Answer to Essential Question 29.7: To reduce the level to ¼ = ½ × ½ of its original value, two half-lives must have passed. Two half-lives for carbon-14 represents 11000 – 12000 years.

29-8 A Table of Isotopes

In doing calculations of mass defect, or nuclear decays and reactions, we need to know the atomic mass(es) of the atom or atoms involved. This information is shown in Table 29.3.

Z, Element	Isotope : Atomic mass
1, Hydrogen	${}^{1}_{1}\text{H}$: 1.00782503 u
	${}^{2}_{1}\text{H}$: 2.01410178 u
	${}^{3}_{1}\text{H}$: 3.01604928 u, (β^-)
2, Helium	${}^{4}_{2}\text{He}$: 4.00260325 u
3, Lithium	${}^{6}_{3}\text{Li}$: 6.01512279 u
	${}^{7}_{3}\text{Li}$: 7.01600455 u
4, Beryllium	${}^{9}_{4}\text{Be}$: 9.0121822 u
5, Boron	${}^{10}_{5}\text{B}$: 10.0129370 u
	${}^{11}_{5}\text{B}$: 11.0093054 u
6, Carbon	${}^{12}_{6}\text{C}$: 12.00000000 u
	${}^{13}_{6}\text{C}$: 13.00335484 u
	${}^{14}_{6}\text{C}$: 14.00324199 u, (β^-)
7, Nitrogen	${}^{14}_{7}\text{N}$: 14.00307400 u
8, Oxygen	${}^{15}_{8}\text{O}$: 15.0030656 u, (β^+)
	${}^{16}_{8}\text{O}$: 15.99491462 u
	${}^{18}_{8}\text{O}$: 17.9991610 u
9, Fluorine	${}^{18}_{9}\text{F}$: 18.0009380 u, (β^+)
	${}^{19}_{9}\text{F}$: 18.99840322 u
10, Neon	${}^{20}_{10}\text{Ne}$: 19.99244018 u
11, Sodium	${}^{22}_{11}\text{Na}$: 21.9944364 u, (β^+)
	${}^{23}_{11}\text{Na}$: 22.98976928 u
12, Magnesium	${}^{24}_{12}\text{Mg}$: 23.98504170 u
13, Aluminum	${}^{27}_{13}\text{Al}$: 26.98153863 u
14, Silicon	${}^{28}_{14}\text{Si}$: 27. 97692653 u
15, Phosphorus	${}^{31}_{15}\text{P}$: 30.97376163 u
16, Sulfur	${}^{32}_{16}\text{S}$: 31.97207100 u
17, Chlorine	${}^{35}_{17}\text{Cl}$: 34.96885268 u
	${}^{37}_{17}\text{Cl}$: 36.96590259 u
18, Argon	${}^{40}_{18}\text{Ar}$: 39.96238312 u
19, Potassium	${}^{39}_{19}\text{K}$: 38.96370668 u
	${}^{41}_{19}\text{K}$: 40.96182576 u
20, Calcium	${}^{40}_{20}\text{Ca}$: 39.96259098 u
21, Scandium	${}^{45}_{21}\text{Sc}$: 44.9559119 u
	${}^{46}_{21}\text{Sc}$: 45.9551719 u, (β^-)
22, Titanium	${}^{46}_{22}\text{Ti}$: 45.9526316 u
	${}^{48}_{22}\text{Ti}$: 47.9479463 u
23, Vanadium	${}^{51}_{23}\text{V}$: 50.9439595 u
24, Chromium	${}^{52}_{24}\text{Cr}$: 51.9405075 u
	${}^{53}_{24}\text{Cr}$: 52.9406494 u
25, Manganese	${}^{55}_{25}\text{Mn}$: 54.9380451 u
26, Iron	${}^{56}_{26}\text{Fe}$: 55.9349375 u
	${}^{58}_{26}\text{Fe}$: 57.9332756 u
27, Cobalt	${}^{59}_{27}\text{Co}$: 58.9331950 u
28, Nickel	${}^{58}_{28}\text{Ni}$: 57.9353429 u
	${}^{62}_{28}\text{Ni}$: 61.9283451 u
29, Copper	${}^{63}_{29}\text{Cu}$: 62.9295975 u
	${}^{65}_{29}\text{Cu}$: 64.9277895 u
30, Zinc	${}^{64}_{30}\text{Zn}$: 63.9291422 u

Table 29.3: A table of selected isotopes and their atomic masses, taken from data made available by the Lawrence Berkeley Laboratory. Note that the mass, in atomic mass units, of an electron or a positron is 0.00054858 u. The neutron mass is 1.008664 u, and the proton mass is 1.007276 u.

Z, Element	Isotope : Atomic mass
31, Gallium	${}^{69}_{31}\text{Ga}$: 68.9255736 u ${}^{71}_{31}\text{Ga}$: 70.9247013 u
32, Germanium	${}^{74}_{32}\text{Ge}$: 73.9211778 u ${}^{76}_{32}\text{Ge}$: 75.9214026 u, (β^-)
33, Arsenic	${}^{75}_{33}\text{As}$: 74.9215965 u
34, Selenium	${}^{80}_{34}\text{Se}$: 79.9165213 u
35, Bromine	${}^{79}_{35}\text{Br}$: 78.9183371 u ${}^{81}_{35}\text{Br}$: 80.9162906 u
36, Krypton	${}^{84}_{36}\text{Kr}$: 83.911507 u ${}^{85}_{36}\text{Kr}$: 84.9125273 u, (β^-)
37, Rubidium	${}^{85}_{37}\text{Rb}$: 84.91178974 u
38, Strontium	${}^{88}_{38}\text{Sr}$: 87.9056121 u
39, Yttrium	${}^{89}_{39}\text{Y}$: 88.905848 u
40, Zirconium	${}^{90}_{40}\text{Zr}$: 89.9047044 u ${}^{92}_{40}\text{Zr}$: 91.9050408 u
41, Niobium	${}^{93}_{41}\text{Nb}$: 92.906378 u
42, Molybdenum	${}^{98}_{42}\text{Mo}$: 97.9054082 u
43, Technetium	${}^{99}_{43}\text{Tc}$: 98.9062547 u, (β^-)
44, Ruthenium	${}^{102}_{44}\text{Ru}$: 101.9043493 u
45, Rhodium	${}^{103}_{45}\text{Rh}$: 102.905504 u
46, Palladium	${}^{106}_{46}\text{Pd}$: 105.903486 u
47, Silver	${}^{107}_{47}\text{Ag}$: 106.905097 u ${}^{109}_{47}\text{Ag}$: 108.904752 u
48, Cadmium	${}^{112}_{48}\text{Cd}$: 111.902758 u
49, Indium	${}^{115}_{49}\text{In}$: 114.903878 u, (β^-)

Z, Element	Isotope : Atomic mass
50, Tin	${}^{120}_{50}\text{Sn}$: 119.902195 u
51, Antimony	${}^{121}_{51}\text{Sb}$: 120.9038157 u
52, Tellurium	${}^{130}_{52}\text{Te}$ * : 129.9062244 u, (β^-)
53, Iodine	${}^{127}_{53}\text{I}$: 126.904473 u ${}^{131}_{53}\text{I}$: 130.9061246 u, (β^-)
54, Xenon	${}^{132}_{54}\text{Xe}$: 131.9041535 u
55, Cesium	${}^{133}_{55}\text{Cs}$: 132.90545193 u
56, Barium	${}^{138}_{56}\text{Ba}$: 137.9052472 u ${}^{141}_{56}\text{Ba}$: 140.914411 u, (β^-)
82, Lead	${}^{208}_{82}\text{Pb}$: 207.9766521 u
83, Bismuth	${}^{209}_{83}\text{Bi}$: 208.9803987 u, (α)
84, Polonium	${}^{210}_{84}\text{Po}$: 209.9828737 u, (α)
85, Astatine	${}^{210}_{85}\text{At}$: 209.987148 u, (β^+)
86, Radon	${}^{222}_{86}\text{Rn}$: 222.0175777 u, (α)
87, Francium	${}^{223}_{87}\text{Fr}$: 223.019736 u, (β^-)
88, Radium	${}^{226}_{88}\text{Ra}$: 226.0254098 u, (α)
89, Actinium	${}^{227}_{89}\text{Ac}$: 227.027752 u, (β^-)
90, Thorium	${}^{232}_{90}\text{Th}$: 232.0380553 u, (α)
91, Protactinium	${}^{231}_{91}\text{Pa}$: 231.0358840 u, (α)
92, Uranium	${}^{235}_{92}\text{U}$: 235.0439299 u, (α) ${}^{238}_{92}\text{U}$: 238.0507882 u, (α)
93, Neptunium	${}^{237}_{93}\text{Np}$: 237.0481734 u, (α)
94, Plutonium	${}^{238}_{94}\text{Pu}$: 238.0495599 u, (α) ${}^{239}_{94}\text{Pu}$: 239.0521634 u, (α)
95, Americium	${}^{241}_{95}\text{Am}$: 241.0568291 u, (α)

Table 29.3, continued: Elements 57 – 81 are emitted to make room for the high-Z elements, which are rather radioactive. Radioactive isotopes are indicated with the decay process in brackets after the mass. *Tellurium-130 actually undergoes double-beta decay, in which two neutrons become protons by emitting electrons.

Related End-of-Chapter Exercises: 19 – 22, 56, 57.

Essential Question 29.8: Table 29.3 shows that krypton-85 experiences beta-minus decay. What does krypton-85 decay into?