29-4 The Chart of the Nuclides

A nuclide is an atom that is characterized by what is in its nucleus. In other words, it is characterized by the number of protons it has, and by the number of neutrons it has. Figure 29.2 shows the chart of the nuclides, which plots, for stable and radioactive nuclides, the value of Z (the atomic number), on the vertical axis, and the value of N (the number of neutrons) on the horizontal axis.

If you look at a horizontal line through the chart, you will find nuclides that all have the same number of protons, but a different number of neutrons. These are all nuclides of the same element, and are known as isotopes (equal proton number, different neutron number).

On a vertical line through the chart, the nuclides all have the same number of neutrons, but a different number of protons. These nuclides are known as isotones (equal neutron number, different proton number).

It is interesting to think about how the various decay processes play a role in the chart of the nuclides. Only the nuclides shown in black are stable. The stable nuclides give the chart a line of stability that goes from the bottom left toward the upper right, curving down and away from the $Z = N$ line as you move toward higher N values. There are many more nuclides that are shown on the chart but which are not stable - these nuclides decay by means of a radioactive decay process.

In general, the dominant decay process for a particular nuclide is the process that produces a nucleus closer to the line of stability than where it started. In an alpha decay process, the resulting nuclide (usually referred to as the daughter nuclide), has a Z value that is 2 less than the parent nuclide, and the N value is also 2 less than that of the parent nuclide. This is because the alpha particle takes away two protons and two neutrons. On the chart of the nuclides, therefore, an alpha decay process moves the nucleus two spaces down and two spaces left. Thus, nuclides that decay via alpha decay are found mainly at the upper right of the chart. Because the line of stability curves down as the number of nucleons increases, as well as because, above a certain number of nucleons, there are no stable nuclides, a decay process that moves a nucleus down and to the left on the chart tends to bring that nucleus closer to the line of stability.

Beta-plus decay, on the other hand, increases the neutron number by one and decreases the proton number by one. In other words, a beta-plus decay moves a nucleus down and to the right on the chart. Nuclides that decay via beta-plus decay, therefore, are generally found above and to the left of the line of stability.

The beta-minus decay is, in many ways, the opposite of beta-plus. Beta-minus decay decreases the neutron number by one and increases the proton number by one, moving a nucleus up and to the left on the chart. Nuclides that decay via beta-plus decay, therefore, are generally found below and to the right of the line of stability.

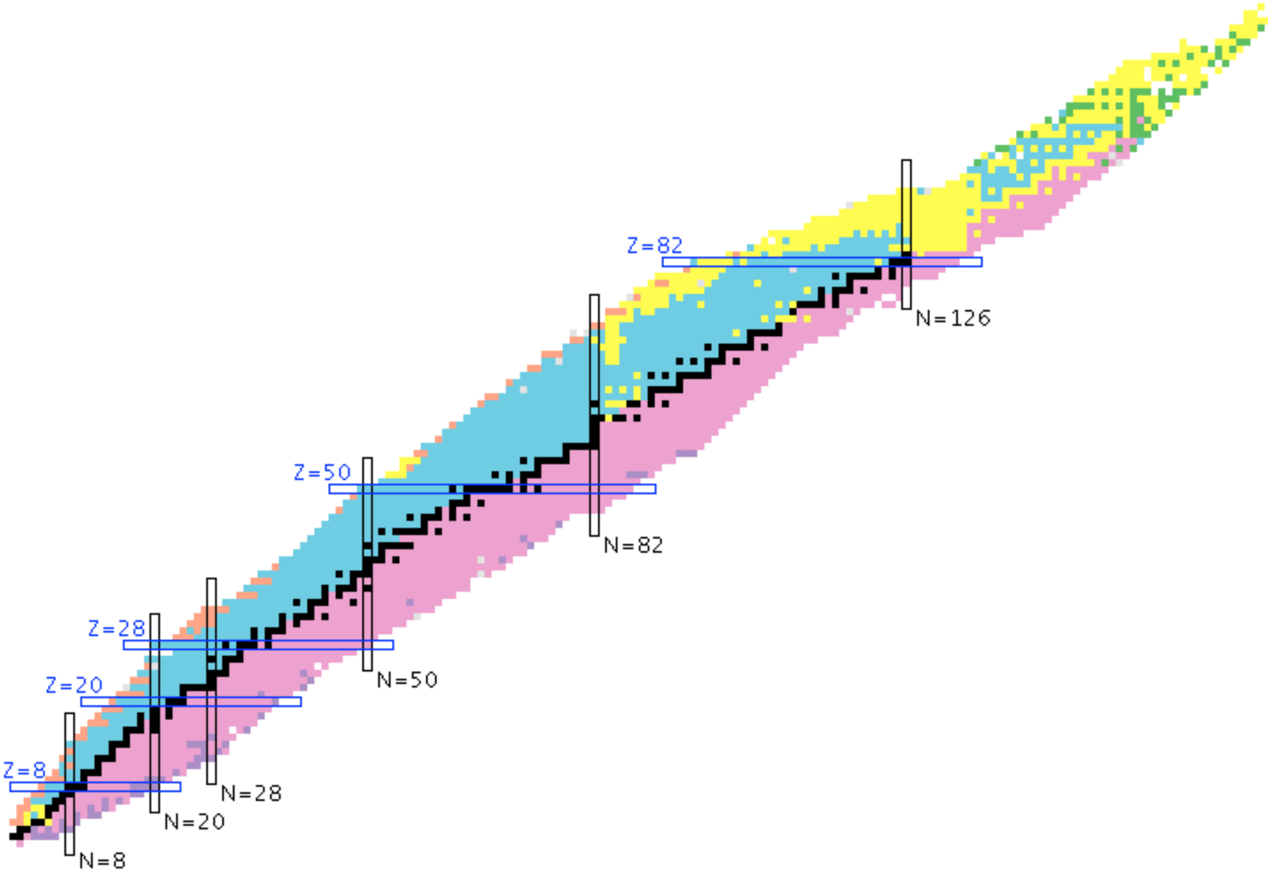

Figure 29.2: The chart of the nuclides, plotted with Z (the atomic number) on the vertical axis, and N (the number of neutrons) on the horizontal axis. Nuclides in black are stable - all other nuclides exhibit radioactive decay. The stable nuclides start out following the line Z = N (at bottom left), but then, as the number of nucleons increases, stable nuclides gradually increase the number of neutrons they have relative to their number of protons. Viewed in color, the chart is color-coded according to the nuclides primary decay mode. Above the line of stability, the chart is mainly light blue - those nuclides decay via beta-plus decay. Below the line of stability, the chart is mainly purple - those nuclides decay via beta-minus decay. At the top right of the chart, many of the nuclides are shown in yellow - those nuclides decay via the alpha decay process. In general, a radioactive decay will produce another nuclide that is closer to the line of stability than the original nuclide was. Also in general, the closer the nuclide is to the line of stability, the more stable it is, and the longer its half-life is. See Section 29-5 for an explanation of half-life. Chart of Nuclides from National Nuclear Data Center, using information extracted from the Chart of Nuclides database, http://www.nndc.bnl.gov/chart/

Related End-of-Chapter Exercises: 60 – 62.

Essential Question 29.4: Sodium-23, which has 11 protons and 12 neutrons, is stable. Sodium-22, however, is unstable. What type of radioactive decay process would you expect sodium-22 to undergo? What is the daughter nuclide that is produced in this decay?