SLABAUGH & PARSONS

GENERAL CHEMISTRY

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TABLE OF ATOMIC WEIGHTS

Element	Symbol	Atomic Number	Atomic Weight	Element	Symbol	Atomic Number	Atomic Weight	Element	Symbol	Atomic Number	Atomic Weight
Actinium	Ac	89	227	Hafnium	Hf	72	178.49	Promethium	Pm	61	147
Aluminum	Al	13	26.9815	Helium	He	2	4.0026	Protactinium	Pa	91	231
Americium	Am	95	243	Holmium	Ho	67	164.930	Radium	Ra	88	226
Antimony	Sb	51	121.75	Hydrogen	H	1	1.00797	Radon	Rn	86	222
Argon	Ar	18	39.948	Indium	In	49	114.82	Rhenium	Re	75	186.2
Arsenic	As	33	74.9216	Iodine	I	53	126.9044	Rhodium	Rh	45	102.905
Astatine	At	85	210	Iridium	Ir	77	192.2	Rubidium	Rb	37	85.47
Barium	Ba	56	137.34	Iron	Fe	26	55.847	Ruthenium	Ru	44	101.07
Berkelium	Bk	97	247	Krypton	Kr	36	83.80	Samarium	Sm	62	150.35
Beryllium	Be	4	9.0122	Lanthanum	La	57	138.91	Scandium	Sc	21	44.956
Bismuth	Bi	83	208.980	Lawrencium	Lw	103	257	Selenium	Se	34	78.96
Boron	B	5	10.811	Lead	Pb	82	207.19	Silicon	Si	14	28.086
Bromine	Br	35	79.909	Lithium	Li	3	6.939	Silver	Ag	47	107.870
Cadmium	Cd	48	112.40	Lutetium	Lu	71	174.97	Sodium	Na	11	22.9898
Calcium	Ca	20	40.08	Magnesium	Mg	12	24.312	Strontium	Sr	38	87.62
Californium	Cf	98	251	Manganese	Mn	25	54.9381	Sulfur	S	16	32.064
Carbon	C	6	12.01115	Mendelevium	Md	101	256	Tantalum	Ta	73	180.948
Cerium	Ce	58	140.12	Mercury	Hg	80	200.59	Technetium	Tc	43	99
Cesium	Cs	55	132.905	Molybdenum	Mo	42	95.94	Tellurium	Te	52	127.60
Chlorine	Cl	17	35.453	Neodymium	Nd	60	144.24	Terbium	Tb	65	158.924
Chromium	Cr	24	51.996	Neon	Ne	10	20.183	Thallium	Tl	81	204.37
Cobalt	Co	27	58.9332	Neptunium	Np	93	237	Thorium	Th	90	232.038
Copper	Cu	29	63.54	Nickel	Ni	28	58.71	Thulium	Tm	69	168.934
Curium	Cm	96	247	Niobium	Nb	41	92.906	Tin	Sn	50	118.69
Dysprosium	Dy	66	162.50	Nitrogen	N	7	14.0067	Titanium	Ti	22	47.90
Einsteinium	Es	99	254	Nobelium	No	102	254	Tungsten	W	74	183.85
Erbium	Er	68	167.26	Osmium	Os	76	190.2	Uranium	U	92	238.03
Europium	Eu	63	151.96	Oxygen	O	8	15.9994	Vanadium	V	23	50.942
Fermium	Fm	100	253	Palladium	Pd	46	106.4	Xenon	Xe	54	131.30
Fluorine	F	9	18.9984	Phosphorus	P	15	30.9738	Ytterbium	Yb	70	173.04
Francium	Fr	87	223	Platinum	Pt	78	195.09	Yttrium	Y	39	88.905
Gadolinium	Gd	64	157.25	Plutonium	Pu	94	242	Zinc	Zn	30	65.37
Gallium	Ga	31	69.72	Polonium	Po	84	210	Zirconium	Zr	40	91.22
Germanium	Ge	32	72.59	Potassium	K	19	39.102				
Gold	Au	79	196.967	Praseodymium	Pr	59	140.907				

PERIODIC TABLE OF THE ELEMENTS

Group:		IA	IIA	IIIB	IVB	VB	VIB	VIIB	VIII			IB	IIB	IIIA	IVA	VA	VIA	VIIA	0
		Representative Elements		Transition Elements—d										Representative Elements					Noble Gas Elements
Period	Valence Shell	s^1	s^2	$d^1s^2f^x$	d^2s^2	(d^3s^2)‡	(d^5s^1)‡	d^5s^2	(d^6s^2)‡	(d^7s^2)‡	(d^8s^2)‡	s^1d^{10}	s^2	s^2p^1	s^2p^2	s^2p^3	s^2p^4	s^2p^5	s^2p^6
$n = 1$	$1s$	1 H 1.00797																	2 He 4.0026
$n = 2$	$2s2p$	3 Li 6.939	4 Be 9.0122											5 B 10.811	6 C 12.01115	7 N 14.0067	8 O 15.9994	9 F 18.9984	10 Ne 20.183
$n = 3$	$3s3p$	11 Na 22.9898	12 Mg 24.312											13 Al 26.9815	14 Si 28.086	15 P 30.9738	16 S 32.064	17 Cl 35.453	18 Ar 39.948
$n = 4$	$4s3d4p$	19 K 39.102	20 Ca 40.08	21 Sc 44.956	22 Ti 47.90	23 V 50.942	24 Cr 51.996	25 Mn 54.9380	26 Fe 55.847	27 Co 58.9332	28 Ni 58.71	29 Cu 63.54	30 Zn 65.37	31 Ga 69.72	32 Ge 72.59	33 As 74.9216	34 Se 78.96	35 Br 79.909	36 Kr 83.80
$n = 5$	$5s4d5p$	37 Rb 85.47	38 Sr 87.62	39 Y 88.905	40 Zr 91.22	41 Nb 92.906	42 Mo 95.94	43 Tc 99	44 Ru 101.07	45 Rh 102.905	46 Pd 106.4	47 Ag 107.870	48 Cd 112.40	49 In 114.82	50 Sn 118.69	51 Sb 121.75	52 Te 127.60	53 I 126.9044	54 Xe 131.30
$n = 6$	$6s4f5d6p$	55 Cs 132.905	56 Ba 137.34	57–71 ☆	72 Hf 178.49	73 Ta 180.948	74 W 183.85	75 Re 186.2	76 Os 190.2	77 Ir 192.2	78 Pt 195.09	79 Au 196.967	80 Hg 200.59	81 Tl 204.37	82 Pb 207.19	83 Bi 208.980	84 Po 210	85 At 210	86 Rn 222
$n = 7$	$7s5f6d7p$	87 Fr 223	88 Ra 226	89–103 ★															

Inner Transition Elements—f

☆Lanthanide Series	57 La 138.91	58 Ce 140.12	59 Pr 140.907	60 Nd 144.24	61 Pm 145	62 Sm 150.35	63 Eu 151.96	64 Gd 157.25	65 Tb 158.924	66 Dy 162.50	67 Ho 164.930	68 Er 167.26	69 Tm 168.934	70 Yb 173.04	71 Lu 174.97
★Actinide Series	89 Ac 227	90 Th 232.038	91 Pa 231	92 U 238.03	93 Np 237	94 Pu 242	95 Am 243	96 Cm 247	97 Bk 247	98 Cf 249	99 Es 254	100 Fm 253	101 Md 256	102 No 254	103 Lw 257

‡Variable valence shells.

GENERAL CHEMISTRY

PREFACE

This book is intended for the college student taking a first-year course in college chemistry. Its contents have been selected and organized so that "descriptive" inorganic chemistry is presented in a manner that emphasizes the application of physical and chemical principles to the properties of substances. Modern concepts of chemical bonding, atoms, molecules, gases, liquids, and changes of state are used to expand further the student's comprehension of both principles and their applications. This greater depth may be explored with confidence since high school science courses have been and are constantly improving. Thus we assume that most students will have had an adequate course in high school chemistry. Nevertheless, Chapter 1 provides a brief review of the fundamentals usually covered in such a course.

In this book, descriptive chemistry is discussed in a horizontal fashion. The topics common to all elements are included under such headings as Monatomic Anions, Monatomic Cations, Oxyanions, Polymeric Anions, and Metals and Nonmetals. Thus, for example, the oxyanions of metals are treated together with those derived from nonmetals. We stress the parallel behavior of metals instead of employing the familiar emphasis on the chemical family.

As a pedagogic device to increase flexibility and scope, additional materials expanding the discussion of selected topics are presented in the outside columns and are set off by a distinctive gray background. These supplementary materials do not affect the continuity of the text; rather, they make available more detailed and complex materials to the more sophisticated student looking for intellectual challenge (e.g., the derivation of the Schrödinger equation) and to the student who requires further assistance (e.g., a different approach to the mole concept). The subjects given such expanded treatments are selected on the basis of our teaching experience, where we have noted both those topics arousing the intellectually curious student and those that students have found difficult.

Historical background and industrial applications are reduced to a minimum. We feel that students will benefit more from historical materials at a later stage in their studies of chemistry. Commercial processes, governed as they are by economic factors, do not ordinarily provide good examples of chemical principles; therefore, we shall discuss only industrial practices illustrative of fundamental chemistry (e.g., oxidation, reduction, and electrolytic methods).

We gratefully acknowledge the stimulation provided by our students over the years. Without their challenge our teaching might have drifted into complacent monotony. We particularly appreciate the helpful comments made by reviewers, and by our students, on the preliminary edition of this book.

WENDELL H. SLABAUGH
THERAN D. PARSONS

Corvallis, Oregon
February, 1966

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1 Elementary Principles of Chemistry

Most of the material in this chapter should be familiar to you. We assume that you already have a rudimentary understanding of mathematics and the elementary principles of physical science; but we shall summarize and review these topics in order to provide a common basis for the discussions that follow.

1.1 The Nature of Chemistry

Chemistry is a branch of the physical sciences, closely related to physics and extending into a variety of other scientific disciplines, from astronomy to zoology. Chemistry has been studied for hundreds of years, though the era of modern chemistry probably dates back to about 1800 when the bases of chemical principles as we know them today were being uncovered. Fragments of chemistry, such as the making of glass, salts, acids, and metals, come to us from much earlier times, but their origins need not concern us here.

Chemistry deals essentially with the composition and behavior of the natural world. It is difficult to draw a strict line between chemistry and the other physical and natural sciences: for example, biology has now come to rely heavily on the chemistry of the cell and microorganisms; geology is partly concerned with the chemical composition of rocks and minerals; and one aspect of modern astronomy is called astrochemistry. Consequently, chemistry and contributions of the chemist may be found in most, if not all the other natural sciences.

Even though chemistry itself is a broad science, several basic divisions have developed within it as a result of its diversity.

Organic chemistry deals primarily with the chemistry of carbon compounds, many of which are derived from natural sources. An attractive feature of organic chemistry lies in the opportunity of creating a host of synthetic compounds whose properties are unknown until they are made. Obviously, organic chemistry has nurtured the stepchild of the biological sciences—biochemistry.

Inorganic chemistry is concerned with the chemistry of all the elements and their compounds. The metals and nonmetals, their simple and complex compounds, and, since 1940, the synthesis of elements that do not occur in nature have been the chief concerns of the inorganic chemist. Acids, bases, and salts are typical inorganic compounds, and the student presumably has a rudimentary understanding of these substances.

Physical chemistry deals with equilibrium and thermodynamics of chemical reactions, energy associated with reactions, and the structure of molecules. It employs both classical and quantum mechanics in solving these problems. In analytical chemistry, the emphasis is on the development of precise methods of analyzing the chemical composition of substances and their mixtures. Analysis may be qualitative (what is in it?) or quantitative (how much of each component is in it?). The wide variety of electronic equipment now available has opened up a vast area of study for the analytical chemist—and has indeed become critically important in all areas of chemistry.

Many areas closely related to chemistry are outgrowths of these basic divisions. *Chemical Abstracts,* a biweekly digest of original articles concerned with chemistry, divides chemical activities into several dozen areas, such as electrochemistry, metallurgy, microbiology, nutrition, soils, petroleum, paints, rubber, and plastics. The impact of chemical science on agriculture, where fertilizers, plant growth regulators, insecticides, and animal nutritional supplements have brought startling improvements, is almost taken for granted by the public. In industry, we have come to expect that better synthetic fibers, stronger metals, better foods, and more effective drugs will be regularly forthcoming. The interaction of science and the technologies has produced spectacular results that make it difficult to predict what will be invented next.

Our study of chemistry will for the most part turn away from the gadgets, rockets, plastics, and other useful things that are commonly associated with science by the newspaper-reading public. We will be primarily concerned with the fact that chemical science is a major attempt to assess and understand the physical world in which we live. We will examine the basic laws of chemistry, and we will try to find suitable answers to the questions that arise from man's curiosity about the world around him. For example, what holds matter together? How do substances react with each other? Is there order among the chaos of materials that composes the universe?