Chapter 23
Nuclear Physics

Selected Isotope Masses

Homework # 175

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

Chapter 23
Nuclear Physics

Selected Isotope Masses

Homework # 176

Atomic Number Z	Element	Symbol	Mass Number A	Atomic Mass
54	Xenon	Xe	132	131.904141
			136	135.90721
55	Cesium	Cs	133	132.905436
56	Barium	Ba	137	136.905816
			138	137.905236
57	Lanthanum	La	139	138.906346
58	Cerium	Ce	140	139.905434
59	Praseodymium	Pr	141	140.907647
60	Neodymium	Nd	142	141.907718
61	Promethium	Pm	145	144.912745
62	Samarium	Sm	152	151.919728
63	Europium	Eu	153	152.921226
64	Gadolinium	Gd	158	157.924099
65	Terbium	Tb	159	158.925344
66	Dysprosium	Dy	164	163.929172
67	Holmium	Ho	165	164.930320
68	Erbium	Er	166	165.930292
69	Thulium	Tm	169	168.934213
70	Ytterbium	Yb	174	173.938861
71	Lutecium	Lu	175	174.940772
72	Hafnium	Hf	180	179.946547
73	Tantalum	Ta	181	180.947993
74	Tungsten	W	184	183.950929
75	Rhenium	Re	187	186.955746
76	Osmium	Os	191	190.960922
			192	191.961468
77	Iridium	Ir	191	190.960585
			193	192.962916
78	Platinum	Pt	195	194.964765
79	Gold	Au	197	196.966543
80	Mercury	Hg	199	198.968253
			202	201.970617
81	Thallium	Tl	205	204.974400
82	Lead	Pb	206	205.974440
			207	206.975871
			208	207.976627
			210	209.984163
			211	210.988734
			212	211.991872
			214	213.999798

Atomic Number Z	Element	Symbol	Mass Number A	Atomic Mass
83	Bismuth	Bi	209	208.980374
			211	210.987254
84	Polonium	Po	210	209.982848
			214	213.995177
85	Astatine	At	218	218.00868
86	Radon	Rn	222	222.017571
87	Francium	Fr	223	223.019733
88	Radium	Ra	226	226.025402
89	Actinium	Ac	227	227.027749
90	Thorium	Th	228	228.028716
			232	232.038051
91	Protactinium	Pa	231	231.035880
92	Uranium	U	232	232.037131
			233	233.039630
			235	235.043924
			236	236.045562
			238	238.050784
			239	239.054289
93	Neptunium	Np	239	239.052932
94	Plutonium	Pu	239	239.052157
95	Amercium	Am	243	243.061373
96	Curium	Cm	245	245.065484
97	Berkelium	Bk	247	247.07030
98	Californium	Cf	249	249.074844
99	Einsteinium	Es	254	254.08802
100	Fermium	Fm	253	253.085174
101	Mendelevium	Md	255	255.09107
102	Nobelium	No	255	255.09324
103	Lawrencium	Lr	257	257.0995
104	Rutherfordium	Rf	261	261.1086
105	Dubnium	Db	262	262.1138
106	Seaborgium	Sg	263	263.1182
107	Bohrium	Bh	262	262.1231
108	Hassium	Hs	264	264.1285
109	Meitnerium	Mt	266	266.1378

Chapter 23
Nuclear Physics
23.1 Nuclear Structure/Binding Energy and Nuclear Forces — Homework # 177

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

Nuclear Structure

I

01. What is the rest energy of an α 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 $^{60}_{28}\text{Ni}$ 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 α particle have to just barely "touch" the surface of a $^{238}_{92}\text{U}$ nucleus? [Hint: The α particle must have enough (kinetic) energy to overcome the electrostatic potential energy that exists when the two nuclei touch (radius of α particle plus radius of $^{238}_{92}\text{U}$ nucleus).]

Binding Energy & Nuclear Forces

I

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

II

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

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

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

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

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

ANSWERS: **01.** 3728.4 MeV **02.** 0.149 u **03.** 4.70 x 10^{-15} m **04.** 64 **05.** 28.4 MeV
06. a.) 127.6 MeV b.) 298.8 MeV c.) 1559.4 MeV d.) 1636.5 MeV **07.** a.) 58.2 MeV b.) 6.46 MeV
08. 10.55 MeV **09.** 10.55 MeV **10.** $m_{2\alpha\text{ particles}} < m_{^{8}_{4}\text{Be}}$ $(8.005204\text{ u} < 8.005308\text{ u})$
11. $m_{3\alpha\text{ particles}} > m_{^{12}_{6}\text{C}}$ $(12.007806\text{ u} > 12.000000\text{ u})$

Chapter 23
Nuclear Physics
23.2 Radioactivity-Alpha, Beta, and Gamma Decays Homework # 178

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

II

01. A $^{232}_{92}U$ nucleus emits an α 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.) $^{236}_{92}U \rightarrow {}^{235}_{92}U + n$ b.) $^{16}_{8}O \rightarrow {}^{15}_{8}O + n$ c.) $^{23}_{11}Na \rightarrow {}^{22}_{11}Na + n$ d.) $^{211}_{82}Pb \rightarrow {}^{210}_{82}Pb + n$

03. A nucleus of $^{12}_{6}C$ in an exited state emits a 4.4-MeV γ 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 β^- 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 β^- 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 β^+ 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 α and β^- 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 α decays, 4 β^- decays

Chapter 23
Nuclear Physics
23.3 Half-Life and Rate of Decay — Homework # 179

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 $^{24}_{11}\text{Na}$ if it has a decay constant of $1.287 \times 10^{-5}\ \text{s}^{-1}$?

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

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

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

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

II

07. A sample of $^{231}_{91}\text{Pa}$ ($T_{\frac{1}{2}} = 3.276 \times 10^{4}$ yr) contains 6.45×10^{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 $^{31}_{14}\text{Si}$ ($T_{\frac{1}{2}} = 157.3$ 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 $^{191}_{76}\text{Os}$ ($T_{\frac{1}{2}} = 1.33 \times 10^{6}$ s)?

10. The activity of a sample of $^{131}_{53}\text{I}$ ($T_{\frac{1}{2}} = 6.95 \times 10^{5}$ s) is 7.35×10^{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% $^{14}_{6}\text{C}$ ($T_{\frac{1}{2}} = 5730$ 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.** 5.39×10^{4} s (15.0 h) **03.** $3.12 \times 10^{-17}\ \text{s}^{-1}$ **04.** 3.24×10^{10} decays/s **05.** $\frac{1}{8}$
06. 6.82×10^{22} nuclei **07.** a.) $6.71 \times 10^{-13}\ \text{s}^{-1}$ b.) 2.60×10^{6} decays/s **08.** a.) 7.48×10^{16} nuclei
08. b.) 5.50×10^{12} decays/s c.) 6.93×10^{15} nuclei d.) 5.09×10^{11} decays/s e.) 17.4 h f.) 111 h
09. 1.26×10^{10} decays/s **10.** 1.60 µg **11.** a.) 21.8 minutes b.) $^{223}_{87}\text{Fr}$ **12.** 4.99×10^{10} decays/s
13. a.) 10.6 h b.) $^{212}_{82}\text{Pb}$