## Selected Isotope Masses                                    Homework #175

| Atomic Number Z | Element | Symbol | Mass Number A | Atomic Mass | Atomic Number Z | Element | Symbol | Mass Number A | Atomic Mass |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Hydrogen | H | 1 | 1.007825 | 23 | Vanadium | V | 51 | 50.943962 |
|  | Deuterium | D | 2 | 2.014102 | 24 | Chromium | Cr | 52 | 51.940511 |
|  | Tritium | T | 3 | 3.016049 | 25 | Manganese | Mn | 55 | 54.938048 |
| 2 | Helium | He | 3 | 3.016029 | 26 | Iron | Fe | 56 | 55.934940 |
|  |  |  | 4 | 4.002602 | 27 | Cobalt | Co | 59 | 58.933198 |
| 3 | Lithium | Li | 6 | 6.015121 |  |  |  | 60 | 59.933820 |
|  |  |  | 7 | 7.016928 | 28 | Nickel | Ni | 58 | 57.935346 |
| 4 | Beryllium | Be | 7 | 7.016928 |  |  |  | 60 | 59.930789 |
|  |  |  | 9 | 9.012182 | 29 | Copper | Cu | 63 | 62.929599 |
| 5 | Boron | B | 10 | 10.012936 |  |  |  | 65 | 64.927791 |
|  |  |  | 11 | 11.009305 | 30 | Zinc | Zn | 64 | 63.929144 |
| 6 | Carbon | C | 11 | 11.011433 |  |  |  | 66 | 65.926035 |
|  |  |  | 12 | 12.000000 | 31 | Gallium | Ga | 69 | 68.925580 |
|  |  |  | 13 | 13.003355 | 32 | Germanium | Ge | 72 | 71.922079 |
|  |  |  | 14 | 14.003242 |  |  |  | 74 | 73.921177 |
| 7 | Nitrogen | N | 13 | 13.005738 | 33 | Arsenic | As | 75 | 74.921594 |
|  |  |  | 14 | 14.003074 | 34 | Selenium | Se | 80 | 79.916519 |
|  |  |  | 15 | 15.000108 | 35 | Bromine | Br | 79 | 78.918336 |
| 8 | Oxygen | O | 15 | 15.003065 | 36 | Krypton | Kr | 84 | 83.911508 |
|  |  |  | 16 | 15.994915 | 37 | Rubidium | Rb | 85 | 84.911793 |
|  |  |  | 18 | 17.999160 | 38 | Strontium | Sr | 86 | 85.909266 |
| 9 | Fluorine | F | 19 | 18.998404 |  |  |  | 88 | 87.905618 |
| 10 | Neon | Ne | 20 | 19.992435 |  |  |  | 90 | 89.907737 |
|  |  |  | 22 | 21.991383 | 39 | Yttrium | Y | 89 | 88.905847 |
| 11 | Sodium | Na | 22 | 21.994434 | 40 | Zirconium | Zr | 90 | 89.904702 |
|  |  |  | 23 | 22.989767 | 41 | Niobium | Nb | 93 | 92.906376 |
|  |  |  | 24 | 23.990961 | 42 | Molybdenum | Mo | 98 | 97.905407 |
| 12 | Magnesium | Mg | 24 | 23.985042 | 43 | Technetium | Tc | 98 | 97.907215 |
| 13 | Aluminum | Al | 27 | 26.981538 | 44 | Ruthenium | Ru | 102 | 101.904348 |
| 14 | Silicon | Si | 28 | 27.976927 | 45 | Rhodium | Rh | 103 | 102.905502 |
|  |  |  | 31 | 30.975362 | 46 | Palladium | Pd | 106 | 105.903481 |
| 15 | Phosphorus | P | 31 | 30.973762 | 47 | Silver | Ag | 107 | 106.905091 |
|  |  |  | 32 | 31.973908 |  |  |  | 109 | 108.904754 |
| 16 | Sulfur | S | 32 | 31.972071 | 48 | Cadmium | Cd | 114 | 113.903359 |
|  |  |  | 35 | 34.969033 | 49 | Indium | In | 115 | 114.903876 |
| 17 | Chlorine | Cl | 35 | 34.968853 | 50 | Tin | Sn | 120 | 119.902197 |
|  |  |  | 37 | 36.965903 | 51 | Antimony | Sb | 121 | 120.903820 |
| 18 | Argon | Ar | 40 | 39.962384 | 52 | Tellurium | Te | 130 | 129.906228 |
| 19 | Potassium | K | 39 | 38.963708 | 53 | Iodine | I | 127 | 126.904474 |
|  |  |  | 40 | 39.964000 |  |  |  | 131 | 130.906111 |
| 20 | Calcium | Ca | 40 | 39.962591 |  |  |  |  |  |
| 21 | Scandium | Sc | 45 | 44.955911 |  |  |  |  |  |
| 22 | Titanium | Ti | 48 | 47.947947 |  |  |  |  |  |

# Selected Isotope Masses

| Atomic Number Z | Element | Symbol | Mass Number A | Atomic Mass | Atomic Number Z | Element | Symbol | Mass Number A | Atomic Mass |
|---|---|---|---|---|---|---|---|---|---|
| 54 | Xenon | Xe | 132 | 131.904141 | 83 | Bismuth | Bi | 209 | 208.980374 |
|  |  |  | 136 | 135.90721 |  |  |  | 211 | 210.987254 |
| 55 | Cesium | Cs | 133 | 132.905436 | 84 | Polonium | Po | 210 | 209.982848 |
| 56 | Barium | Ba | 137 | 136.905816 |  |  |  | 214 | 213.995177 |
|  |  |  | 138 | 137.905236 | 85 | Astatine | At | 218 | 218.00868 |
| 57 | Lanthanum | La | 139 | 138.906346 | 86 | Radon | Rn | 222 | 222.017571 |
| 58 | Cerium | Ce | 140 | 139.905434 | 87 | Francium | Fr | 223 | 223.019733 |
| 59 | Praseodymium | Pr | 141 | 140.907647 | 88 | Radium | Ra | 226 | 226.025402 |
| 60 | Neodymium | Nd | 142 | 141.907718 | 89 | Actinium | Ac | 227 | 227.027749 |
| 61 | Promethium | Pm | 145 | 144.912745 | 90 | Thorium | Th | 228 | 228.028716 |
| 62 | Samarium | Sm | 152 | 151.919728 |  |  |  | 232 | 232.038051 |
| 63 | Europium | Eu | 153 | 152.921226 | 91 | Protactinium | Pa | 231 | 231.035880 |
| 64 | Gadolinium | Gd | 158 | 157.924099 | 92 | Uranium | U | 232 | 232.037131 |
| 65 | Terbium | Tb | 159 | 158.925344 |  |  |  | 233 | 233.039630 |
| 66 | Dysprosium | Dy | 164 | 163.929172 |  |  |  | 235 | 235.043924 |
| 67 | Holmium | Ho | 165 | 164.930320 |  |  |  | 236 | 236.045562 |
|  |  |  |  |  |  |  |  | 238 | 238.050784 |
| 68 | Erbium | Er | 166 | 165.930292 |  |  |  | 239 | 239.054289 |
| 69 | Thulium | Tm | 169 | 168.934213 | 93 | Neptunium | Np | 239 | 239.052932 |
| 70 | Ytterbium | Yb | 174 | 173.938861 | 94 | Plutonium | Pu | 239 | 239.052157 |
| 71 | Lutecium | Lu | 175 | 174.940772 | 95 | Amercium | Am | 243 | 243.061373 |
| 72 | Hafnium | Hf | 180 | 179.946547 | 96 | Curium | Cm | 245 | 245.065484 |
| 73 | Tantalum | Ta | 181 | 180.947993 | 97 | Berkelium | Bk | 247 | 247.07030 |
| 74 | Tungsten | W | 184 | 183.950929 | 98 | Californium | Cf | 249 | 249.074844 |
| 75 | Rhenium | Re | 187 | 186.955746 | 99 | Einsteinium | Es | 254 | 254.08802 |
| 76 | Osmium | Os | 191 | 190.960922 | 100 | Fermium | Fm | 253 | 253.085174 |
|  |  |  | 192 | 191.961468 | 101 | Mendelevium | Md | 255 | 255.09107 |
| 77 | Iridium | Ir | 191 | 190.960585 | 102 | Nobelium | No | 255 | 255.09324 |
|  |  |  | 193 | 192.962916 | 103 | Lawrencium | Lr | 257 | 257.0995 |
| 78 | Platinum | Pt | 195 | 194.964765 | 104 | Rutherfordium | Rf | 261 | 261.1086 |
| 79 | Gold | Au | 197 | 196.966543 | 105 | Dubnium | Db | 262 | 262.1138 |
| 80 | Mercury | Hg | 199 | 198.968253 | 106 | Seaborgium | Sg | 263 | 263.1182 |
|  |  |  | 202 | 201.970617 | 107 | Bohrium | Bh | 262 | 262.1231 |
| 81 | Thallium | Tl | 205 | 204.974400 | 108 | Hassium | Hs | 264 | 264.1285 |
| 82 | Lead | Pb | 206 | 205.974440 | 109 | Meitnerium | Mt | 266 | 266.1378 |
|  |  |  | 207 | 206.975871 |  |  |  |  |  |
|  |  |  | 208 | 207.976627 |  |  |  |  |  |
|  |  |  | 210 | 209.984163 |  |  |  |  |  |
|  |  |  | 211 | 210.988734 |  |  |  |  |  |
|  |  |  | 212 | 211.991872 |  |  |  |  |  |
|  |  |  | 214 | 213.999798 |  |  |  |  |  |

---

## Nuclear Structure
### I

01. What is the rest energy of an $\alpha$ particle?

02. Convert the mass of a pi meson (139 MeV/$c^2$) to atomic mass units.

### II

03. What is the approximate radius of a $^{60}_{28}$Ni nucleus?

04. What is the approximate value of $A$ for a nucleus with a radius of 4.8 x 10$^{-15}$ m?

05. How much energy must an $\alpha$ particle have to just barely "touch" the surface of a $^{238}_{92}$U nucleus?  [Hint:  The $\alpha$ particle must have enough (kinetic) energy to overcome the electrostatic potential energy that exists when the two nuclei touch (radius of $\alpha$ particle plus radius of $^{238}_{92}$U nucleus).]

## Binding Energy & Nuclear Forces
### I

06. Estimate the total binding energy of _____.
    a.) $^{16}_{8}$O               b.) $^{35}_{16}$S                 c.) $^{197}_{79}$Au                    d.) $^{208}_{82}$Pb

### II

07. Calculate the total _____ for $^{9}_{4}$Be.
    a.) binding energy                          b.) binding energy per nucleon

08. What is the binding energy of the last neutron in a $^{14}_{7}$N nucleus?  [Hint: compare the mass of the $^{14}_{7}$N to the combined mass of $^{13}_{7}$N + $^{1}_{0}$n.]

09. How much energy would be required to remove a single neutron from a $^{14}_{7}$N nucleus?

10. Show that the nucleus $^{8}_{4}$Be (mass = 8.005308 u) is unstable to decay into two $\alpha$ particles.

11. Determine if $^{12}_{6}$C is stable against decay into three $\alpha$ particles.

---

**See the Table of "Selected Isotopes" on this first two pages of this chapter.**

**II**

01. A $^{232}_{92}$U nucleus emits an $\alpha$ particle with 5.32 MeV of kinetic energy.

   a.) What is the daughter nucleus?                                     b.) What is the approximate mass of the daughter nucleus?

02. State whether or not each of the following decays are possible.  Provide energy calculations as support for your statements.

   a.) $^{236}_{92}U \to\ ^{235}_{92}U\ +\ n$      b.) $^{16}_{8}O \to\ ^{15}_{8}O\ +\ n$          c.) $^{23}_{11}Na \to\ ^{22}_{11}Na\ +\ n$          d.) $^{211}_{82}Pb \to\ ^{210}_{82}Pb\ +\ n$

03. A nucleus of $^{12}_{6}C$ in an exited state emits a 4.4-MeV $\gamma$ ray as it drops to its ground state.  What is the mass of the excited carbon atom?

04. A $^{239}_{93}$Np nucleus undergoes a $\beta^-$ decay.

   a.) Write the complete equation for this decay.
   b.) How much energy is released in this decay?

05. A $^{23}_{10}$Ne (mass = 22.9945 u) undergoes a $\beta^-$ decay.

   a.) Write the complete equation for this decay.
   b.) What is the maximum kinetic energy of the emitted electron?
   c.) What is the energy of the neutrino when the electron has its maximum energy?
   d.) What is the minimum kinetic energy of the emitted electron?
   e.) What is the energy of the neutrino when the electron has its minimum energy?

06. A $^{15}_{8}$O undergoes a $\beta^+$ decay.

   a.) Write the complete equation for this decay.
   b.) What is the maximum kinetic energy of the emitted proton?
   c.) What is the energy of the neutrino when the proton has its maximum energy?
   d.) What is the minimum kinetic energy of the emitted proton?
   e.) What is the energy of the neutrino when the proton has its minimum energy?

07. Write the complete decay equation to describe a $^{81}_{36}$Kr nucleus undergoing an electron capture decay.

08. In a decay series, a $^{235}_{92}$U nuclide becomes $^{207}_{82}$Pb.  How many $\alpha$ and $\beta^-$ particles are emitted in this series?

---

ANSWERS:  **01.** a.) $^{228}_{90}$Th    b.) 228.028818 u    **02.** a.) Impossible (-6.55 MeV)    b.) Impossible (-15.66 MeV)
**02.** c.) Impossible (-12.4 MeV)    d.) Impossible (-3.81 MeV)    **03.** 12.004724 u    **04.** b.) 0.722 MeV
**05.** b.) 3.91 MeV    c.) 0 MeV    d.) 0 MeV    e.) 3.91 MeV
**06.** b.) 2.76 MeV    c.) 0 MeV    d.) 0 MeV    e.) 2.76 MeV    **08.** 7 $\alpha$ decays, 4 $\beta^-$ decays

**See the Table of "Selected Isotopes" on this first two pages of this chapter.**

**I**

01. A sample of radioactive material produces 1560 decays per minute when first tested and 390 decays per minute 8.00 h later. What is its half-life?

02. What is the half-life of $^{24}_{11}$Na if it has a decay constant of $1.287 \times 10^{-5}$ s?

03. What is the decay constant of $^{235}_{92}$U which has a half-life of $7.038 \times 10^{8}$ years?

04. What is the activity of a sample of $^{14}_{6}$C that contains $8.45 \times 10^{21}$ nuclei, if it has a half-life of 5730 years?

05. What fraction of a sample of $^{32}_{15}$P, which has a half-life of about 14 days, will remain after 42 days?

06. How many nuclei of $^{115}_{49}$In, which has a half life of $4.41 \times 10^{14}$ years, are present in an iron ore if an activity registers 3.40 decays per second?

**II**

07. A sample of $^{231}_{91}$Pa ($T_{\frac{1}{2}} = 3.276 \times 10^{4}$ yr) contains $6.45 \times 10^{16}$ nuclei.
   a.) What is the decay constant?                    b.) What is the approximate number of decays/min?

08. The activity of a 3.85-µg sample of pure $^{31}_{14}$Si ($T_{\frac{1}{2}} = 157.3$ minutes) is being monitored.

   a.) How many nuclei are initially present?
   b.) What is the initial activity?
   c.) How many nuclei are present after 9.00 h?
   d.) What is the activity after 9.00 h?
   e.) How much time elapses from the start of monitoring until the activity drops to 1.00 % of the original sample?
   f.) How much time elapses from the start of monitoring will the activity to drop to about 1 per second?

09. What is the activity of a 7.65-µg sample of pure $^{191}_{76}$Os ($T_{\frac{1}{2}} = 1.33 \times 10^{6}$ s)?

10. The activity of a sample of $^{131}_{53}$I ($T_{\frac{1}{2}} = 6.95 \times 10^{5}$ s) is $7.35 \times 10^{9}$ decays/sec. What is the mass of the sample?

11. The activity of a sample drops by a factor of 10 in 72.4 minutes.
   a.) What is its half-life?                    b.) What might be the identity of this nuclide?

12. A 27.5-g sample of pure carbon is 1.10% $^{14}_{6}$C ($T_{\frac{1}{2}} = 5730$ yr). How many disintegrations occur each second?

13. A radioactive nuclide produces 6740 decays per minute initially, and 1400 decays per minute exactly 1 day later.
   a.) What is its half-life?                    b.) What might be the identity of this nuclide?

---

ANSWERS: **01.** 4.00 h    **02.** $5.39 \times 10^{4}$ s (15.0 h)    **03.** $3.12 \times 10^{-17}$ s$^{-1}$    **04.** $3.24 \times 10^{10}$ decays/s    **05.** $\frac{1}{8}$
**06.** $6.82 \times 10^{22}$ nuclei    **07.** a.) $6.71 \times 10^{-13}$ s$^{-1}$    b.) $2.60 \times 10^{6}$ decays/s    **08.** a.) $7.48 \times 10^{16}$ nuclei
**08.** b.) $5.50 \times 10^{12}$ decays/s    c.) $6.93 \times 10^{15}$ nuclei    d.) $5.09 \times 10^{11}$ decays/s    e.) 17.4 h    f.) 111 h
**09.** $1.26 \times 10^{10}$ decays/s    **10.** 1.60 µg    **11.** a.) 21.8 minutes    b.) $^{223}_{87}$Fr    **12.** $4.99 \times 10^{10}$ decays/s
**13.** a.) 10.6 h    b.) $^{212}_{82}$Pb