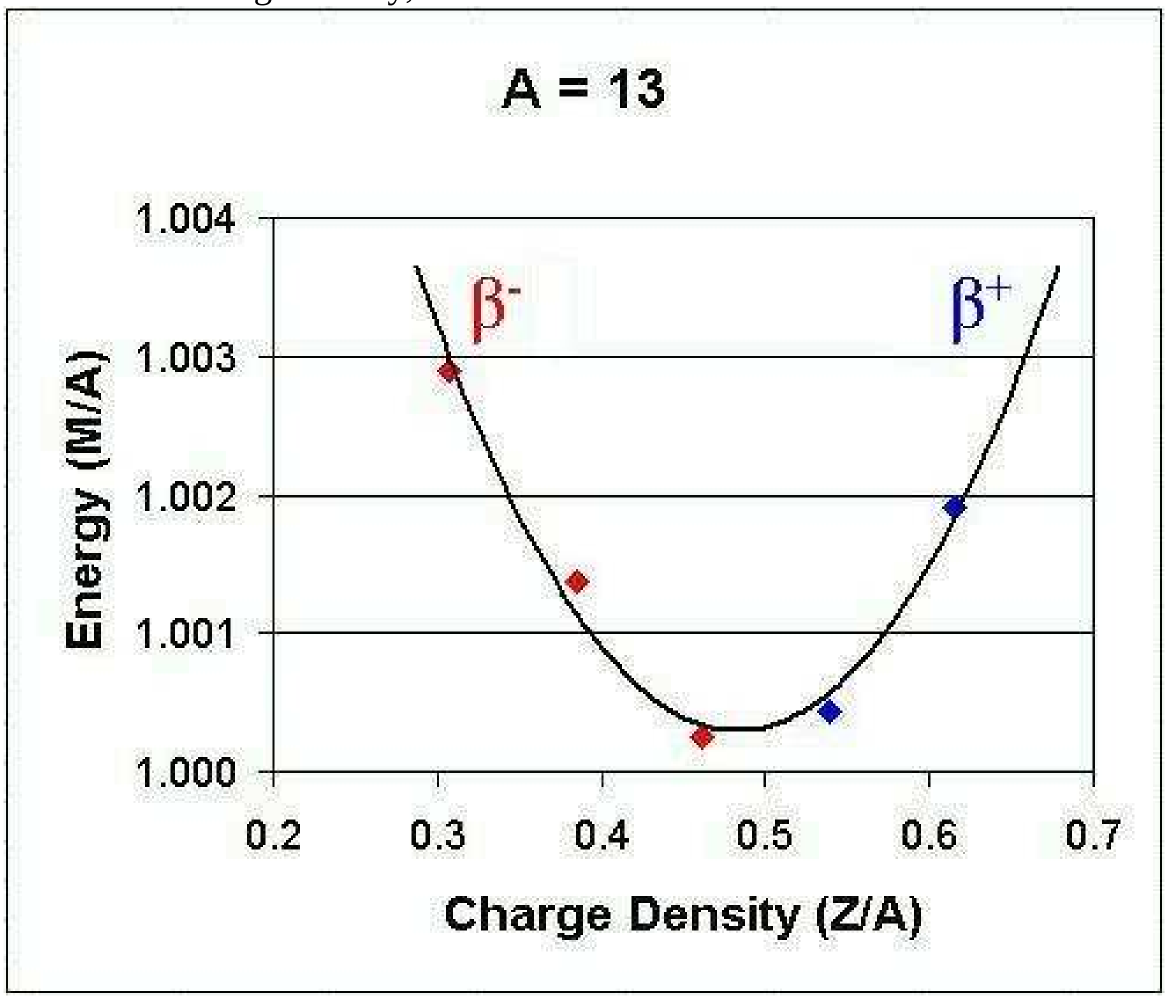

Figure 2. The isobars at A = 13 show approximate symmetry in the emission of positrons, β^+, on the right and electrons, β^-, on the left when values of the charge density, Z/A, are too high or too low. However, greater symmetry is observed in the capture and emission of electrons.

Isobars[8] on the right side of Z/A = 6/13 in Figure 2 decay by electron-capture or by the emission of positrons; those on the left side decay by the emission of neutrons or electrons. There is, however, an asymmetry between β^+-emission and β^--emission. β^--emission can occur when $M_{(Parent)} - M_{(Daughter)} > 0$, but β^+-emission must overcome a 1.022 MeV barrier, i.e., β^+-emission can only occur when $M_{(Parent)} - M_{(Daughter)} \geq 1.022$ MeV.

Thus, there is no barrier to increasing the positive charge on the nucleus by β^--emission, i.e., moving from left to right in Figure 2. However, there is a 1.022 MeV barrier to decreasing the positive charge on the nucleus by β^+-emission, i.e., moving from right to left. In the presence of atomic electrons, this barrier to decreasing the positive nuclear charge can be by-passed by electron-capture (E.C.).

This is illustrated in more detail in Figure 3 for the decay of ^{13}N.

$$^{13}N \longrightarrow {}^{13}C + \beta^+ + 1.198 \text{ MeV}$$

The total decay energy, $Q_{total} = M(^{13}N) - M(^{13}C) = 2.220$ MeV but only 1.198 MeV remains after overcoming the 1.022 MeV barrier to β^+-emission. By convention the 1.022 MeV barrier is attributed to production of an electron-positron pair, an electron and a "hole", each with the same, identical rest mass. Thus, the positron is widely viewed as experimental confirmation of Dirac's 1931 prediction of "*a hole … having the same mass, and opposite charge of the electron.*" [Quinn[1], p. 31].

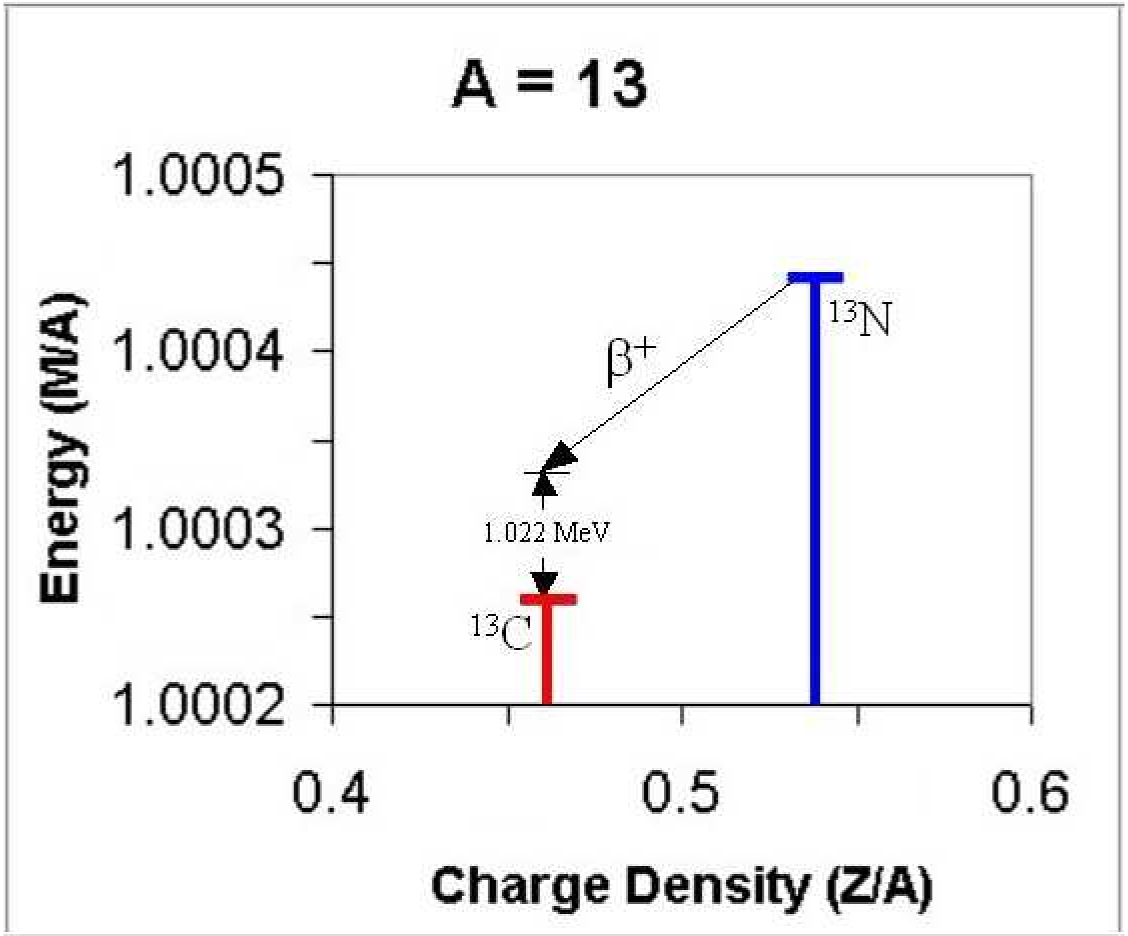

Figure 3. Details of the β^+-emission of ^{13}N show the 1.022 MeV barrier to this mode of beta-decay. The total decay energy is 2.220 MeV[8], but the energy available after positron production is only 2.220 MeV - 1.022 MeV = 1.198 MeV.

However, the decay of ^{13}N, with 7 protons and 6 neutrons, to ^{13}C, with 7 neutrons and 6 protons, is but one example of the mirror nuclides that "… *can be made from each other by interchanging all protons and neutrons.*" [Evans[9], p. 33]. For such nuclides, beta decay does not change the number of n-p interactions nor the total number of n-n plus p-p interactions. The number of n-n interactions will decrease (or increase) as the number of p-p interactions increase (or decrease).

For β^--emission of the mirror nuclides close to the line of β-stability, such as (^1n, ^1H), (^3H, ^3He), …..(^{13}C, ^{13}N), ….(^{39}K, ^{39}Ca), (^{41}Ca, ^{41}Sc), the parent nuclide has A = 2Z + 1, the daughter has A = 2Z -1, and the decay energy, $Q_{\beta-}$ = M(A=2Z+1) - M(A=2Z-1) = ΔE_C, the change in Coulomb energy[2,4-9]. Values of ΔE_C are proportional to $A^{2/3}$, as shown in Figure 4, when a neutron, <n>, is transformed into a proton, <p>, and an atomic electron, e^-, releasing 1.5 MeV of energy minus the increased Coulomb energy, ΔE_C, from increasing the positive nuclear charge:

$$\langle n\rangle \longrightarrow \langle p\rangle + e^- + 1.5\ \text{MeV} - \Delta E_C$$

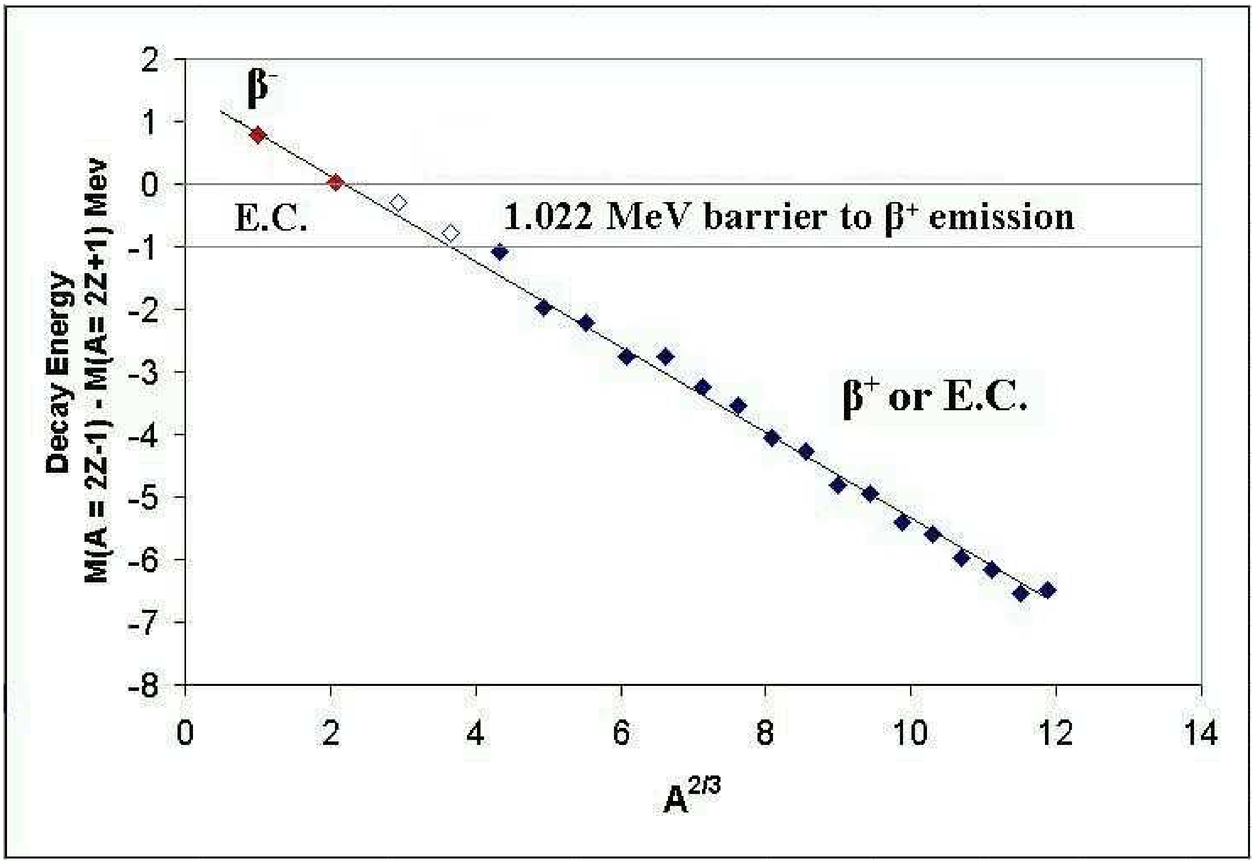

Figure 4. The energy for beta-decay in 21 pairs of mirror nuclides [(parent,daughter) = (^{1}n, ^{1}H), (^{3}H, ^{3}He), …(^{13}C, ^{13}N), …(^{39}K, ^{39}Ca), (^{41}Ca, ^{41}Sc)] illustrates the regions where electron and positron emission occur. These are separated by a 1.022 MeV barrier to β^+-emission where proton-rich nuclides decay by electron capture (E.C.). These mirror nuclides are equidistant from Z = N.

For example at mass number, A = 1, Figure 4 indicates that the neutron would release 1.5 MeV of energy and be transformed into an atom of ^{1}H, except that the latter has 0.7 MeV more Coulomb energy associated with the positive charge on the nucleus. Thus, the actual neutron decay energy[8] is only 0.8 MeV. At mass number, A = 3, a bound neutron in ^{3}H would be transformed into a bound proton in ^{3}He and release 1.5 MeV of energy, except that the increased Coulomb energy on ^{3}He is almost that amount so the actual decay energy[8] of tritium is only 0.02 MeV. At mass number, A = 7, a bound neutron in ^{7}Li cannot be transformed into a bound proton in ^{7}Be and release 1.5 MeV of energy because that is less than the increased Coulomb energy on ^{7}Be relative to ^{7}Li. Thus, the reaction goes in the opposite direction and an electron goes from the atomic orbital of ^{7}Be into the nucleus to produce ^{7}Li with the release of 0.9 MeV of energy. In the case of electron capture, however, there is no evidence that the disappearance of an atomic electron leaves a "hole" with rest mass.

Figure 4 illustrates important trends in β-decay of *matter* when there is no change in the energy associated with the interactions between nucleons:

1. In all cases the spontaneous process involves a negative charge moving from a nuclear volume of radius (r ≈ 1 F) to an atomic volume of radius (r ≈ 10^5 F) with the release of 1.5 MeV of energy minus the increased Coulomb energy, ΔE_C, associated with the increased positive charge on the nucleus.

2. When ΔE_C < 1.5 MeV (e.g., at A = 1 and 3), β^--emission occurs.

3. When 1.5 MeV < ΔE_C < 2.5 MeV, the reverse reaction occurs: A negative charge moves from the atomic volume of radius (r ≈ 10^5 F) to the nuclear volume (r ≈ 1 F) via electron-capture (E.C.). However, β^+-emission cannot occur and there is no evidence that electron-capture leaves a massive "hole".

4. When ΔE_C > 2.5 MeV, the decay energy may exceed the 1.022 MeV barrier to β^+-emission and this decay mode starts to compete with electron-capture.

5. The charge on the nucleus readily increases by electron-emission or decreases by electron-capture, but there is a 1 MeV energy barrier to positron-emission.

If matter and anti-matter are symmetric, as commonly assumed[1] and as strongly suggested by recent measurements on the charge-to-mass ratio of the anti-proton[10], then β-decay in anti-matter should exhibit equal and opposite trends. However, the dominance of matter over anti-matter in the universe suggests that all these trends in β-decay of *matter* may not be reversed in β-decay of *anti-matter*. For example, there may exist a basic asymmetry in nature by which negative charges preferentially occupy larger volumes than positive charges.

Conclusions and Proposed Test

The paucity of *anti-matter* in the universe may reflect asymmetries seen in positive and negative charges in β-decay trends of ordinary *matter* (Figures 2-4).

New measurements could disprove this hypothesis by showing that all β-decay trends of ordinary *matter* are reversed in the case of *anti-matter*, i.e.,

1. In all cases the spontaneous process involves a positive charge moving from a nuclear volume of radius (r ≈ 1 F) to an atomic volume of radius (r ≈ 10^5 F) with the release of 1.5 MeV of energy minus the increased Coulomb energy, ΔE_C, associated with the increased negative charge on the nucleus.

2. When ΔE_C < 1.5 MeV (e.g., at A = 1 and 3), only β^+-emission occurs.

3. When 1.5 MeV < ΔE_C < 2.5 MeV, the reverse reaction occurs: A positive charge moves from the atomic volume of radius (r ≈ 10^5 F) to the nuclear volume (r ≈ 1 F) in positron-capture (P.C.). However, β^--emission does not occur and there is no evidence that positron-capture leaves a massive "hole".

4. When ΔE_C > 2.5 MeV, the total decay energy exceeds the 1.022 MeV barrier to β^--emission and this decay mode starts to compete with positron-capture.

5. The charge on the nucleus readily increases by positron-emission or decreases by positron-capture, but there is a 1 MeV energy barrier to electron-emission.

However if the emission of a positron is always inhibited by a 1.022 MeV energy barrier, e.g., in moving from right to left in Figure 1 from Z/A = 0 to Z/A = -1, then neutrons and anti-neutrons could not decay to anti-protons even if these particles were produced in some highly compressed initial state of the universe. For the neutron and the anti-neutron, there are no atomic electrons that might be captured to by-pass this barrier to β^+-emission.

Acknowledgements

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Many products are created by Matter and Anti Matter collision but is dependent on what matter antimatter that is annihilating. Example electron and a positron annihilate create 2 photons. Proton-anti-proton annihilation produces as many as nine mesons have been observed. If there were equal amounts of matter and antimatter in the beginning we would now see high amounts of gamma rays at the boundary's between regions of matter and antimatter. Which we do not observe. That is my answer. We can create anti-matter using particle accelerators and we can capture it using a magnetic field. Electric charges and magnetic fields are representative of the EM force, and when you create the right magnetic field, anti-matter will hover. So long as this field is created in a vacuum, no explosion between anti-matter and matter will occur. Paul on December 02, 2011: If, when antimatter touches matter results in an explosion, then how are we able to capture or create anti-matter with tools that are made with matter. Leonard Kelley (author) on May 09, 2011: Jay Estux, if you look at the sub-a Anti-matter and matter should be the same thing except the charge they have. Meaning, anti-electrons are the same as elections, except positively charged where electrons are negatively charged. Anti-protons are protons with negative charge instead of a proton's positive charge. If a particle collides with its anti-particle, it turns back into energy (photons). So, if anti-matter is the same as matter, we think they were created in equal number during the big-bang, because why not? But if that's true, where is anti-matter in the universe?Â It wouldn't explain the matter-antimatter asymmetry. It doesn't even address gravity at all. It is entirely complete without adding gravity, and that is just not complete. Request PDF | Symmetry between matter and anti-matter | Variations of potential energy per nucleon (M/A = 1.00 +/- 0.01 amu/nucleon) with nuclear charge density (0â‰¤Z/Aâ‰¤1 charge/nucleon) [1] indicate | Find, read and cite all the research you need on ResearchGate.Â 1 [3] shows matter and antimatter as reflections of one another across a symmetry plane at Z/A = 0. However, matter and anti-matter are both on the right of Z/A = 0 in Fig 1, e.g., the beta-decay of mirror nuclides in Fig. 2 [4]. Decay must overcome a 1.022 MeV barrier to Î²+ emission, as shown in Fig. 3 [5] for ^13N arrow ^13C + Î²+ + 1.198 MeV; Q_total = M(^13N) - M(^13C) = 2.220 MeV = 1.022 MeV + 1.198 MeV. The matter-antimatter asymmetry problem. The Big Bang should have created equal amounts of matter and antimatter. So why is there far more matter than antimatter in the universe? The Big Bang should have created equal amounts of matter and antimatter in the early universe. But today, everything we see from the smallest life forms on Earth to the largest stellar objects is made almost entirely of matter. Comparatively, there is not much antimatter to be found. Something must have happened to tip the balance. One of the greatest challenges in physics is to figure out what happened to the antimat...