CHEMISTRY SUMMER PACKETS

PERIODIC TABLE OF THE ELEMENTS

Table of Selected Radioactive Isotopes

$_{0}$n	1	(15.3 min) β^-
$_{1}$H	3	(12.26 y) β^-
$_{4}$Be	7	(53.3 d) EC
	10	(1.6 × 10^6 y) β^-
$_{6}$C	11	(20.40 min) β^+
	14	(5730 y) β^-
$_{9}$F	18	(109.8 min) β^+
$_{11}$Na	22	(2.602 y) β^+, EC
	24	(15.02 h) β^-
$_{12}$Mg	28	(20.9 h) β^-
$_{13}$Al	26	(7.2 × 10^5 y) β^+, EC
$_{15}$P	32	(14.26 d) β^-
$_{16}$S	35	(87.2 d) β^-
$_{17}$Cl	36	(3.01 × 10^5 y) β^-
	38	(37.2 min) β^-
$_{18}$Ar	37	(35.02 d) EC
	39	(265 y) β^-
$_{19}$K	40	(1.28 × 10^9 y) EC
	42	(12.36 h) β^-
$_{20}$Ca	45	(165 d) β^-
$_{21}$Sc	46	(83.80 d) β^-
$_{24}$Cr	51	(27.70 d) EC
$_{25}$Mn	53	(2 × 10^6 y) EC
	54	(313.0 d) EC
	56	(2.578 h) β^-
$_{26}$Fe	59	(44.6 d) β^-
$_{27}$Co	56	(78.8 d) β^+, EC
	57	(270 d) EC
	58	(71.3 d) β^+, EC
	60	(5.272 y) β^-
$_{28}$Ni	57	(36.0 h) β^+, EC
	59	(8 × 10^4 y) EC
	63	(92 y) β^-
$_{29}$Cu	64	(12.70 h) β^-, β^+, EC
	67	(61.88 h) β^-
$_{30}$Zn	65	(244.1 d) β^+, EC
$_{31}$Ga	67	(78.2 h) EC
	72	(14.10 h) β^-
$_{32}$Ge	68	(275 d) EC
$_{33}$As	73	(80.3 d) EC
	74	(17.9 d) β^-, β^+, EC
$_{34}$Se	75	(118.5 d) β^-
	79	(6.5 × 10^4 y) β^-
$_{35}$Br	82	(35.34 h) β^-
$_{36}$Kr	81	(2.1 × 10^5 y) EC
	85	(10.72 y) β^-
$_{37}$Rb	86	(18.7 d) β^-
	87	(4.8 × 10^{10} y) β^-
$_{38}$Sr	90	(28.8 y) β^-
$_{39}$Y	88	(106.6 d) β^+, EC
$_{40}$Zr	93	(1.5 × 10^6 y) β^-
	95	(64.0 d) β^-
$_{41}$Nb	94	(2.0 × 10^4 y) β^-
	95	(35.15 d) β^-
$_{42}$Mo	99	(66.02 h) β^-
$_{43}$Tc	97	(2.6 × 10^6 y) EC
	98	(4.2 × 10^6 y) β^-
	99	(2.13 × 10^5 y) β^-
$_{44}$Ru	106	(367 d) β^-
$_{45}$Rh	101	(3.3 y) EC
$_{46}$Pd	103	(17.0 d) EC
	107	(7 × 10^6 y) β^-
$_{47}$Ag	108	(127 y) EC
	110	(252 d) β^-
	111	(7.45 d) β^-
$_{48}$Cd	109	(453 d) EC
$_{49}$In	114	(49.51 d) IT
$_{50}$Sn	121	(76 y) β^-
$_{51}$Sb	124	(60.20 d) β^-
	125	(2.7 y) β^-
$_{52}$Te	121 m	(154 d) IT
	123 m	(119.7 d) IT
	127 m	(109 d) IT
$_{53}$I	129	(1.6 × 10^7 y) β^-
	131	(8.040 d) β^-
$_{54}$Xe	133	(5.25 d) β^-
	135	(9.10 h) β^-
$_{55}$Cs	134	(2.06 y) β^-
	135	(2.9 × 10^6 y) β^-
	137	(30.17 y) β^-
$_{56}$Ba	140	(12.8 d) β^-
$_{57}$La	137	(6 × 10^4 y) EC
	140	(40.3 h) β^-
$_{58}$Ce	144	(284 d) β^-
$_{59}$Pr	142	(19.1 h) β^-
$_{60}$Nd	147	(11.1 d) β^-
$_{61}$Pm	145	(18 y) EC
	147	(2.62 y) β^-
$_{62}$Sm	146	(7 × 10^7 y) α
	151	(93 y) β^-
$_{63}$Eu	152	(13 y) β^+, EC, β^-
	154	(8.5 y) β^-
$_{64}$Gd	150	(2.1 × 10^6 y) α
$_{65}$Tb	158	(1.2 × 10^2 y) EC, β^-
	160	(72.3 d) β^-
$_{67}$Ho	166 m	(1.2 × 10^3 y) β^-
$_{69}$Tm	170	(128.6 d) β^-
	171	(1.92 y) β^-
$_{70}$Yb	169	(32.0 d) EC
	175	(4.19 d) β^-
$_{71}$Lu	176	(3.7 × 10^{10} y) β^-
$_{73}$Ta	182	(115.0 d) β^-
$_{74}$W	181	(140 d) EC
	185	(75.1 d) β^-
	188	(69 d) β^-
$_{75}$Re	187	(5 × 10^{10} y) β^-
$_{76}$Os	194	(6.0 y) β^-
$_{77}$Ir	192	(74.2 d) β^-, β^+, EC
$_{79}$Au	195	(183 d) EC
	196	(6.18 d) β^-, EC, β^+
	198	(2.696 d) β^-
	199	(3.15 d) β^-
$_{80}$Hg	203	(46.8 d) β^-
$_{81}$Tl	204	(3.77 y) β^-
$_{82}$Pb	202	(3 × 10^5 y) EC
	205	(3 × 10^7 y) EC
	210	(22.3 y) β^-, α
$_{83}$Bi	207	(38 y) EC
	208	(3.7 × 10^5 y) EC
	210	(5.01 d) β^-, α
	210 m	(3 × 10^6 y) α
$_{84}$Po	208	(2.90 y) α
	209	(102 y) α
	210	(138.38 d) α
$_{85}$At	209	(5.4 h) EC, α
	210	(8.1 h) EC
	211	(7.21 h) EC, α
$_{86}$Rn	222	(3.824 d) α
$_{87}$Fr	212	(19.3 min) EC, α
	222	(15 min) β^-
	223	(21.8 min) β^-
$_{88}$Ra	226	(1.60 × 10^3 y) α
$_{89}$Ac	227	(21.77 y) β^-
$_{90}$Th	228	(1.913 y) α
	230	(7.7 × 10^4 y) α
	232	(1.40 × 10^{10} y) α
$_{91}$Pa	231	(3.28 × 10^4 y) α
$_{92}$U	233	(1.59 × 10^5 y) α
	234	(2.44 × 10^5 y) α
	235	(7.04 × 10^8 y) α
	236	(2.34 × 10^7 y) α
	238	(4.47 × 10^9 y) α
$_{93}$Np	236	(1.1 × 10^5 y) EC, β^-
	237	(2.14 × 10^6 y) α
	239	(2.346 d) β^-
$_{94}$Pu	238	(87.75 y) α
	239	(2.41 × 10^4 y) α
	240	(6.54 × 10^3 y) α
	242	(3.8 × 10^5 y) α
	244	(8.3 × 10^7 y) α
$_{95}$Am	241	(432 y) α
	243	(7.37 × 10^3 y) α
$_{96}$Cm	242	(163.2 d) α
	244	(18.12 y) α
	247	(1.55 × 10^7 y) α
	248	(3.5 × 10^5 y) α, SF
$_{97}$Bk	247	(1.4 × 10^3 y) α
$_{98}$Cf	249	(351 y) α
	251	(900 y) α
$_{99}$Es	252	(472 d) α
	253	(20.47 d) α
	254	(276 d) α
$_{100}$Fm	255	(20.1 h) α
	257	(100.5 d) α
$_{101}$Md	258	(55 d) α
$_{102}$No	259	(58 min) α
$_{103}$Lr	260	(3.0 min) α
$_{104}$Rf	261	(65 s) α
$_{105}$Db	262	(40 s) α
$_{106}$Sg	263	(0.9 s) α

Selected Radioactive Isotopes

Naturally occurring radioactive isotopes are designated by a mass number in blue (although some are also manufactured). Letter m indicates an isomer of another isotope of the same mass number. Half-lives follow in parentheses, where s, min, h, d, and y stand respectively for seconds, minutes, hours, days, and years. The table includes mainly the longer-lived radioactive isotopes; many others have been prepared. Isotopes known to be radioactive but with half-lives exceeding 10^{12} y have not been included. Symbols describing the principal mode (or modes) of decay are as follows (these processes are generally accompanied by gamma radiation):

- α alpha particle emission
- β^- beta particle (electron) emission
- β^+ positron emission
- EC orbital electron capture
- IT isomeric transition from upper to [illegible]
- SF spontaneous fission

GROUP 1/IA · 2/IIA · 3/IIIA · 4/IVA · 5/VA · 6/VIA · 7/VIIA · 8 · 9 (VIIIA) · 10 · 11/IB · 12/IIB · 13/IIIB · 14/IVB · 15/VB · 16/VIB · 17/VIIB · 18/VIII

Atomic number	Symbol	Name	Atomic weight (2)	Oxidation states	Boiling point, K	Melting point, K	Density at 300 K (3) (g/cm³)	Electron configuration
1	H	Hydrogen	1.00794	1	20.28	13.81	0.0899 †	$1s^1$
2	He	Helium	4.00260		4.216	0.95 at 26 atm	0.1785 †	$1s^2$
3	Li	Lithium	6.941	1	1615	453.7	0.53	$1s^22s^1$
4	Be	Beryllium	9.01218	2	3243	1560	1.85	$1s^22s^2$
5	B	Boron	10.811	3	4275	2365	2.34	$1s^22s^2p^1$
6	C	Carbon	12.011	±4,2	5100*	3825*	2.26	$1s^22s^2p^2$
7	N	Nitrogen	14.0067	±3,5,4,2	77.344	63.15	1.251 †	$1s^22s^2p^3$
8	O	Oxygen	15.9994	-2	90.188	54.8	1.429 †	$1s^22s^2p^4$
9	F	Fluorine	18.99840	-1	85.0	53.55	1.696 †	$1s^22s^2p^5$
10	Ne	Neon	20.1797		27.10	24.55	0.900 †	$1s^22s^2p^6$
11	Na	Sodium	22.98977	1	1156	371.0	0.97	$[Ne]3s^1$
12	Mg	Magnesium	24.305	2	1380	922	1.74	$[Ne]3s^2$
13	Al	Aluminum	26.98154	3	2740	933.5	2.70	$[Ne]3s^2p^1$
14	Si	Silicon	28.0855	4,2	2630	1683	2.33	$[Ne]3s^2p^2$
15	P	Phosphorus	30.97376	±3,5,4	553	317.3	1.82	$[Ne]3s^2p^3$
16	S	Sulfur	32.066	±2,4,6	717.82	392.2	2.07	$[Ne]3s^2p^4$
17	Cl	Chlorine	35.4527	±1,3,5,7	239.18	172.17	3.214 †	$[Ne]3s^2p^5$
18	Ar	Argon	39.948		87.45	83.95	1.784 †	$[Ne]3s^2p^6$
19	K	Potassium	39.0983	1	1033	336.8	0.86	$[Ar]4s^1$
20	Ca	Calcium	40.078	2	1757	1112	1.55	$[Ar]4s^2$
21	Sc	Scandium	44.9559	3	3109	1814	2.99	$[Ar]3d^14s^2$
22	Ti	Titanium	47.87	4,3	3560	1935	4.54	$[Ar]3d^24s^2$
23	V	Vanadium	50.9415	5,4,3,2	3650	2163	6.11	$[Ar]3d^34s^2$
24	Cr	Chromium	51.996	6,3,2	2945	2130	7.19	$[Ar]3d^54s^1$
25	Mn	Manganese	54.9380	7,6,4,2,3	2235	1518	7.44	$[Ar]3d^54s^2$
26	Fe	Iron	55.845	2,3,6	3023	1808	7.874	$[Ar]3d^64s^2$
27	Co	Cobalt	58.9332	2,3	3143	1768	8.90	$[Ar]3d^74s^2$
28	Ni	Nickel	58.6934	2,3	3005	1726	8.90	$[Ar]3d^84s^2$
29	Cu	Copper	63.546	2,1	2840	1356.6	8.96	$[Ar]3d^{10}4s^1$
30	Zn	Zinc	65.39	2	1180	692.73	7.13	$[Ar]3d^{10}4s^2$
31	Ga	Gallium	69.723	3	2478	302.92	5.91	$[Ar]3d^{10}4s^2p$
32	Ge	Germanium	72.61	4	3107	1211.5	5.32	$[Ar]3d^{10}4s^2p^2$
33	As	Arsenic	74.9216	±3,5	876 (subl.)	1090 (28 atm)	5.78	$[Ar]3d^{10}4s^2p^3$
34	Se	Selenium	78.96	-2,4,6	958	494	4.79	$[Ar]3d^{10}4s^2p^4$
35	Br	Bromine	79.904	±1,5,7	331.85	265.95	3.12	$[Ar]3d^{10}4s^2p^5$
36	Kr	Krypton	83.80	0,2	120.85	116	3.75 †	$[Ar]3d^{10}4s^2p^6$
37	Rb	Rubidium	85.4678	1	961	312.63	1.532	$[Kr]5s^1$
38	Sr	Strontium	87.62	2	1655	1042	2.54	$[Kr]5s^2$
39	Y	Yttrium	88.9059	3	3611	1795	4.47	$[Kr]4d^15s^2$
40	Zr	Zirconium	91.224	4	4682	2128	6.51	$[Kr]4d^25s^2$
41	Nb	Niobium	92.9064	5,3	5015	2742	8.57	$[Kr]4d^45s^1$
42	Mo	Molybdenum	95.94	6,5,4,3,2	4912	2896	10.22	$[Kr]4d^55s^1$
43	Tc	Technetium	(98)	7	4538	2477	11.5	$[Kr]4d^55s^2$
44	Ru	Ruthenium	101.07	2,3,4,6,8	4425	2610	12.37	$[Kr]4d^75s^1$
45	Rh	Rhodium	102.9055	2,3,4	3970	2236	12.41	$[Kr]4d^85s^1$
46	Pd	Palladium	106.42	2,4	3240	1825	12.0	$[Kr]4d^{10}$
47	Ag	Silver	107.868	1	2436	1235.08	10.50	$[Kr]4d^{10}5s^1$
48	Cd	Cadmium	112.41	2	1040	594.26	8.65	$[Kr]4d^{10}5s^2$
49	In	Indium	114.82		2350	429.78	7.31	$[Kr]4d^{10}5s^2p^1$
50	Sn	Tin	118.710	4,2	2876	5.12	7.31	$[Kr]4d^{10}5s^2p^2$
51	Sb	Antimony	121.760	±3,5	1860	903.91	6.69	$[Kr]4d^{10}5s^2p^3$
52	Te	Tellurium	127.60	-2,4,6	1261	722.72	6.24	$[Kr]4d^{10}5s^2p^4$
53	I	Iodine	126.9045	±1,5,7	457.5	386.7	4.93	$[Kr]4d^{10}5s^2p^5$
54	Xe	Xenon	131.29	0,2,4,6	165.1	161.39	5.90 †	$[Kr]4d^{10}5s^2p^6$
55	Cs	Cesium	132.9054	1	944	301.54	1.87	$[Xe]6s^1$
56	Ba	Barium	137.33	2	2078	1002	3.59	$[Xe]6s^2$
57 ★	La	Lanthanum	138.9055	3	3737	1191	6.15	$[Xe]5d^16s^2$
72	Hf	Hafnium	178.49	4	4875	2504	13.31	$[Xe]4f^{14}5d^26s^2$
73	Ta	Tantalum	180.9479	5	5730	3293	16.65	$[Xe]4f^{14}5d^36s^2$
74	W	Tungsten	183.84	6,5,4,3,2	5825	3695	19.3	$[Xe]4f^{14}5d^46s^2$
75	Re	Rhenium	186.207	7,6,4,2	5870	3455	21.0	$[Xe]4f^{14}5d^56s^2$
76	Os	Osmium	190.23	2,3,4,6,8	5300	3300	22.6	$[Xe]4f^{14}5d^66s^2$
77	Ir	Iridium	192.22	2,3,4,6	4700	2720	22.6	$[Xe]4f^{14}5d^76s^2$
78	Pt	Platinum	195.08	2,4	4100	2042.1	21.45	$[Xe]4f^{14}5d^96s^1$
79	Au	Gold	196.9665	3,1	3130	1337.58	19.3	$[Xe]4f^{14}5d^{10}6s^1$
80	Hg	Mercury	200.59	2,1	629.88	234.31	13.55	$[Xe]4f^{14}5d^{10}6s^2$
81	Tl	Thallium	204.383	3,1	1746	577	11.85	$[Xe]4f^{14}5d^{10}6s^2p^1$
82	Pb	Lead	207.2	4,2	2023	600.65	11.35	$[Xe]4f^{14}5d^{10}6s^2p^2$
83	Bi	Bismuth	208.9804	3,5	1837	544.59	9.75	$[Xe]4f^{14}5d^{10}6s^2p^3$
84	Po	Polonium	(209)	4,2,6	—	527	9.3	$[Xe]4f^{14}5d^{10}6s^2p^4$
85	At	Astatine	(210)	±1,3,5,7	610*	575	—	$[Xe]4f^{14}5d^{10}6s^2p^5$
86	Rn	Radon	(222)	0,2	211.4	202	9.73	$[Xe]4f^{14}5d^{10}6s^2p^6$
87	Fr	Francium	(223)	1	950	300	—	$[Rn]7s^1$
88	Ra	Radium	(226)	2	1413	973	5.0	$[Rn]7s^2$
89 ★★	Ac	Actinium	(227)	3	3470*	1324	10.07	$[Rn]6d^17s^2$
104	Rf	Rutherfordium	(261)		—	—	—	$[Rn]5f^{14}6d^27s^2$*
105	Db	Dubnium	(262)		—	—	—	$[Rn]5f^{14}6d^37s^2$*
106	Sg	Seaborgium	(263)		—	—	—	$[Rn]5f^{14}6d^47s^2$*
107	Bh	Bohrium	(264)		—	—	—	$[Rn]5f^{14}6d^57s^2$*
108	Hs	Hassium	(265)		—	—	—	$[Rn]5f^{14}6d^67s^2$*
109	Mt	Meitnerium	(268)		—	—	—	$[Rn]5f^{14}6d^77s^2$*
110	Uun	(Ununnilium)	(269)		—	—	—	$[Rn]5f^{14}6d^87s^2$*
111	Uuu	(Unununium)	(272)		—	—	—	$[Rn]5f^{14}6d^97s^2$*
112	Uub	(Ununbium)	(277)		—	—	—	$[Rn]5f^{14}6d^{10}7s^2$*
113		(Ununtrium)						
114	Uuq	(Ununquadium)	(285)		—	—	—	$[Rn]5f^{14}6d^{10}7s^27p^2$*
115		(Ununpentium)						
116	Uuh	(Ununhexium)	(289)		—	—	—	[illegible]
117		(Ununseptium)						
118	Uuo	(Ununoctium)	(293)		—	—	—	$[Rn]5f^{14}6d^{10}7s^27p^6$*

* Estimated Values

Atomic number	Symbol	Name	Atomic weight (2)	Oxidation states	Boiling point, K	Melting point, K	Density at 300 K (3) (g/cm³)	Electron configuration
★ 58	Ce	Cerium	140.12	3,4	3715	1071	6.77	$[Xe]4f^15d^16s^2$
59	Pr	Praseodymium	140.9077	3,4	3785	1204	6.77	$[Xe]4f^36s^2$
60	Nd	Neodymium	144.24	3	3347	1294	7.01	$[Xe]4f^46s^2$
61	Pm	Promethium	(145)	3	3273	1315	7.22	$[Xe]4f^56s^2$
62	Sm	Samarium	150.36	3,2	2067	1347	7.52	$[Xe]4f^66s^2$
63	Eu	Europium	151.964	3,2	1800	1095	5.24	$[Xe]4f^76s^2$
64	Gd	Gadolinium	157.25	3	3545	1585	7.90	$[Xe]4f^75d^16s^2$
65	Tb	Terbium	158.9253	3,4	3500	1629	8.23	$[Xe]4f^96s^2$
66	Dy	Dysprosium	162.50	3	2840	1685	8.55	$[Xe]4f^{10}6s^2$
67	Ho	Holmium	164.9303	3	2968	1747	8.80	$[Xe]4f^{11}6s^2$
68	Er	Erbium	167.26	3	3140	1802	9.07	$[Xe]4f^{12}6s^2$
69	Tm	Thulium	168.9342	3,2	2223	1818	9.32	$[Xe]4f^{13}6s^2$
70	Yb	Ytterbium	173.04	3,2	1469	1092	6.97	$[Xe]4f^{14}6s^2$
71	Lu	Lutetium	174.967	3	3668	1936	9.84	$[Xe]4f^{14}5d^16s^2$
★★ 90	Th	Thorium	232.0381	4	5060	2028	11.72	$[Rn]6d^27s^2$
91	Pa	Protactinium	231.0359	5,4	4300*	1845	15.4	$[Rn]5f^26d^17s^2$
92	U	Uranium	238.029	6,5,4,3	4407	1408	18.95	$[Rn]5f^36d^17s^2$
93	Np	Neptunium	(237)	6,5,4,3	4175*	912	20.2	$[Rn]5f^46d^17s^2$
94	Pu	Plutonium	(244)	6,5,4,3	3505	913	19.84	$[Rn]5f^67s^2$
95	Am	Americium	(243)	6,5,4,3	2880	1449	13.7	$[Rn]5f^77s^2$
96	Cm	Curium	(247)	3	—	1620	13.5	$[Rn]5f^76d^17s^2$
97	Bk	Berkelium	(247)	4,3	—	—	14*	$[Rn]5f^97s^2$
98	Cf	Californium	(251)	3	—	1170*	—	$[Rn]5f^{10}7s^2$
99	Es	Einsteinium	(252)	3	—	1130*	—	$[Rn]5f^{11}7s^2$
100	Fm	Fermium	(257)	3	—	1800*	—	$[Rn]5f^{12}7s^2$
101	Md	Mendelevium	(258)	3	—	1100*	—	$[Rn]5f^{13}7s^2$
102	No	Nobelium	(259)	2,3	—	1100*	—	$[Rn]5f^{14}7s^2$
103	Lr	Lawrencium	(262)	3	—	1900*	—	$[Rn]5f^{14}6d^17s^2$

KEY

ATOMIC NUMBER: 30
ATOMIC WEIGHT (2): 65.39
OXIDATION STATES (Bold most stable): 2
BOILING POINT, K: 1180
MELTING POINT, K: 692.73
DENSITY at 300 K (3) (g/cm³): 7.13
SYMBOL: Zn
ELECTRON CONFIGURATION: $[Ar]3d^{10}4s^2$
NAME: Zinc

NOTES:

(1) Black — solid.
Red — gas.
Blue — liquid.
Outline — synthetically prepared.

(2) Based upon carbon-12. ( ) indicates most stable or best known isotope.

(3) Entries marked with daggers refer to the gaseous state at 273 K and 1 atm and are given in units of g/l.

The A & B subgroup designations, are those recommended by the International Union of Pure and Applied Chemistry.

Catalog Number WLS-18806

VWR Sargent-Welch
Scientific Products
P.O. Box 5229, Buffalo Grove, IL 60089-5229
1-800-727-4368 FAX 1-800-676-2540

Common Polyatomic Ions

Anions

1–

acetate, CH_3COO^-
amide, NH_2^-
azide, N_3^-
benzoate, $C_6H_5COO^-$
bromate, BrO_3^-
chlorate, ClO_3^-
chlorite, ClO_2^-
cyanate, OCN^-
cyanide, CN^-
dihydrogen phosphate, H_2PO_4
formate, $HCOO^-$
hydrogen carbonate, HCO_3^-
(bicarbonate)
hydrogen sulfate, HSO_4^-
(bisulfate)
hydrogen sulfide, HS^-
(bisulfide or hydrosulfide)
hydroxide, OH^-
(called hydroxyl when aqueous)
hypochlorite, ClO^-
iodate, IO_3^-
nitrate, NO_3^-
nitrite, NO_2^-
perchlorate, ClO_4^-
permanganate, MnO_4^-
thiocyanate, SCN^-
(thiocyanato)
triiodide, I_3^-
vanadate, VO_3^-

2–

carbide, C_2^{2-}
(saltlike)
carbonate, CO_3^{2-}
chromate, CrO_4^{2-}
dichromate, $Cr_2O_7^{2-}$
imide, NH^{2-}
manganate, MnO_4^{2-}
metasilicate, SiO_3^{2-}
monohydrogen phosphate, HPO_4^{2-}
oxalate, $C_2O_4^{2-}$
peroxide, O_2^{2-}
peroxydisulfate, $S_2O_8^{2-}$
phthalate, $C_8H_4O_4^{2-}$
polysulfide, S_x^{2-}
selenate, SeO_4^{2-}
sulfate, SO_4^{2-}
sulfite, SO_3^{2-}
tartrate, $C_4H_4O_6^{2-}$
tellurate, TeO_4^{2-}
tetraborate, $B_4O_7^{2-}$
thiosulfate, $S_2O_3^{2-}$
tungstate, WO_4^{2-}
zincate, ZnO_2^{2-}

3–

aluminate, AlO_3^{3-}
arsenate, AsO_4^{3-}
borate, BO_3^{3-}
citrate, $C_6H_5O_7^{3-}$
phosphate, PO_4^{3-}

4–

orthosilicate, SiO_4^{4-}
pyrophosphate, $P_2O_7^{4-}$

5–

tripolyphosphate, $P_3O_{10}^{5-}$

Cations

1+

ammonium, NH_4^+
hydronium, H_3O^+

Name ______________________ Class __________ Date ____________

Significant Figures

See Section 1.18.

The ***significant figures*** *in a measurement expression are all the digits that are known with certainty, plus the first digit that is uncertain.* Significant figures indicate the uncertainty of a measurement. The measurement 5.83 cm is precise to the second decimal place. The digit 3 is the last significant figure and the first uncertain digit. 5.83 cm contains *three* significant figures.

All nonzero digits in a measurement are always significant. Zero, however, is not always a digit. Sometimes, zero is a placeholder. When a zero is a placeholder, it is not a significant figure. The following rules will assist you in determining whether a zero is a significant figure or a placeholder.

Rule	Measurement expression	Significant figures
1. All nonzero digits **are** significant.	83.591 m	5
2. All zeros between two nonzero digits **are** significant.	5007 L	4
	10.0005 g	6
3. Zeros to the **right** of a nonzero digit, but to the **left** of an understood decimal point, are **not** significant **unless** specifically indicated as significant by a bar placed above the rightmost such zero that is significant.	200,800 km	4
	$200,8\bar{0}0$ km	5
	$200,80\bar{0}$ km	6
	1,000,000 g	1
4. All zeros to the **right** of a decimal point but to the **left** of a nonzero digit are **not** significant. A lone zero to the left of a decimal point is never significant.	0.00012 g	2
	0.853 m	3
5. All zeros to the **right** of a decimal point and to the **right** of a nonzero digit **are** significant.	40.00 g	4
	0.005070 kg	4

Sample Problem 1
How many significant figures are there in 21.589 m?

According to rule 1, all **nonzero** digits are significant. There are **five** significant figures.

Sample Problem 2
How many significant figures are there in 28005 km?

According to rule 2, all zeros between two nonzero digits **are** significant. There are **five** significant figures.

Sample Problem 3
How many significant figures are there in 0.00025 kg?

According to rule 4, zeros to the **right** of a **decimal** but to the **left** of a **nonzero** number **are not** significant. Also, the lone zero before the decimal point is never significant. There are only **two** significant figures.

Sample Problem 4
How many significant figures are there in 23,000 L?

According to rule 3, all zeros to the **right** of a nonzero digit but to the **left** of an understood decimal point are **not** significant. The only exception is indicated by a bar placed over the rightmost of the significant zeros. Since there is no bar, there are only **two** significant figures.

Sample Problem 5
How many significant figures are there in 80.0 cm?

According to rule 5, all zeros to the **right** of a **decimal** point and to the **right** of a **nonzero** digit are significant. The last zero is to the right of both the decimal point and a nonzero digit (8). The zero immediately following the "8" is not to the right of the decimal. But this zero is between two significant figures. This zero, therefore, must also be significant. There are **three** significant figures.

Name ______________________ Class __________ Date __________

Problems

Indicate the number of significant figures in each of the following measurements.

1. 28,875 m [redacted]	**5.** 0.81 g [redacted]
2. 0.00051 kg [redacted]	**6.** 51.2000 m [redacted]
3. 258,000 km [redacted]	**7.** 2.00 g [redacted]
4. 505,100 cm [redacted]	**8.** 0.00500 kg [redacted]

Operations with Significant Figures

See Section 1.20.

Suppose you wished to multiply 24 cm by 318 cm. How many significant figures should the answer contain? The result of calculations involving measurements can only be as precise as the least precise measurement. In the above problem the answer can only have two significant figures. The following rules will enable you to determine the number of significant figures in the result of calculations involving measurements.

Rule 1—Multiplication and Division

The product or quotient contains the same number of significant figures as the measurement with the least number of significant figures.

NOTE: The position of the decimal point *does not* determine the precision of the answer.

Sample Problem 1

Determine the precision of the product of 24 cm × 31.8 cm.

24 cm	×	31.8 cm	=	763.2 cm^2
2 significant figures		3 significant figures		4 significant figures

Since the least precise measurement has only **two** significant figures, the answer must have only **two.** 763.2 cm^2 is rounded off to 760 cm^2. Is the zero a significant figure or a place holder?

Sample Problem 2

Determine the correct number of significant figures for the quotient of 8.40 g ÷ 4.2 mL.

8.40 g	÷	4.2 mL	=	2 g/mL
3 significant figures		2 significant figures		1 significant figure

The least precise measurement has **two** significant figures. The quotient must have **two.** Since there is only one significant figure, another digit must be added without changing the value of the result. The correct answer is 2.0 g/mL. The numerical value is the same, but the number of significant figures is now **two.** Is the zero a significant figure or a place holder?

Rule 2—Addition and Subtraction

The sum or difference has the same number of decimal places as the measurement with the ***least*** *number of decimal places.*

NOTE: The position of the decimal point determines the precision of the answer.

Sample Problem 3

Determine the precision of the sum of 49.1 g + 8.001 g.

49.1 g	+	8.001 g	=	57.101 g
1 decimal place		3 decimal places		3 decimal places

The least precise measurement has only one decimal place. The answer must have only **one** decimal place. Round off 57.101 g to 57.1 g.

Name ______________________ Class ________ Date ________

Sample Problem 4

Determine the precision of the difference of 81.350 m − 7.35 m.

81.350 m	−	7.35 m	=	74 m
3 decimal places		2 decimal places		0 decimal places

The least precise measurement has **two** decimal places. The answer must have **two** decimal places. The correct precision of the answer is 74.00 m. Did the value of the number change? Are the zeros significant figures or placeholders?

Problems

The following problems have been performed on a calculator. Rewrite the answers so that they have the correct precision.

1. 1.25 g × 8.6°C = 10.75 g°C *ans.* [redacted]
2. 100.00 g ÷ 25.0 mL = 4 g/mL *ans.* [redacted]
3. 500.00 cm × 40.00 cm = 20,000 cm^2 *ans.* [redacted]
4. 38 cm + 5.100 cm + 4.13 cm = 47.23 cm *ans.* [redacted]
5. 716.55 g − 0.005 g = 716.545 g *ans.* [redacted]
6. 28.00 g ÷ 85.2 cm^3 = 0.3286385 g/cm^3 *ans.* [redacted]
7. 8.000 km − 0.54 km = 7.46 km *ans.* [redacted]
8. 23.18 m + 6.819 m = 29.999 m *ans.* [redacted]

Name ______________________ Class __________ Date __________

Scientific Notation

See Sections 1.19, 1.20.

A number written in scientific notation is written in the form

$$M \times 10^n$$

where M is a number equal to or greater than one and less than ten. M must always have only one digit (other than 0) to the left of the decimal point. n is an integer. The following numbers are in correct scientific notation:

$$1 \times 10^5,\ 3.58 \times 10^{-6},\ 9.9 \times 10^{15}$$

The numbers 12×10^6 and 0.58×10^{-3} are not in scientific notation because M does not have a single digit other than zero to the left of the decimal point.

Sample Problem 1
Write 17,500 in scientific notation.

Step 1: Determine M by moving the decimal point in the original number to the left or right so that only one nonzero digit is to the left of the decimal.

1.7500

Step 2: Determine n by counting the number of places the decimal point has been moved. If moved to the left, n is positive; if moved to the right, n is negative.

1.7500
4 3 2 1
<---- 4 places to the left

$$17{,}500 = 1.75 \times 10^4$$

NOTE: In scientific notation all digits in M are significant. The zeros in this problem were placeholders.

Sample Problem 2
Write 0.0050 in scientific notation.

Step 1: 0.005.0

Step 2: 0.005.0
123
3 places to the right --->

$$0.0050 = 5.0 \times 10^{-3}$$

Note that the zero was retained. Why?

When performing mathematical operations with numbers in scientific notation, the rules for exponents apply. The following is a summary of those rules.

1. Multiplication—multiply the M's and add the n's.
2. Division—divide the M's and subtract the n's.
3. Addition—all numbers must be changed to the same value of n. Add the M's and attach the common value of n.
4. Subtraction—both numbers must have the same value of n. Subtract the M's and attach the common value of n.

Sample Problem 3
Find the product of $(3.0 \times 10^5)(5.0 \times 10^{-2})$.

$$(3.0 \times 10^5)(5.0 \times 10^{-2}) = (3.0 \times 5.0) \times 10^{5+(-2)} = 15 \times 10^3 = 1.5 \times 10^4$$

Note that the answer—15×10^3—would not be in scientific notation. The decimal must be moved one place to the **left** and n **increased** by one.

Name ______________________ Class __________ Date __________

Sample Problem 4

Find the quotient:

$$\frac{3.5 \times 10^{-3}}{8.1 \times 10^{4}}$$

$$\frac{3.5 \times 10^{-3}}{8.1 \times 10^{4}} = \frac{3.5}{8.1} \times 10^{-3-(+4)} = 0.43 \times 10^{-7} = 4.3 \times 10^{-8}$$

Note that the answer—0.43×10^{-7}—would not be in scientific notation. The decimal must be moved one place to the **right** and n *decreased* by **one.**

Sample Problem 5

Find the sum:

$$\begin{array}{r} 8.3 \times 10^{2} \\ + \underline{5.7 \times 10^{3}} \end{array}$$

Before adding, the n's must be the **same.** It is more convenient to change the lower value of n to the higher value.

$8.3 \times 10^2 = 0.8.3 \times 10^3$ <——— n increased by **one**
1 place to the left

$$\begin{array}{r} 0.83 \times 10^{3} \\ + \underline{5.7 \quad \times 10^{3}} \\ 6.53 \times 10^{3} \end{array} = 6.5 \times 10^{3}$$

Why must the last digit (3) be dropped?

Sample Problem 6

Find the difference:

$$\begin{array}{r} 6.7 \times 10^{5} \\ - \underline{9.2 \times 10^{4}} \end{array}$$

Raise the lower value of n to the higher value of n.

$9.2 \times 10^4 = 0.9.2 \times 10^5$ <——— n increased by **one**
1 place to the left

$$\begin{array}{r} 6.7 \quad \times 10^{5} \\ - \underline{0.92 \times 10^{5}} \\ 5.78 \times 10^{5} \end{array} = 5.8 \times 10^{5}$$

Problems

1. Convert 0.00800 to scientific notation. [redacted]
2. Convert 1,680,000 to scientific notation. [redacted]
3. Find the sum: $\begin{array}{r} 3.8 \times 10^{5} \\ - \underline{4.5 \times 10^{5}} \end{array}$ [redacted]
4. Find the product: $(7.0 \times 10^{4})(6.0 \times 10^{4})$ [redacted]
5. Find the product: $(8.2 \times 10^{-5})(3.7 \times 10^{9})$ [redacted]
6. Find the quotient: $\dfrac{8.35 \times 10^{8}}{3.2 \times 10^{3}}$ [redacted]
7. Find the quotient: $\dfrac{2.15 \times 10^{3}}{8.2 \times 10^{-3}}$ [redacted]
8. Find the difference: $\begin{array}{r} 1.8 \times 10^{8} \\ - \underline{5.[illegible] \times 10^{7}} \end{array}$ [redacted]
9. Find the difference: $\begin{array}{r} 9.[illegible] \times 10^{-5} \\ - \underline{9.[illegible] \times 10^{-6}} \end{array}$ [redacted]

Name ______________________ Class __________ Date __________

Metric System

See Section 1.12.

The following conversion factors will be very useful in making metric conversions.

$$\frac{1000\text{ mm}}{1\text{ m}} \text{ or } \frac{1\text{ m}}{1000\text{ mm}}$$

$$\frac{100\text{ cm}}{1\text{ m}} \text{ or } \frac{1\text{ m}}{100\text{ cm}}$$

$$\frac{1000\text{ m}}{1\text{ km}} \text{ or } \frac{1\text{ km}}{1000\text{ m}}$$

These conversion factors can be used for grams and liters as well as meters.

Sample Problem 1
Convert 112 cm to m.

map $\quad \text{cm} \xrightarrow{\frac{\text{m}}{\text{cm}}} \text{m}$

conversion factor $\quad \dfrac{1\text{ m}}{100\text{ cm}}$

Solution: $\quad 112\ \cancel{\text{cm}} \times \dfrac{1\text{ m}}{100\ \cancel{\text{cm}}} = 1.12\text{ m}$

Sample Problem 2
Convert 21,510 mL to L.

map $\quad \text{mL} \xrightarrow{\frac{\text{L}}{\text{mL}}} \text{L}$

conversion factor $\quad \dfrac{1\text{ L}}{1000\text{ mL}}$

Solution: $\quad 21{,}510\ \cancel{\text{mL}} \times \dfrac{1\text{ L}}{1000\ \cancel{\text{mL}}} = 21.51\text{ L}$

Sample Problem 3
Convert 2.18 kg to g.

map $\quad \text{kg} \xrightarrow{\frac{\text{g}}{\text{kg}}} \text{g}$

conversion factor $\quad \dfrac{1000\text{ g}}{1\text{ kg}}$

Solution: $\quad 2.18\ \cancel{\text{kg}} \times \dfrac{1000\text{ g}}{1\ \cancel{\text{kg}}} = 2180\text{ g}$

Sample Problem 4
Convert 208,182 cm to km.

map $\quad \text{cm} \xrightarrow{\frac{\text{m}}{\text{cm}}} \text{m} \xrightarrow{\frac{\text{km}}{\text{m}}} \text{km}$

conversion factors $\quad \dfrac{1\text{ m}}{100\text{ cm}} \qquad \dfrac{1\text{ km}}{1000\text{ m}}$

Solution: $\quad 208{,}182\ \cancel{\text{cm}} \times \dfrac{1\ \cancel{\text{m}}}{100\ \cancel{\text{cm}}} \times \dfrac{1\text{ km}}{1000\ \cancel{\text{m}}} = 2.08182\text{ km}$

Problems for Modern Chemistry
Holt, Rinehart and Winston, Publishers

Name ______________________ Class __________ Date __________

Problems

1. 2118 mL = __?__ L [redacted]
2. 0.015 L = __?__ mL [redacted]
3. 52.5 m = __?__ mm [redacted]
4. 22.7 cg = __?__ g [redacted]
5. 102 g = __?__ mg [redacted]
6. 45.2 mm = __?__ cm [redacted]
7. 22,100 mm = __?__ km [redacted]
8. 0.025 kg = __?__ cg [redacted]

Name ______________________ Class __________ Date __________

Density

See Sections 1.7, 1.13.

Density is mass per unit volume:

$$D = \frac{m}{V}$$

where: D = density
m = mass
V = volume

The most common units of density are g/cm^3 and g/mL ($1\ cm^3 = 1$ mL). Since the units are expressed as a quotient, density can be used as a conversion factor between mass and volume.

Sample Problem 1

What is the density of an object whose mass is 25.5 g and that displaces 6.2 mL of water?

map $\quad g \xrightarrow{\frac{1}{mL}} \frac{g}{mL}$

conversion factor $\quad \frac{1}{6.2\ mL}$

Solution: $\quad 25.5\ g \times \frac{1}{6.2\ mL} = 4.1\ \frac{g}{mL}$

Sample Problem 2

A rock has a density of $4.85\ g/cm^3$. What is its mass if it displaces $22.5\ cm^3$ of water?

map $\quad cm^3 \xrightarrow{\frac{g}{cm^3}} g$

conversion factor $\quad \frac{4.85\ g}{1\ cm^3}$

Solution: $\quad 22.5\ \cancel{cm^3} \times \frac{4.85\ g}{1\ \cancel{cm^3}} = 109\ g$

Sample Problem 3

What is the volume of 58.3 g of a liquid if its density is $0.788\ g/cm^3$?

map $\quad g \xrightarrow{\frac{cm^3}{g}} cm^3$

conversion factor $\quad \frac{1\ cm^3}{0.788\ g}$

Solution: $\quad 58.3\ \cancel{g} \times \frac{1\ cm^3}{0.788\ \cancel{g}} = 74.0\ cm^3$

Problems

1. What is the density of a liquid with a mass of 25.0 g and a volume of $30.0\ cm^3$? [redacted]
2. A student determines that the mass of a metal rod is 12.0 g. He places 10.0 mL of water in a 25 mL graduated cylinder. When the metal rod is placed in the water, the graduated cylinder then reads 15.0 mL. What is the density of the metal rod? [redacted]
3. The density of sulfuric acid is $1.84\ g/cm^3$. What is the mass of $75.0\ cm^3$ of sulfuric acid? [redacted]
4. The density of alcohol at 20 °C is $0.78945\ g/cm^3$. What volume would be required to obtain 100.0 g of alcohol? [redacted]
5. What volume would be required in Problem 4 if 1.00 **kg** were used? [redacted]
6. How many grams are there in 1.00 **L** of alcohol? (Remember: 1 mL = $1\ cm^3$.) [redacted]

Problems for Modern Chemistry
Holt, Rinehart and Winston, Publishers