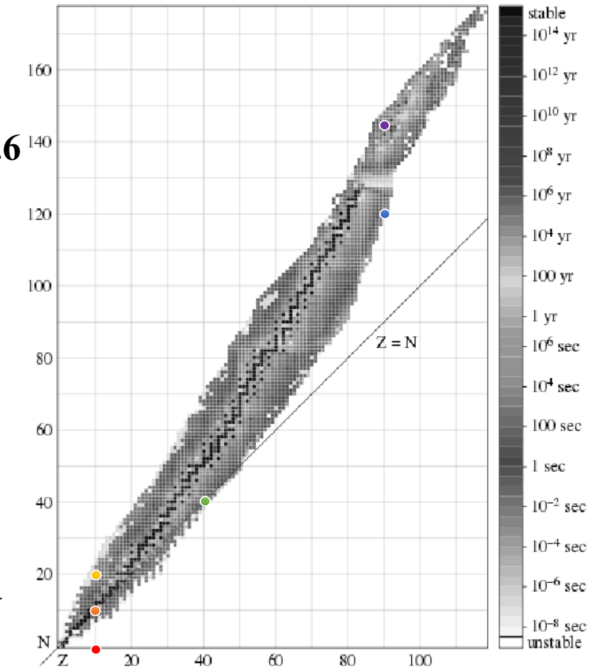
Answers to Exercise 2.6
Stability of Isotopes



Band of Stability Graph (on data sheets of all CHEM 1000 tests)

The graph at the right shows the band of stability.
Stable isotopes are in black. Isotopes that exist but are not stable are shown in varying shades of gray with the shades of gray corresponding to different half-lives.
The original version of the graph used a rainbow colour scale (see next page).

http://commons.wikimedia.org/wiki/File:Isotopes_and_half-life_eo.svg

1.

(a) ^{1}H only contains one proton, so there are no electrostatic repulsions between protons within the same nucleus.

All other nuclei are held together by the strong force (attractive force between nucleons that decays very quickly as nucleon-nucleon distance increases), and neutrons experience strong force attractions to each other and to protons (without introducing electrostatic repulsions).

(b) The attractive strong force between nucleons decays much more quickly with distance than the repulsive electrostatic force between protons. Therefore, as nuclei have more protons (beyond iron), the repulsive electrostatic forces begin to dominate and the nuclei become less stable.

(c) When a neutron decomposes into a proton and an electron, beta decay results.
So, beta decay occurs when N decreases by 1 and Z increases by 1. N/Z must therefore be reduced.

(d) When a proton is converted into a neutron and a positron, positron emission results.

So, positron emission occurs when N increases by 1 and Z decreases by 1. N/Z must therefore be increased.

Electron capture has the exact same effect on N/Z because the captured electron combines with a proton to give a neutron. You will never be able to predict whether a nuclide will undergo positron emission vs. electron capture – but you will be able to predict that one of the two should occur.

(e) Alpha decay is primarily observed for large isotopes (as it also decreases their total mass) for which N > Z. Alpha decay reduces N by 2 *and* reduces Z by 2. Since N is larger than Z, 2 is a smaller fraction of N. Since Z is smaller than N, 2 is a larger fraction of Z. Thus, the denominator of N/Z is decreased by a larger proportion than the numerator and N/Z becomes larger.

If you find this logic hard to follow, try a concrete example. ^{210}Th undergoes alpha decay. It has N = 120 and Z = 90 therefore N/Z = 120/90 = 1.33 The product of the alpha decay is ^{206}Ra. It has N= 118 and Z = 88 therefore N/Z = 118/88 = 1.34. N/Z increases because losing 2 of 90 protons is more significant than losing 2 of 120 neutrons.

2.

(a)	^{10}Ne	Z = 10	N = 0	non-existent	• on graph
(b)	^{20}Ne	Z = 10	N = 10	stable	• on graph
(c)	^{30}Ne	Z = 10	N = 20	unstable	• on graph
(d)	^{80}Zr	Z = 40	N = 40	unstable	• on graph
(e)	^{210}Th	Z = 90	N = 120	unstable	• on graph
(f)	^{235}Th	Z = 90	N = 145	unstable	• on graph

3.

(c)	^{30}Ne	N/Z = 2 (above band of stability)	β^- decay
(d)	^{80}Zr	N/Z = 1 (below band of stability) and Z < 52	positron emission *or* electron capture *The smallest nuclides to undergo α decay are isotopes of Te (Z = 52) so you can eliminate that as an option for ^{80}Zr (Z = 40).* *^{80}Zr actually decays by positron emission but you have no way of knowing that it's not electron capture.*
(e)	^{210}Th	N/Z = 1.33 (below band of stability) and Z > 82	α decay *α decay is much more common than either positron emission or electron capture for large nuclides.*
(f)	^{235}Th	N/Z = 1.61 (above band of stability)	β^- decay