Nuclear Stability

Chemistry Honors

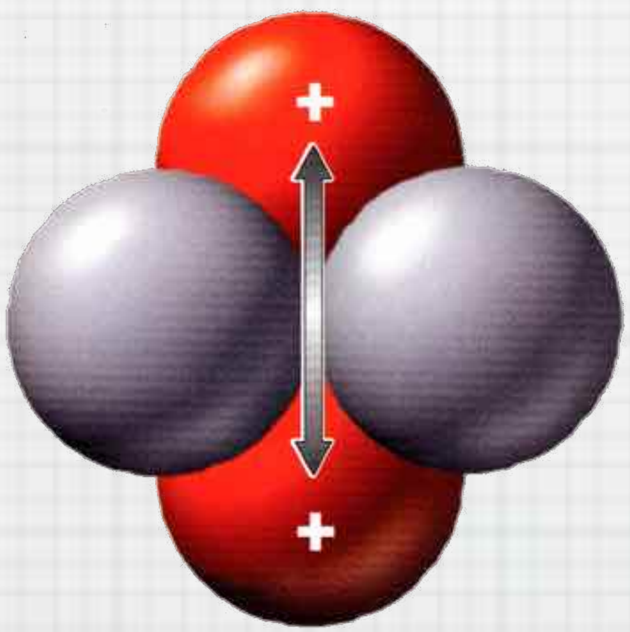
Nuclear Stability

Or: Why do we need neutrons?

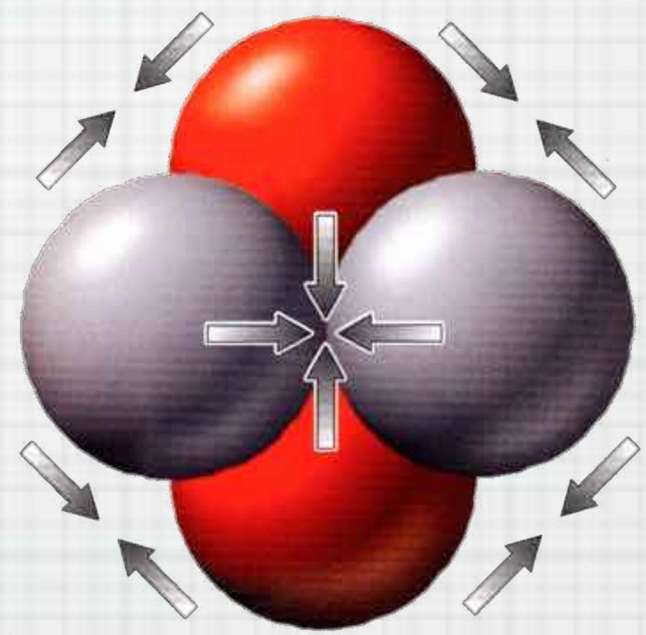
Protons repel each other (all charges), would blow nucleus apart from *electrostatic* repulsion

All nucleons (protons & neutrons) attracted by *strong nuclear force* (SNF)

- Neutrons act a "glue"—hold nucleus together

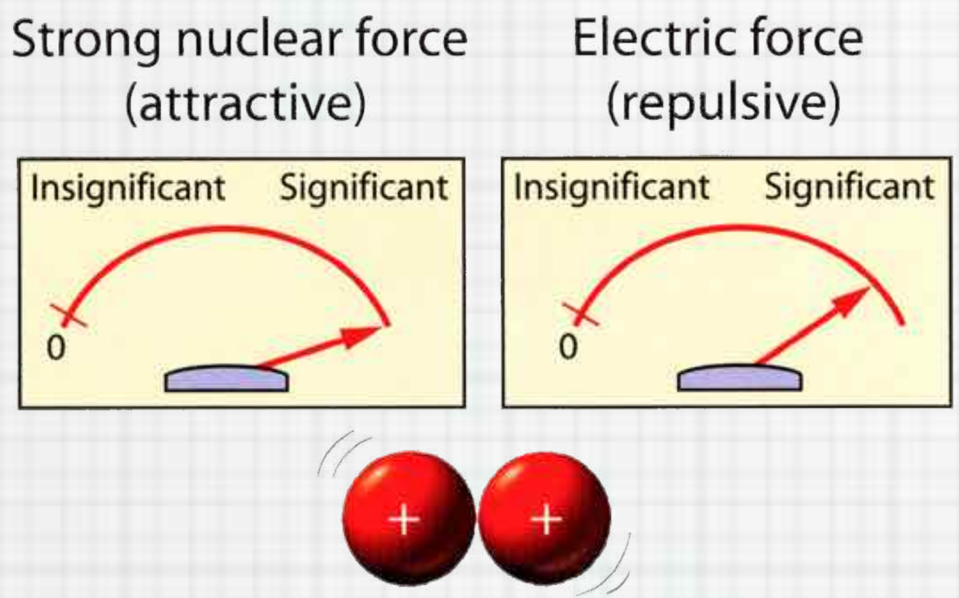


Only protons repel one another by the electric force.

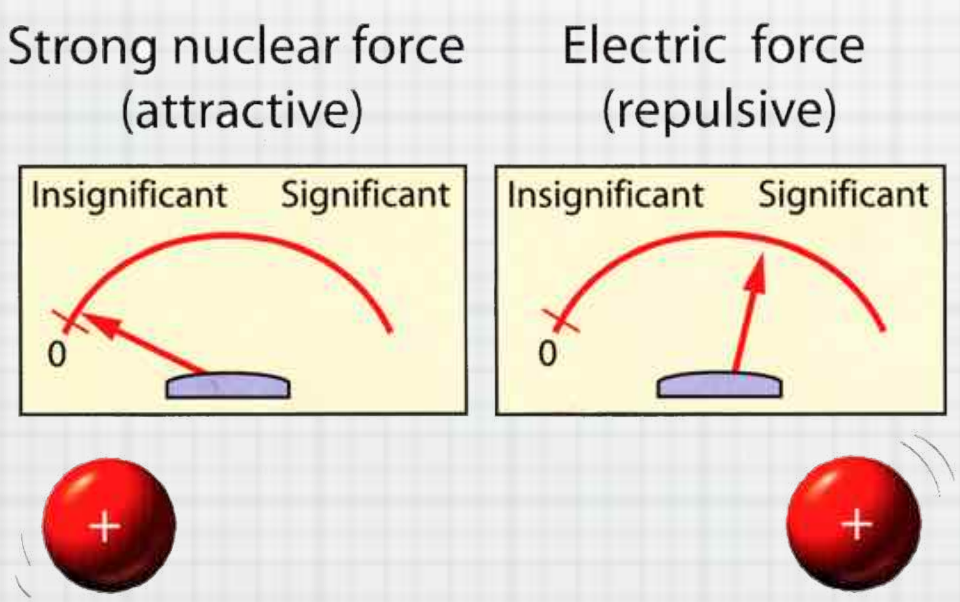


All nucleons, both protons and neutrons, attract one another by the strong nuclear force.

Strong nuclear force works only on distances within nucleus:



(a) Protons close: SNF more significant (larger) than electrostatic repulsion



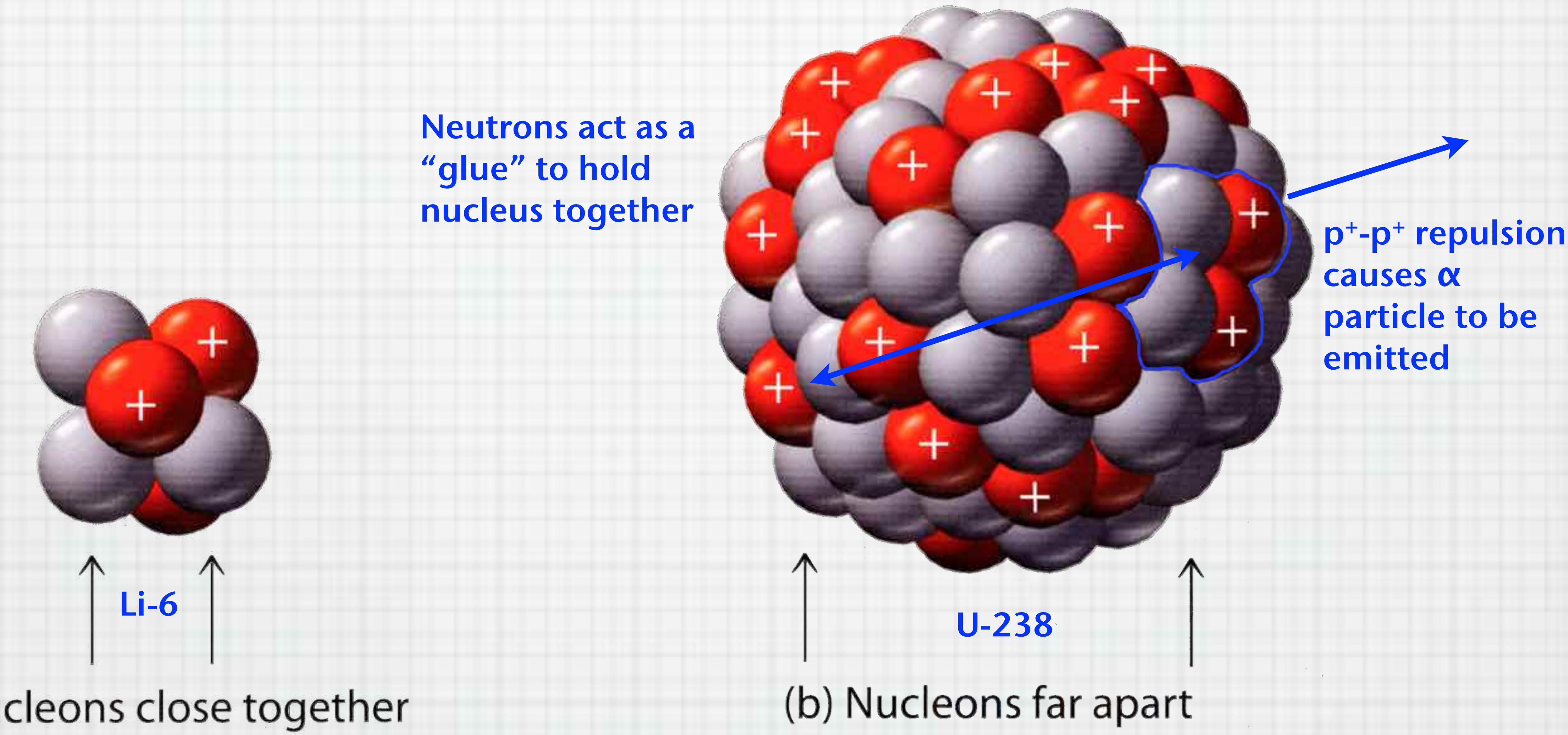
(b) Protons farther: Both forces weaker but electrostatic repulsion more significant than SNF

Strong Nuclear Force Extremely strong, but only effective at very short distances.

Electrostatic repulsion medium-high strength, effective over larger distances

Unstable Nucleus

- Small nucleus easier to stabilize than large nucleus (Li-6)
- As number of protons (atomic #) increases, need more neutrons to stabilize nucleus (U-238)



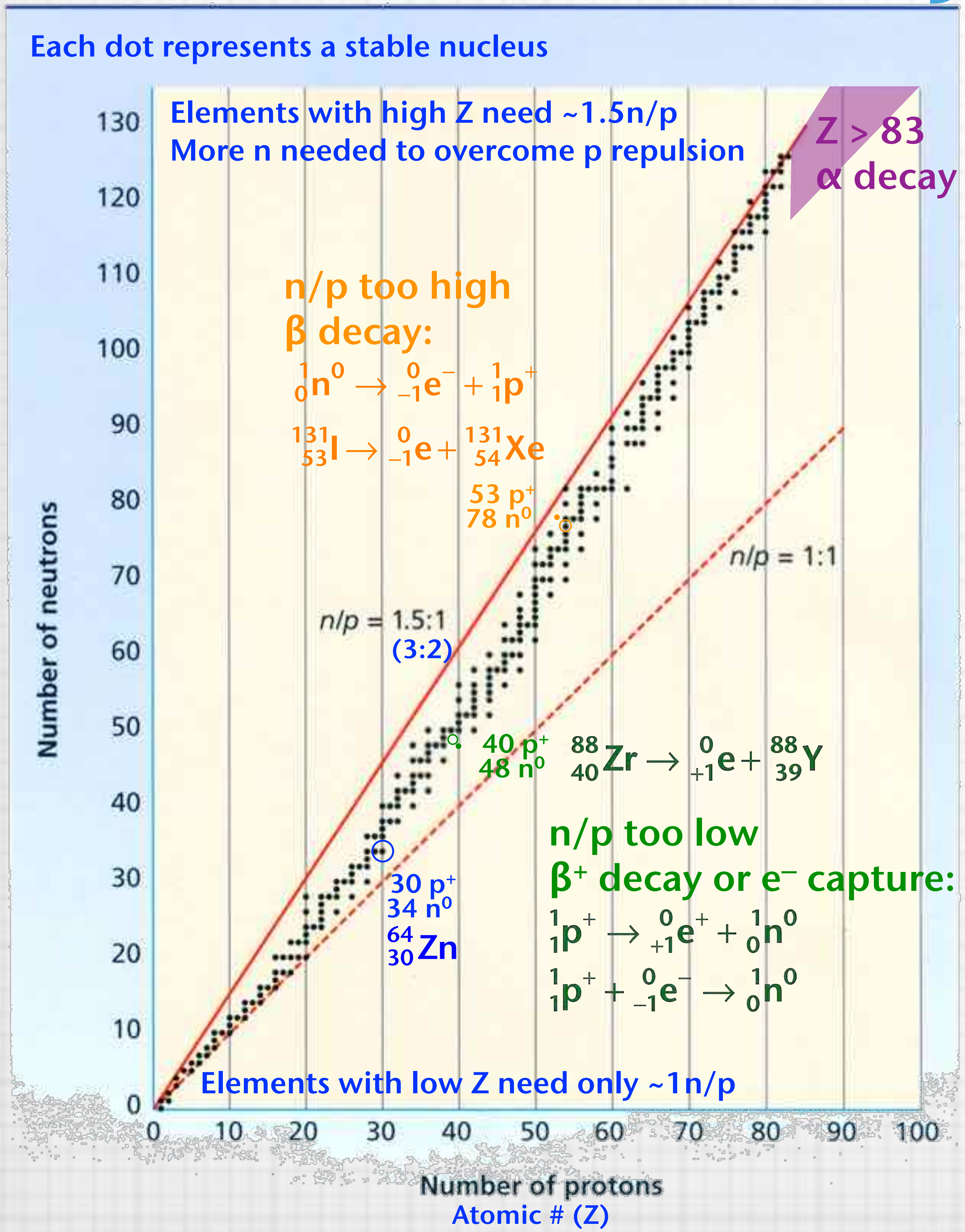
SNF large enough to overcome electrostatic repulsion and hold nucleus together

n^0 / p^+ ratio 1:1 sufficient to overcome repulsion

Electrical repulsion larger than SNF for protons far apart

n^0 / p^+ ratio 1.5: 1 (3:2) needed to overcome repulsion

Nuclear Decay Mechanisms



Band of Stability shows ratio of neutrons to protons (n/p) for stable isotopes

All other nuclei are unstable

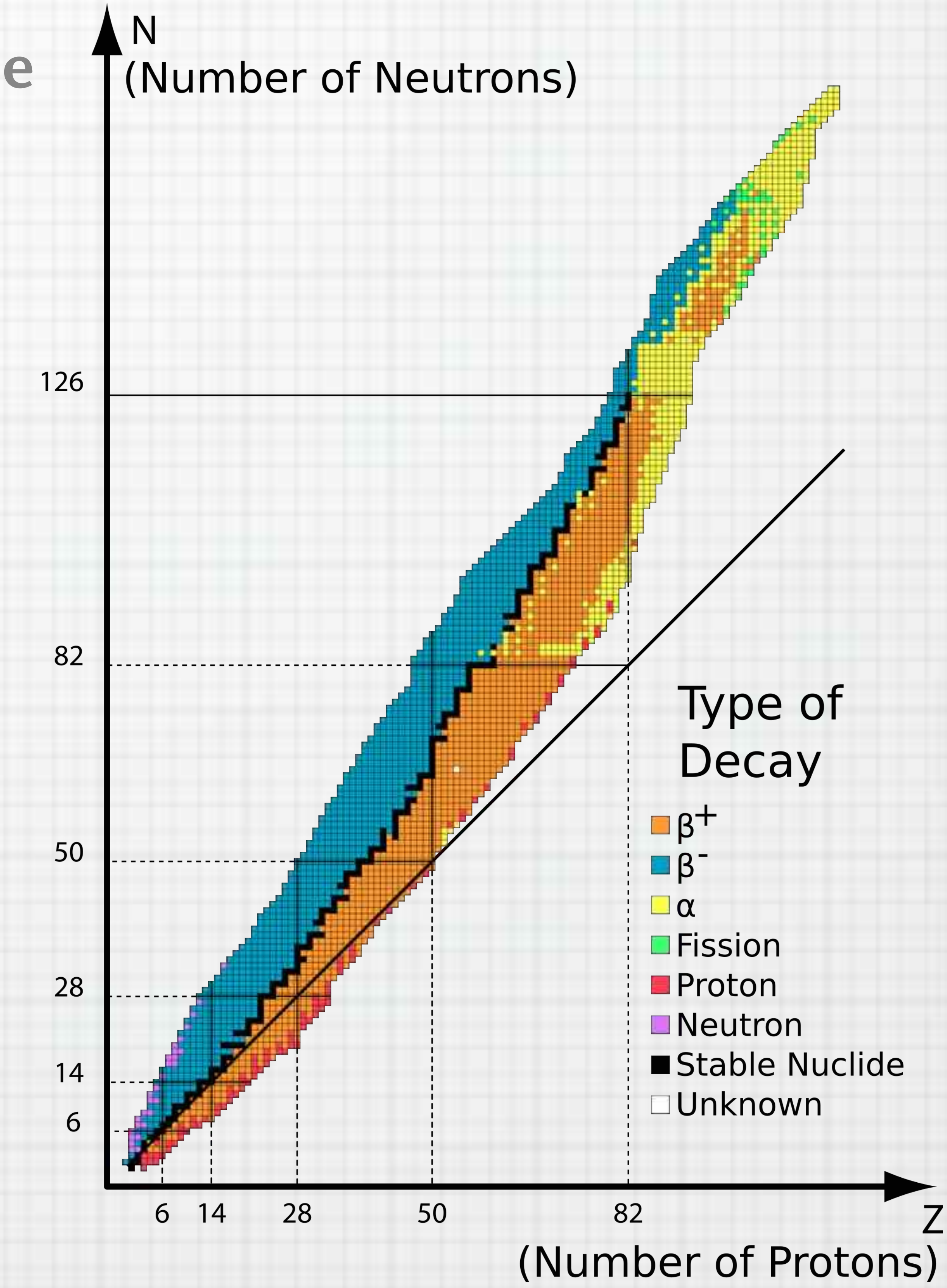
a) For elements with Z>83 (Bi), no stable isotopes: α decay
   - Too many n^0+p^+ total
   - Emit $2p^+ + 2n^0$: α particle

b) For n^0/p^+ too high: β^- decay
   - Need to reduce n^0, increase p^+
   - n^0 emits β^-, becomes p^+

c) For n^0/p^+ too low: β^+ (positron) decay or e^- capture
   - Need to reduce p^+, increase n^0
   - p^+ becomes n^0 by emitting β^+ or capturing e^-

Alternate Version

Colors indicate known unstable nuclei and their decay types



Summary

- Neutrons needed to stabilize protons, use strong nuclear force (SNF) to overcome electrostatic repulsion
- Larger nuclei harder to stabilize since protons' electrostatic repulsion works over longer distances than SNF
- Band of Stability shows "map" of stable and unstable nuclei
  - Nuclei unstable when nucleus has too many protons, too many neutrons, or too many of both
  - Decay type depends on location on chart, use n^0/p^+ ratio to determine decay type