

Figure 2. The ground states of the 2,850 nuclides define a “cradle”

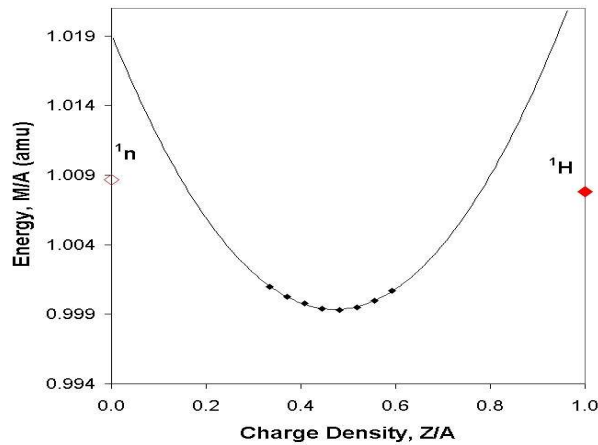


Figure 3. An illustrative cross section through Fig. 2 at $A = 27$

by ^{27}F , ^{27}Ne , ^{27}Na , ^{27}Mg , ^{27}Al , ^{27}Si , ^{27}P , and ^{27}S yields much higher values of M/A for an assemblage of 27 neutrons at $Z/A = 0$ or for an assemblage of 27 protons at $Z/A = 1.0$, respectively. Cross-sectional cuts through Fig. 2 at any other value of $A > 1$ reveal an empirical mass parabola with values of $M/A > M(^1\text{n})$ at $Z/A = 0$ and values of $M/A > M(^1\text{H})$ at $Z/A = 1.0$.

Typically the excess energy associated with these assemblages of pure neutrons or protons is ~ 10 MeV per nucleon, plus the energy from Coulomb repulsion at $Z/A = 1$. Unlike the imagined dripping of neutrons near $Z/A \approx 0$ [ref. 19, page 381], it thus appears that neutron emission may release significant amounts of energy from a neutron star.

Coulomb repulsion contributes to the high value of M/A for the assemblage of 27 protons on the right side of Fig. 3, but not to a nucleus of 27 neutrons on the left. In fact, Coulomb repulsion accounts for the difference between values of M/A at the intercepts where $Z/A = 1.0$ and $Z/A = 0$, and this difference increases linearly with $A^{2/3}$ over the mass range, $A = 1 - 41$ [20]. The slope of this line is indistinguishable from that defined by the familiar β -decay of mirror nuclei close to the line of β -stability, e.g., $(^1\text{H}, ^1\text{n})$, $(^3\text{He}, ^3\text{H})$, $(^5\text{Li}, ^5\text{He})$, $(^7\text{Be}, ^7\text{Li})$, . . . , $(^{41}\text{Sc}, ^{41}\text{Ca})$ [20].

Thus, the values obtained for M/A from empirical mass parabolas at $Z/A = 1.0$ and Z/A

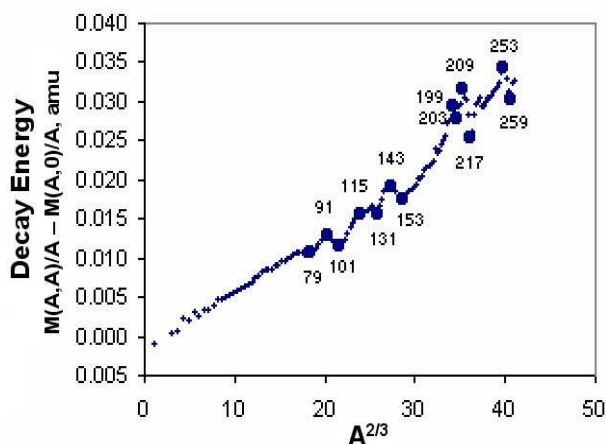


Figure 4. Decay energies of extreme nuclides, where the Coulomb energy drives ($Z/A = 1$) \rightarrow ($Z/A = 0$), for all odd values of A from $A = 1$ to 263

$= 0$ yield the same nuclear radius and the same coefficient for the Coulomb energy term as the mirror nuclei close to the line of β -stability for $A = 1 - 41$ [20].

The decay energy, and hence the Coulomb energy of heavier nuclides, $A > 41$, can also be obtained from differences indicated by mass parabolas for values of M/A at $Z/A = 1.0$ and $Z/A = 0$. Fig. 4 shows the results for all odd values of A , from $A = 1$ to $A = 263$.

The decay energies of light nuclides in Fig. 4 vary linearly with $A^{2/3}$, but fine structure starts to appear near $A \approx 80$. Peak energies, at $A = 91, 115, 143, 199, 209$ and 253 , likely arise from high Coulomb energy at $Z/A = 1$ because of clustering of nucleons into tightly packed structures. Likewise, valleys at $A = 79, 101, 131, 153, 203, 217$ and 259 likely mean low Coulomb energy at $Z/A = 1$ because of more loosely packed nucleons.

There is no Coulomb energy associated with the other extreme form of nuclides, at $Z/A = 0$. These are the intercepts of mass parabolas at each value of A with the front plane in Fig. 2. However, these neutron-rich nuclides at $Z/A = 0$ also reveal fine structure, as shown in Fig. 5 for all odd values of A from $A = 1$ to 263 .

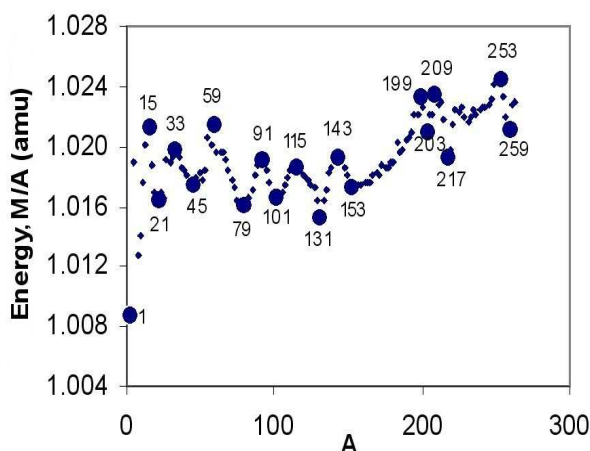


Figure 5. Values of M/A at $Z/A = 0$ for all odd- A parabolas, $A = 1-263$

The data in Fig. 5 includes, for example, $M/A = 1.019$ at $A = 27$, as shown earlier in Fig.

3. Note that all values of M/A for $A > 1$ are higher than that of the free neutron at $A = 1$. This was first recognized as an indication of repulsive interactions between neutrons [17]. Neutron emission from these nuclides would typically generate about 10 MeV per nucleon, as shown by the example in Fig. 3 at $A = 27$.

The rhythmic distribution with A in values of M/A at $Z/A = 0$ was not understood in 2000. However, the peaks and valleys in Fig. 5 occur at the same mass numbers as those in Fig. 4 for $A \geq 79$. Nuclear clustering into tightly packed structures produces peaks at $A = 91, 115, 143, 199, 209$ and 253 in Fig. 4 from enhanced Coulomb repulsion. Nuclear clustering into tightly packed structures produce peaks at these same mass numbers in Fig. 5 from enhanced repulsion between neutrons. Loosely packed nucleons produce valleys at $A = 79, 101, 131, 153, 203, 217$ and 259 in Fig. 4 from reduced Coulomb repulsion between loosely packed protons and in Fig. 5 from reduced repulsion between loosely packed neutrons.

The rhythmic scatter of data in Fig. 5 suggests that nuclear clustering also occurs below $A = 79$. However, the positive charge on light nuclei apparently maintains a spherical shape. Thus, the Coulomb energy is proportional to $A^{2/3}$ at $A < 79$ in Fig. 4, as well as in ordinary mirror nuclides [20].

4. Theoretical and experimental studies needed

The structure of the solar core likely involves a central neutron star surrounded by iron-rich material. In order to see if neutron emission from the central neutron star might trigger a series of reactions that generate solar luminosity, neutrinos, and an outpouring of H^+ ions from the solar surface [14], a better theoretical understanding is needed of:

- (a) repulsive interactions between neutrons
- (b) clustering of nucleons, and
- (c) neutron emission by penetration of a gravitational barrier.

Likewise, the proposed structure of the solar core can be tested by experimental measurements to look for evidence of:

- (d) low energy ($E < 0.782$ MeV), anti-neutrinos coming from neutron decay near the solar core
- (e) another source for the neutral neutrino current detected by SNO experiment [21], and
- (f) a dense object (about 10 km) at the solar core.

The empirical basis for concluding the likely involvement of processes (a) – (c) in the operation of the Sun was presented above. However, a better theoretical basis for these processes is needed.

The presence of process (d) could be detected by measuring inverse β -decay induced by low energy anti-neutrinos coming from the Sun. For example, the $^{35}\text{Cl} \rightarrow ^{35}\text{S}$ reaction might produce measurable levels of 87-day ^{35}S in the Homestake Mine or in underground deposits of salt (NaCl).

Regarding item (e), the SNO experiment [21] on solar neutrinos shows that the charge current comes from the direction of the Sun, but new measurements are needed to determine the source of the much larger neutral current.

A recent paper [15] suggests that the 22-year cycle of solar magnetic storms may arise from the neutron star at the solar core and/or from the iron-rich super-conducting material that surrounds it. Measurements of gravity anomalies and of the Sun's quadrupole moment might also provide information on (f), a dense object at the solar core.

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