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ach generation has its unique needs and aspirations. When Charles Wiley first opened his small printing shop in lower Manhattan in 1807, it was a generation of boundless potential searching for an identity. And we were there, helping to define a new American literary tradition. Over half a century later, in the midst of the Second Industrial Revolution, it was a generation focused on building the future. Once again, we were there, supplying the critical scientific, technical, and engineering knowledge that helped frame the world. Throughout the 20th Century, and into the new millennium, nations began to reach out beyond their own borders and a new international community was born. Wiley was there, expanding its operations around the world to enable a global exchange of ideas, opinions, and know-how.

For 200 years, Wiley has been an integral part of each generation's journey, enabling the flow of information and understanding necessary to meet their needs and fulfill their aspirations. Today, bold new technologies are changing the way we live and learn. Wiley will be there, providing you the must-have knowledge you need to imagine new worlds, new possibilities, and new opportunities.

Generations come and go, but you can always count on Wiley to provide you the knowledge you need, when and where you need it!

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	Group						Per	Periodic Table of the Elements	Fable (of the J	∃lemeı	nts						Noble Gases
	1 1A		Current ACS and IUPAC Preferred U.S.	IUPAC													'	18 8A
1	\mathbf{H}^{-1}			Atc	Atomic number-	ıber→	11 Z	Atomic n carbon-12	Atomic masses are based on carbon-12. Elements marked with # have no stable isotone	Atomic masses are based on carbon-12. Elements marked with † have no stable isotones								2 He
	1.008	2 2A		Na Afc	Name———Atomic mass		Sodium 22 99	The atom of the isol	ic mass gi	The atomic mass given is that of the isotope with the longest			13 3A	14 4A	15 5A	16 6A	17 7A	Helium 4.003
7	3 Li Lithium 6.941	Be Beryllium 9.012					():17	known half-life.	lf-life.	0			5 B Boron 10.81	6 C Carbon 12.01	7 N Nitrogen 14.01	8 O 0xygen 16.00	9 F Huorine 19.00	10 Neon Neon 20.18
(*)	11 N	12 Mg	•			— Traı	Transition Elements	Elemen 8		10		1	13 A	4 2	15 P	92	L1 2	18 Ar
•	Sodium 22.99	Magnesium 24.31	3 3B	4 P	5 5B	6 6B	7 7B		₩ {		11 11B	12 2 B	Aluminum 26.98	Silicon 28.09	Phosphorus 30.97	Sulfur 32.07	Chlorine 35.45	Argon 39.95
boiraq 4	19 K Potassium 39.10	20 Ca Calcium 40.08	21 Sc Scandium 44.96	22 Ti Titanium 47.87	23 V Vanadium 50.94	24 Cr Chromium 52.00	25 Mm Manganese 54.94	26 Fe Iran 55.85	27 Co Cobalt 58.93	28 Ni Nickel 58.69	29 Cu (opper	30 Zn Zinc 25.39	31 Ga Gallium 69.72	32 Ge Germanium 72.61	33 As Arsenic 74.92	34 Se Selenium 78.96	35 Br Bromine 79.90	36 Kr Krypton 83.80
w	37 Rb Rubidium 85.47	38 Sr Strontium 87.62	39 Y Yffrium 88.91	40 Zr Zirconium 91.22		42 Mo Molybdenum 95.94		44 Ru Ruthenium 101.1	45 Rh Rhodium 102.9	46 Pdladium 106.4	47 Ag Silver 107.9	48 Cd Cadmium 112.4		50 Sn Tin 118.7	51 Sb Antimony 121.8	52 Te Tellurium 127.6	53 I lodine 126.9	54 Xe Xenon 131.3
9	55 Cs Cesium 132.9	56 Ba Barium 137.3	57 ** La Lanthanum 138.9	Hf Hafnium 178.5	73 Ta Iantalum 180.9	74 W Iungsten 183.8	75 Re Rhenium 186.2	76 Os 0smium 190.2	77 Ir Iridium 192.2	78 Pt Platinum 195.1	79 Au 60ld 197.0	80 Hg Mercury 200.6	81 TI Thallium 204.4	82 Pb Lead 207.2	83 Bis Bismuth 209.0	84 Po Polonium 209†	85 At Astutine 210†	86 Rn Radon 222†
7	87 Fr Francium 223†	88 Ra Radium 226†	89 ** Ac Actinium 227 [†]	Rutherfordium 261	105 Db Dubnium 262†	Sg Seaborgium 266†	107 Bh Bohrium 264†	108 Hs Hassium 277†	$\frac{109}{\mathbf{Mt}}$ Meitherium 268^{\dagger}	110 DS Darmstadtium 1 271†	111 Rg Roentgenium 272†	colors i s or s	ors indicate p s orbitals p orbitals	olacement of the disconnection	of the oritals	utermost	colors indicate placement of the outermost electrons s orbitals dorbitals forbitals	
														<u></u>				

Inner Transition Elements

nthanide Series	58 Ce Cerium 140.1	59 Pr Praseodymium 140.9	60 Nd Neodymium 144.2	61 Pm Promethium 145 [‡]	62 Sm Samarium 150.4	63 Eu Europium 152.0	64 Gd Gadolinium 157.3	65 Tb Terbium 158.9	66 Dy Dysprosium 162.5	67 Ho Holmium 164.9	68 Er Erbium 167.3	69 Tm Ihulium 168.9	70 Y b Ytterbium 173.0	71 Lu Lutetium 175.0
** Actinide Series 7	90 Th Thorium 232.0	Pa Protectinium 231.0	92 U Uranium 238.0	93 Np	Pu Plutonium 244	95 Am Americium 243 [‡]	96 Cm Curium 247†	97 Bk Berkelium 247 [†]	98 Cf Californium 251	99 Es Einsteinium 252†	100 Fm Fermium 257†	101 Md Mendelevium 258†	No Nobelium 259†	$\begin{array}{c} 103 \\ \textbf{Lr} \\ \textbf{Lowrendum} \\ 262^{\dagger} \end{array}$

Atomic Masses of the Elements Based on the 2005 IUPAC Table of Atomic Masses

Name	Symbol	Atomic Number	Atomic Mass	Name	Symbol	Atomic Number	Atomic Mass
Actinium*	Ac	89	227	Meitnerium*	Mt	109	268
Aluminum	Al	13	26.981538	Mendelevium*	Md	101	258
Americium*	Am	95	243	Mercury	Hg	80	200.59
Antimony	Sb	51	121.760	Molybdenum	Mo	42	95.94
Argon	Ar	18	39.948	Neodymium	Nd	60	144.24
Arsenic	As	33	74.92160	Neon	Ne	10	20.1797
Astatine*	At	85	210	Neptunium*	Np	93	237
Barium	Ba	56	137.327	Nickel	Ni	28	58.6934
Berkelium*	Bk	97	247	Niobium	Nb	41	92.90638
Beryllium	Be	4	9.012182	Nitrogen	N	7	14.00674
Bismuth	Bi	83	208.98038	Nobelium*	No	102	259
Bohrium*	Bh	107	264	Osmium	Os	76	190.23
Boron	В	5	10.811	Oxygen	0	8	15.9994
Bromine	Br	35	79.904	Palladium	Pd	46	106.42
Cadmium	Cd	48	112.411	Phosphorus	P	15	30.973762
Calcium	Ca	20	40.078	Platinum	Pt	78	195.078
Californium*	Cf	98	251	Plutonium*	Pu	94	244
Carbon	C	6	12.0107	Polonium*	Po	84	209
Cerium	Ce	58	140.116	Potassium	K	19	39.0983
Cesium	Cs	55	132.90545	Praseodymium	Pr	59	140.90765
Chlorine	Cl	17	35.4527	Promethium*	Pm	61	145
Chromium	Cr	24	51.9961	Protactinium	Pa	91	231.03588
Cobalt	Co	27	58.933200	Radium*	Ra	88	226
Copper	Cu	29	63.546	Radon*	Rn	86	222
Curium*	Cm	96	247	Rhenium	Re	75	186.207
Darmstadtium*	Ds	110	271	Rhodium	Rh	45	102.90550
Dubnium*	Db	105	262	Roentgenium*	Rg	111	272
Dysprosium	Dy	66	162.500	Rubidium	Rb	37	85.4678
Einsteinium*	Es	99	252	Ruthenium	Ru	44	101.07
Erbium	Er	68	167.26	Rutherfordium*	Rf	104	261
Europium	Eu	63	151.964	Samarium	Sm	62	150.36
Fermium*	Fm	100	257	Scandium	Sc	21	44.955910
Fluorine	F	9	18.9984032	Seaborgium*	Sg	106	266
Francium*	Fr	87	233	Selenium	Se	34	78.96
Gadolinium	Gd	64	157.25	Silicon	Si	14	28.0855
Gallium	Ga	31	69.723	Silver	Ag	47	107.8682
Germanium	Ge	32	72.61	Sodium	Na	11	22.989770
Gold	Au	79	196.96655	Strontium	Sr	38	87.62
Hafnium	Hf	72	178.49	Sulfur Tantalum	S Ta	16 73	32.066 180.9479
Hassium*	Hs	108	277	Technetium*		73 43	180.9479 98
Helium	He	2	4.002602	Tellurium	Tc Te	43 52	127.60
Holmium	Но	67	164.93032	Terbium	Tb	65	158.92534
Hydrogen	Н	1	1.00794	Thallium	Tl	81	204.3833
Indium	In	49	114.818	Thorium	Th	90	232.0381
Iodine	I	53	126.90447	Thulium	Tm	69	168.93421
Iridium	Ir	77	192.217	Tin	Sn	50	118.710
Iron	Fe	26	55.845	Titanium	Ti	22	47.867
Krypton	Kr	36	83.80	Tungsten	W	74	183.94
Lanthanum	La	57	138.9055	Uranium	Ü	92	238.0289
Lawrencium*	Lr	103	262	Vanadium	V	23	50.9415
Lead	Pb	82	207.2	Xenon	Xe	54	131.29
Lithium	Li	3	6.941	Ytterbium	Yb	70	173.04
Lutetium	Lu	71	174.967	Yttrium	Y	39	88.90585
Magnesium	Mg	12	24.3050	Zinc	Zn	30	65.39
Manganese	Mn	25	54.938049	Zirconium	Zr	40	91.224
0							

 $^{^{\}star}$ This element has no stable isotopes. The atomic mass given is that of the isotope with the longest known half-life.

	Names, Formulas, and Charges of Common lons								
	Positive lo	ns (Cations)		Negative Ions	s (Anions)				
1+	Ammonium Copper(I) (Cuprous) Hydrogen Potassium Silver Sodium Barium Cadmium Calcium Cobalt(II) Copper(II) (Cupric)	NH ₄ ⁺ Cu ⁺ H ⁺ K ⁺ Ag ⁺ Na ⁺ Ba ²⁺ Cd ²⁺ Ca ²⁺ Cv ²⁺ Cv ²⁺ Cu ²⁺	1-	Acetate Bromate Bromide Chlorate Chloride Chlorite Cyanide Fluoride Hydride Hydrogen carbonate (Bicarbonate) Hydrogen sulfate (Bisulfate)	$C_2H_3O_2^ BrO_3^ Br^ ClO_3^ Cl^ ClO_2^ CN^ F^ H^ HCO_3^-$				
2+	Iron(II) (Ferrous) Lead(II) Magnesium Manganese(II) Mercury(II) (Mercuric) Nickel(II) Tin(II) (Stannous) Zinc	Fe^{2+} Pb^{2+} Mg^{2+} Mn^{2+} Hg^{2+} Ni^{2+} Sn^{2+} Zn^{2+}		Hydrogen sulfite (Bisulfite) Hydroxide Hypochlorite Iodate Iodide Nitrate Nitrite Perchlorate Permanganate	HSO ₃ OH ⁻ CIO ⁻ IO ₃ I ⁻ NO ₃ NO ₂ CIO ₄ MnO ₄				
3+	Aluminum Antimony(III) Arsenic(III) Bismuth(III) Chromium(III) Iron(III) (Ferric) Titanium(III) (Titanous) Manganese(IV)	Al ³⁺ Sb ³⁺ As ³⁺ Bi ³⁺ Cr ³⁺ Fe ³⁺ Ti ³⁺ Mn ⁴⁺ Sn ⁴⁺	2-	Thiocyanate Carbonate Chromate Dichromate Oxalate Oxide Peroxide Silicate Sulfate Sulfide Sulfite	$\begin{array}{c} SCN^{-} \\ CO_{3}^{2-} \\ CrO_{4}^{2-} \\ Cr_{2}O_{7}^{2-} \\ C_{2}O_{4}^{2-} \\ O^{2-} \\ O_{2}^{2-} \\ SiO_{3}^{2-} \\ SO_{4}^{2-} \\ S^{2-} \\ SO_{3}^{2-} \end{array}$				
5+	Tin(IV) (Stannic) Titanium(IV) (Titanic) Antimony(V) Arsenic(V)	Sn ⁴⁺ Ti ⁴⁺ Sb ⁵⁺ As ⁵⁺	_3-	Arsenate Borate Phosphate Phosphide Phosphite	AsO ₃ ³⁻ BO ₃ ³⁻ PO ₄ ³⁻ PO ₃ ³⁻ PO ₃ ³⁻				

atto

Prefixes and Numerical Values for SI Units							
Prefix	Symbol	Numerical value	Power of 10 equivalent				
exa	Е	1,000,000,000,000,000,000	10^{18}				
peta	P	1,000,000,000,000,000	10^{15}				
tera	T	1,000,000,000,000	10^{12}				
giga	G	1,000,000,000	10^{9}				
mega	M	1,000,000	10^{6}				
kilo	k	1,000	10^{3}				
hecto	h	100	10^{2}				
deka	da	10	10^{1}				
_	_	1	10^{0}				
deci	d	0.1	10^{-1}				
centi	С	0.01	10^{-2}				
milli	m	0.001	10^{-3}				
micro	μ	0.000001	10^{-6}				
nano	n	0.000000001	10^{-9}				
pico	р	0.00000000001	10^{-12}				
femto	f	0.00000000000001	10^{-15}				
			10				

SI Units and Conversion Factors

0.0000000000000000001

 $10^{-15} \\ 10^{-18}$

Leng	ţth			Mass			Vo	lume
SI unit: me	eter (m)	s	l un	it: kilogram (kg)	S	SI unit	: cu	bic meter (m³)
1 meter =	1000 millimeters	1 kilogram	=	1000 grams	1 lite	er	=	1000 milliliters
=	1.0936 yards	, and the second	=	2.20 pounds			=	$10^{-3}\mathrm{m}^3$
1 centimeter =	0.3937 inch	1 gram	=	1000 milligrams			=	$1 \mathrm{dm}^3$
1 inch = 2	2.54 centimeters	1 pound	=	453.59 grams			=	1.0567 quarts
	(exactly)		=	0.45359 kilogram	1 gal	llon		4 quarts
1 kilometer =	0.62137 mile		=	16 ounces	0			8 pints
1 mile = .	5280 feet	1 ton	=	2000 pounds				3.785 liters
=	1.609 kilometers		=	907.185 kilograms	1 qu	art	=	32 fluid ounces
1 angstrom =	10^{-10} meter	1 ounce		28.3 grams	•		=	0.946 liter
		1 atomic					=	4 cups
		mass unit	=	1.6606×10^{-27} kilograms	1 flu	id		*
					οι	ınce	=	29.6 mL

Temperature	Energy	Pressure
SI unit: kelvin (K)	SI unit: joule (J)	SI unit: pascal (Pa)
0 K = -273.15°C = -459.67 °F	1 joule = $1 \text{ kg m}^2/\text{s}^2$ = 0.23901 calorie	1 pascal = 1 kg/(ms ²) 1 atmosphere = 101.325 kilopascals
$K = {}^{\circ}C + 273.15$	1 calorie = 4.184 joules	= 760 torr = 760 mm Hg
$^{\circ}C = \frac{(^{\circ}F - 32)}{1.8}$		= 14.70 pounds
$^{\circ}$ C = $\frac{5}{9}$ ($^{\circ}$ F - 32)		per square inch (psi)
$^{\circ}F = 1.8(^{\circ}C) + 32$		



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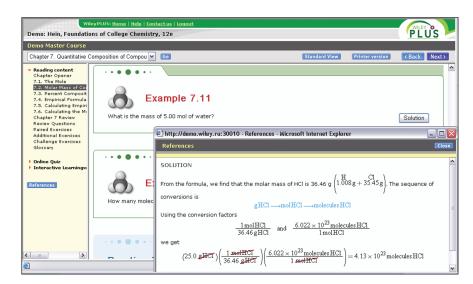
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Foundations of College Chemistry

ALTERNATE TWELFTH EDITION

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Mount San Antonio College

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University of Illinois, Urbana-Champaign



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An Education isn't how much you have committed to memory, or even how much you know. It's being able to differentiate between what you do know and what you don't. It's knowing where to go to find out what you need to know; and it's knowing how to use the information once you get it.

William Feather

For Our Future Generations

Dillon Brayden Prum

Great-grandson of Morris Hein

Jessica, Joshua, Moriah and David Hendrie

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Alexander Wettergren

Grandchildren of Susan Arena

ABOUT THE AUTHORS

Morris Hein is professor emeritus of chemistry at Mt. San Antonio College, where he regularly taught the preparatory chemistry course and organic chemistry. He is the original author of *Foundations of College Chemistry* and his name has become synonymous with clarity, meticulous accuracy, and a step-by-step approach that students can follow. Over the years, more than three million students have learned chemistry using a text by Morris Hein. In addition to *Foundations of College Chemistry*, Twelfth Edition, he is co-author of *Introduction to General*, *Organic, and Biochemistry*, Eighth Edition, and *Introduction to Organic and Biochemistry*. He is also co-author of *Foundations of Chemistry in the Laboratory*, Twelfth Edition, and *Introduction to General*, *Organic and Biochemistry in the Laboratory*, Eighth Edition.

Susan Arena earned a BS and MA in Chemistry at California State University-Fullerton. She has taught science and mathematics at all levels, including middle school, high school, community college, and university. At the University of Illinois she developed a program for increasing the retention of minorities and women in science and engineering. This program focused on using active learning and peer teaching to encourage students to excel in the sciences. She has coordinated and led workshops and progrms for science teachers from elementary through college levels that encourage and support active learning and creative science teaching techniques. For several years she was director of an Institute for Chemical Education (ICE) field center in Southern California. Susan enjoys reading, knitting, traveling, classic cars, and gardening in her spare time when she is not playing with her grandchildren.