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4. Right circular cylinder of radius r and height h (see Figure E7):

$$\begin{aligned} \text{Surface area} &= 2\pi r^2 + 2\pi rh \\ \text{Volume} &= \pi r^2 h \end{aligned}$$

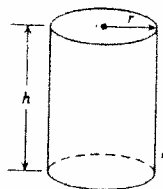


Figure E7

E2 TRIGONOMETRY

Basic Trigonometric Functions

1. For a right triangle, the sine, cosine, and tangent of an angle θ are defined as follows (see Figure E8):

$$\begin{aligned} \sin \theta &= \frac{\text{Side opposite } \theta}{\text{Hypotenuse}} = \frac{h_o}{h} \\ \cos \theta &= \frac{\text{Side adjacent to } \theta}{\text{Hypotenuse}} = \frac{h_a}{h} \\ \tan \theta &= \frac{\text{Side opposite } \theta}{\text{Side adjacent to } \theta} = \frac{h_o}{h_a} \end{aligned}$$

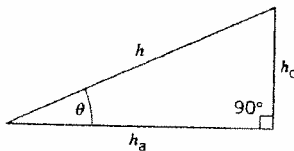


Figure E8

2. The secant ($\sec \theta$), cosecant ($\csc \theta$), and cotangent ($\cot \theta$) of an angle θ are defined as follows:

$$\sec \theta = \frac{1}{\cos \theta} \quad \csc \theta = \frac{1}{\sin \theta} \quad \cot \theta = \frac{1}{\tan \theta}$$

Triangles and Trigonometry

1. The *Pythagorean theorem* states that the square of the hypotenuse of a right triangle is equal to the sum of the squares of the other two sides (see Figure E8):

$$h^2 = h_o^2 + h_a^2$$

2. The *law of cosines* and the *law of sines* apply to any triangle, not just a right triangle, and they relate the angles and the lengths of the sides (see Figure E9):

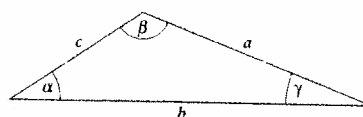


Figure E9

$$\text{Law of cosines} \quad c^2 = a^2 + b^2 - 2ab \cos \gamma$$

$$\text{Law of sines} \quad \frac{a}{\sin \alpha} = \frac{b}{\sin \beta} = \frac{c}{\sin \gamma}$$

Other Trigonometric Identities

- $\sin(-\theta) = -\sin \theta$
- $\cos(-\theta) = \cos \theta$
- $\tan(-\theta) = -\tan \theta$
- $(\sin \theta) / (\cos \theta) = \tan \theta$
- $\sin^2 \theta + \cos^2 \theta = 1$
- $\sin(\alpha \pm \beta) = \sin \alpha \cos \beta \pm \cos \alpha \sin \beta$

$$\text{If } \alpha = 90^\circ, \sin(90^\circ \pm \beta) = \cos \beta$$

$$\text{If } \alpha = \beta, \sin 2\beta = 2 \sin \beta \cos \beta$$

- $\cos(\alpha \pm \beta) = \cos \alpha \cos \beta \mp \sin \alpha \sin \beta$

$$\text{If } \alpha = 90^\circ, \cos(90^\circ \pm \beta) = \mp \sin \beta$$

$$\text{If } \alpha = \beta, \cos 2\beta = \cos^2 \beta - \sin^2 \beta = 1 - 2 \sin^2 \beta$$

APPENDIX F SELECTED ISOTOPES^a

Atomic No. Z	Element	Symbol	Atomic Mass No. A	Atomic Mass u	% Abundance, or Decay Mode If Radioactive	Half-life (If Radioactive)
0	(Neutron)	n	1	1.008 665	β^-	10.37 min
1	Hydrogen	H	1	1.007 825	99.985	
	Deuterium	D	2	2.014 102	0.015	
	Tritium	T	3	3.016 050	β^-	12.33 yr

^a Data for atomic masses are taken from *Handbook of Chemistry and Physics*, 66th ed., CRC Press, Boca Raton, FL. The masses are those for the neutral atom, including the Z electrons. Data for percent abundance, decay mode, and half-life are taken from E. Browne and R. Firestone, *Table of Radioactive Isotopes*, V. Shirley, Ed., Wiley, New York, 1986. α = alpha particle emission, β^- = negative beta emission, β^+ = positron emission, γ = γ -ray emission, EC = electron capture.

APPENDIX F Selected Isotopes (continued)

Atomic No. Z	Element	Symbol	Atomic Mass No. A	Atomic Mass u	% Abundance, or Decay Mode If Radioactive	Half-life (If Radioactive)
2	Helium	He	3	3.016 030	0.000 138	
			4	4.002 603	≈100	
3	Lithium	Li	6	6.015 121	7.5	
			7	7.016 003	92.5	
4	Beryllium	Be	7	7.016 928	EC, γ	53.29 days
			9	9.012 182	100	
5	Boron	B	10	10.012 937	19.9	
			11	11.009 305	80.1	
6	Carbon	C	11	11.011 432	β^+ , EC	20.39 min
			12	12.000 000	98.90	
			13	13.003 355	1.10	
			14	14.003 241	β^-	
7	Nitrogen	N	13	13.005 738	β^+ , EC	5730 yr
			14	14.003 074	99.634	
			15	15.000 108	0.366	
8	Oxygen	O	15	15.003 065	β^+ , EC	122.2 s
			16	15.994 915	99.762	
			18	17.999 160	0.200	
9	Fluorine	F	18	18.000 937	EC, β^+	1.8295 h
			19	18.998 403	100	
10	Neon	Ne	20	19.992 435	90.51	
			22	21.991 383	9.22	
11	Sodium	Na	22	21.994 434	β^+ , EC, γ	2.602 yr
			23	22.989 767	100	
			24	23.990 961	β^- , γ	
12	Magnesium	Mg	24	23.985 042	78.99	14.659 h
13	Aluminum	Al	27	26.981 539	100	
14	Silicon	Si	28	27.976 927	92.23	2.622 h
			31	30.975 362	β^- , γ	
15	Phosphorus	P	31	30.973 762	100	14.282 days
			32	31.973 907	β^-	
16	Sulfur	S	32	31.972 070	95.02	87.51 days
			35	34.969 031	β^-	
17	Chlorine	Cl	35	34.968 852	75.77	
			37	36.965 903	24.23	
18	Argon	Ar	40	39.962 384	99.600	1.277 $\times 10^9$ yr
19	Potassium	K	39	38.963 707	93.2581	
			40	39.963 999	β^- , EC, γ	
20	Calcium	Ca	40	39.962 591	96.941	
21	Scandium	Sc	45	44.955 910	100	
22	Titanium	Ti	48	47.947 947	73.8	
23	Vanadium	V	51	50.943 962	99.750	
24	Chromium	Cr	52	51.940 509	83.789	
25	Manganese	Mn	55	54.938 047	100	

APPENDIX F Selected Isotopes (continued)

Atomic No. Z	Element	Symbol	Atomic Mass No. A	Atomic Mass μ	% Abundance, or Decay Mode If Radioactive	Half-life (If Radioactive)
26	Iron	Fe	56	55.934 939	91.72	
27	Cobalt	Co	59	58.933 198	100	
28	Nickel	Ni	60	59.933 819	β^- , γ	5.271 yr
			58	57.935 346	68.27	
29	Copper	Cu	60	59.930 788	26.10	
			63	62.939 598	69.17	
30	Zinc	Zn	65	64.927 793	30.83	
			64	63.929 145	48.6	
31	Gallium	Ga	69	68.925 580	27.9	
32	Germanium	Ge	72	71.922 079	60.1	
			74	73.921 177	27.4	
33	Arsenic	As	75	74.921 594	36.5	
34	Selenium	Se	80	79.916 520	100	
35	Bromine	Br	79	78.918 336	49.7	
36	Krypton	Kr	84	83.911 507	50.69	
			89	88.917 640	57.0	
			92	91.926 270	β^- , γ	3.16 min
37	Rubidium	Rb	85	84.911 794	β^- , γ	1.840 s
38	Strontium	Sr	86	85.909 267	72.165	
			88	87.905 619	9.86	
			90	89.907 738	82.58	
			94	93.915 367	β^-	28.5 yr
39	Yttrium	Y	89	88.905 849	β^- , γ	1.235 s
40	Zirconium	Zr	90	89.904 703	100	
41	Niobium	Nb	93	92.906 377	51.45	
42	Molybdenum	Mo	98	97.905 406	100	
43	Technecium	Tc	98	97.907 215	24.13	
44	Ruthenium	Ru	102	101.904 348	β^- , γ	4.2 × 10 ⁶ yr
45	Rhodium	Rh	103	102.905 500	31.6	
46	Palladium	Pd	106	105.903 478	100	
47	Silver	Ag	107	106.905 092	27.33	
			109	108.904 757	51.839	
			114	113.903 357	48.161	
48	Cadmium	Cd	114	113.903 357	28.73	
49	Indium	In	115	114.903 880	95.7; β^-	4.41 × 10 ¹⁴ yr
50	Tin	Sn	120	119.902 200	32.59	
51	Antimony	Sb	121	120.903 821	57.3	
52	Tellurium	Te	130	129.906 229	38.8; β^-	2.5 × 10 ²¹ yr
53	Iodine	I	127	126.904 473	100	
54	Xenon	Xe	131	130.906 114	β^- , γ	8.040 days
			132	131.904 144	26.9	
			136	135.907 214	8.9	
			140	139.921 620	β^- , γ	13.6 s

APPENDIX F Selected Isotopes (continued)

Atomic No. Z	Element	Symbol	Atomic Mass No. A	Atomic Mass u	% Abundance, or Decay Mode If Radioactive	Half-life (If Radioactive)	
55	Cesium	Cs	133	132.905 429	100	2.062 yr	
			134	133.906 696	β^- , EC, γ		
56	Barium	Ba	137	136.905 812	11.23	18.27 min	
			138	137.905 232	71.70		
			141	140.914 363	β^- , γ		
57	Lanthanum	La	139	138.906 346	99.91		
58	Cerium	Ce	140	139.905 433	88.48		
59	Praseodymium	Pr	141	140.907 647	100		
60	Neodymium	Nd	142	141.907 719	27.13		
61	Promethium	Pm	145	144.912 743	EC, α , γ	17.7 yr	
62	Samarium	Sm	152	151.919 729	26.7		
63	Europium	Eu	153	152.921 225	52.2		
64	Gadolinium	Gd	158	157.924 099	24.84		
65	Terbium	Tb	159	158.925 342	100		
66	Dysprosium	Dy	164	163.929 171	28.2		
67	Holmium	Ho	165	164.930 319	100		
68	Erbium	Er	166	165.930 290	33.6		
69	Thulium	Tm	169	168.934 212	100		
70	Ytterbium	Yb	174	173.938 859	31.8		
71	Lutetium	Lu	175	174.940 770	97.41		
72	Hafnium	Hf	180	179.946 545	35.100		
73	Tantalum	Ta	181	180.947 992	99.988		
74	Tungsten (wolfram)	W	184	183.950 928	30.67		
75	Rhenium	Re	187	186.955 744	62.60; β^-	4.6×10^{10} yr	
76	Osmium	Os	191	190.960 920	β^- , γ	15.4 days	
			192	191.961 467	41.0		
77	Iridium	Ir	191	190.960 584	37.3		
			193	192.962 917	62.7		
78	Platinum	Pt	195	194.964 766	33.8		
79	Gold	Au	197	196.966 543	100	2.6935 days	
			198	197.968 217	β^- , γ		
80	Mercury	Hg	202	201.970 617	29.80		
81	Thallium	Tl	205	204.974 401	70.476	3.053 min	
			208	207.981 988	β^- , γ		
82	Lead	Pb	206	205.974 440	24.1	22.3 yr	
			207	206.975 872	22.1		
			208	207.976 627	52.4		
			210	209.984 163	α , β^- , γ		
			211	210.988 735	β^- , γ		36.1 min
			212	211.991 871	β^- , γ		10.64 h
			214	213.999 798	β^- , γ	26.8 min	

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APPENDIX F Selected Isotopes (continued)

Atomic No. Z	Element	Symbol	Atomic Mass No. A	Atomic Mass <i>u</i>	% Abundance, or Decay Mode If Radioactive	Half-life (If Radioactive)
83	Bismuth	Bi	209	208.980 374	100	
			211	210.987 255	α, β^-, γ	2.14 min
			212	211.991 255	β^-, α, γ	1.0092 h
84	Polonium	Po	210	209.982 848	α, γ	138.376 days
			212	211.988 842	α, γ	45.1 s
			214	213.995 176	α, γ	163.69 μ s
			216	216.001 889	α, γ	150 ms
85	Astatine	At	218	218.008 684	α, β^-	1.6 s
86	Radon	Rn	220	220.011 368	α, γ	55.6 s
			222	222.017 570	α, γ	3.825 days
87	Francium	Fr	223	223.019 733	α, β^-, γ	21.8 min
88	Radium	Ra	224	224.020 186	α, γ	3.66 days
			226	226.025 402	α, γ	1.6×10^3 yr
			228	228.031 064	β^-, γ	5.75 yr
89	Actinium	Ac	227	227.027 750	α, β^-, γ	21.77 yr
			228	228.031 015	β^-, γ	6.13 h
90	Thorium	Th	228	228.028 715	α, γ	1.913 yr
			231	231.036 298	β^-, γ	1.0633 days
			232	232.038 054	100; α, γ	1.405×10^{10} yr
			234	234.043 593	β^-, γ	24.10 days
91	Protactinium	Pa	231	231.035 880	α, γ	3.276×10^4 yr
			234	234.043 303	β^-, γ	6.70 h
			237	237.051 140	β^-, γ	8.7 min
92	Uranium	U	232	232.037 130	α, γ	68.9 yr
			233	233.039 628	α, γ	1.592×10^5 yr
			235	235.043 924	0.7200; α, γ	7.037×10^8 yr
			236	236.045 562	α, γ	2.342×10^7 yr
			238	238.050 784	99.2745; α, γ	4.468×10^9 yr
			239	239.054 289	β^-, γ	23.47 min
93	Neptunium	Np	239	239.052 933	β^-, γ	2.355 days
94	Plutonium	Pu	239	239.052 157	α, γ	2.411×10^4 yr
			242	242.058 737	α, γ	3.763×10^5 yr
95	Americium	Am	243	243.061 375	α, γ	7.380×10^3 yr
96	Curium	Cm	245	245.065 483	α, γ	8.5×10^3 yr
97	Berkelium	Bk	247	247.070 300	α, γ	1.38×10^3 yr
98	Californium	Cf	249	249.074 844	α, γ	350.6 yr
99	Einsteinium	Es	254	254.088 019	α, γ, β^-	275.7 days
100	Fermium	Fm	253	253.085 173	EC, α, γ	3.00 days
101	Mendelevium	Md	255	255.091 081	EC, α	27 min
102	Nobelium	No	255	255.093 260	EC, α	3.1 min
103	Lawrencium	Lr	257	257.099 480	α, EC	646 ms
104	Rutherfordium	Rf	261	261.108 690	α	1.08 min
105	Hahnium	Ha	262	262.113 760	α	34 s