ROGERS'

INORGANIC PHARMACEUTICAL CHEMISTRY

SOINE

WILSON

SEVENTH EDITION

Rogers' Inorganic Pharmaceutical Chemistry

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PREFACE TO THE SEVENTH EDITION

This work has been revised so that it may be used advantageously with the United States Pharmacopeia XVI and the National Formulary XI by students of pharmacy and pharmacists. The basic principles on which the book was originally written have remained unchanged and will be found in the Preface to the First Edition.

In the sixth revision of this text the authors have made every effort to include new and current materials and, in particular, to provide a treatment for new chemicals that have been introduced into the official compendia. The revisions of the official compendia have been notable in the fact that they have finally dropped from official recognition certain compounds which have long been considered of doubtful value. Among these are the hypophosphites and glycerophosphates and certain of the acids. Nevertheless, it is deemed advisable to retain a brief discussion of these for the present revision of the text at least because lack of official recognition does not automatically remove these chemicals from consideration as therapeutic agents. In the future, as they drop more or less completely from common usage, they will also be deleted from consideration in the text. It is our belief that teachers and students of pharmacy will find these valuable for reference purposes. The alphabetical arrangement of the compounds of each element, based on the Periodic Table, and the monographic treatment characteristic of the book in the past has been retained. The authors feel that this mode of presentation permits the instructor to adopt any method of presentation he prefers and provides the student with a relatively complete consideration of any useful compound being considered.

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CHAPTER 1

ATOMIC STRUCTURE AND CHEMICAL BONDING

ALL matter is made up of elements, which are either combined or uncombined. How these combinations occur and what the composition of an element is have been questions of man for centuries.

The Greek philosophers proposed the "continuous" theory of infinite subdivision with no unit and the "atomistic" theory of multiple units called atoms.

About 1805 John Dalton proposed his "Atomic Theory." In brief it is:

1. All elements consist of minute discrete particles called atoms.
2. Atoms of a given element are alike and have the same mass.
3. Atoms can not be subdivided nor those of one element changed into another.
4. Atoms are incapable of being destroyed or created.
5. Atoms of different elements differ, each element having unique atoms.
6. Chemical reaction is the combination of atoms in definite numerical proportions.

The points of Dalton's theory are all quite well agreed on and have guided chemical thinking since their inception. Statements 2, 3, and 4 are not necessarily true in light of recent research on atomic structure.

Due to some brilliant research, we now have a fairly clear picture of atomic structure. The particles of an atom which are of concern to pharmaceutical inorganic chemistry are the electron, proton and neutron. The general configuration of an atom is often likened to a planetary system with protons and neutrons as the nucleus and electrons moving in elliptical or circular paths about the nucleus (see Fig. 1).

The modern interpretation, however, is that electrons *do not* travel in fixed orbits and that the electron cloud concept is more valid. In the hydrogen atom, for example, one pictures a spherical cloud which has the greatest density near its nucleus, *i.e.*, where the electron is found most often. Nevertheless, the older representation shown in Figure 2 is useful as a bookkeeping method and rather vividly portrays the two main divisions of the atom, namely the nucleus and the orbital electrons. The carbon atom is represented as having a nucleus of six neutrons and six protons (a mass of 12) surrounded by six electrons in two shells of 2 and 4 electrons each.

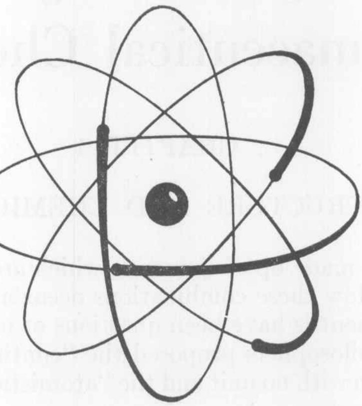
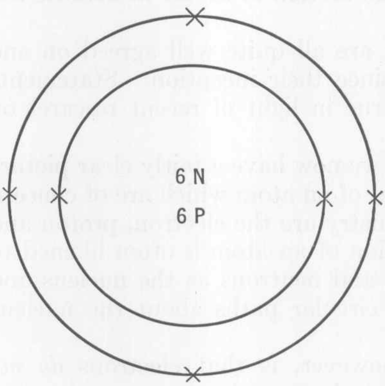


FIG. 1

The electron represents the elementary unit of negative electricity and a mass of $\frac{1}{1839}$ of a proton, so small that it is ignored for practical purposes. The proton has a mass of one and a positive electrical charge equal to that of the electron (negative). The hydrogen ion is identical with the proton. Neutrons have been found to be neutral particles within the nucleus having about the same mass (one) as the proton.[1] It might be that a neutron is a specific union



6 protons (P) } nucleus
6 neutrons (N) }
6 electrons (x)

FIG. 2.—Typical Carbon Atom.

[1] The actual atomic weights are:

H atom = 1.00785	Neutron = 1.00866
Proton = 1.0073	Electron = 0.00055

of a proton and an electron to give a neutral mass of approximately one but yet differs from a hydrogen atom.

Atoms, of the elements then, in simple terms are represented by a systematic addition of neutrons and protons to the nucleus and addition of electrons to the outer area equal to the number of protons so that electrical neutrality is maintained. A series can now be visualized starting with one proton and one electron (Hydrogen atom), next two protons and two neutrons with two electrons (Helium atom), etc. The number of protons are always equal to the number of electrons (Atomic Number). The number of neutrons and protons are equal only for the lightest elements. Within the same element, atoms containing different numbers of neutrons account for isotopes. Isotopes are atoms of elements differing only in mass but having the same electron configuration and, therefore, the same chemical properties. An example is natural oxygen containing O^{16} (99.757%) with 8 neutrons, O^{17} (0.039%) with 9 neutrons and O^{18} (0.204%) with 10 neutrons. These isotopes account in part for the fractional atomic weights of the elements. For example, if natural carbon atoms all had 6 neutrons the atomic weight would be 12 but, as we know, this is not the case.

For convenience, as indicated earlier, the electron arrangement about the nucleus is considered to be planetary with the electrons moving about the nucleus in characteristic orbits. Each electron spins on its axis in a manner similar to the earth. The electrons arrange themselves about the nucleus in energy levels (shells) or quantum states.

Table 1 shows the elements arranged according to their atomic number and increasing number of electrons. Usually the electrons in the outer shell are responsible for chemical reactions in compound formation. Up to chromium this is quite true but from here on with the heavier elements some electrons in the next to last shell are available for chemical reaction. This, as will be seen later, helps explain the several valence possibilities of some elements (Cu, Cr, Mn, Au, Fe, etc.

Considering the nuclei of atoms to be made up primarily of protons and neutrons one wonders what holds this together. Protons are positive and should repel each other and the neutrons should have no effect. Physicists are undecided as to the right explanation but "Nuclear Forces" are at play. We must, at present, accept the theory of nuclear positive charge equal to the negative charge of surrounding electrons.

Periodic Table.—During the growth of chemistry and the discovery of the elements it became more and more evident that the elements were related in some way. We are all now familiar with the various families: alkali metals, alkaline earth metals, coinage metals, halogens, etc. By 1868–1870, sufficient chemical data was available to prompt Mendeléeff of Russia and Lothar Meyer of Germany, each working independently, to suggest a periodic table.

They assumed that the properties of elements were a function of their atomic weights but today it is known that the properties are better based on atomic number.

Table 1 shows that, in general, elements with the same number of electrons in their outer orbits will have similar chemical properties. The Periodic Table was based on this observation of similar chemical properties but was done before electron distribution was fully understood. There have been several forms or arrangements of the

TABLE 1.—ELECTRONIC DISTRIBUTIONS

Element	*Atomic No.*	1s	2s	2p	3s	3p	3d	4s	4p	4d	5s
H	1	1									
He	2	2									
Li	3	2	1								
Be	4	2	2								
B	5	2	2	1							
C	6	2	2	2							
N	7	2	2	3							
O	8	2	2	4							
F	9	2	2	5							
Ne	10	2	2	6							
Na	11	2	2	6	1						
Mg	12	2	2	6	2						
Al	13	2	2	6	2	1					
Si	14	2	2	6	2	2					
P	15	2	2	6	2	3					
S	16	2	2	6	2	4					
Cl	17	2	2	6	2	5					
A	18	2	2	6	2	6					
K	19	2	2	6	2	6		1			
Ca	20	2	2	6	2	6		2			
Sc	21	2	2	6	2	6	1	2			
Ti	22	2	2	6	2	6	2	2			
V	23	2	2	6	2	6	3	2			
Cr	24	2	2	6	2	6	5	1			
Mn	25	2	2	6	2	6	5	2			
Fe	26	2	2	6	2	6	6	2			
Co	27	2	2	6	2	6	7	2			
Ni	28	2	2	6	2	6	8	2			
Cu	29	2	2	6	2	6	10	1			
Zn	30	2	2	6	2	6	10	2			
Ga	31	2	2	6	2	6	10	2	1		
Ge	32	2	2	6	2	6	10	2	2		
As	33	2	2	6	2	6	10	2	3		
Se	34	2	2	6	2	6	10	2	4		
Br	35	2	2	6	2	6	10	2	5		
Kr	36	2	2	6	2	6	10	2	6		
Rb	37	2	2	6	2	6	10	2	6		1
Sr	38	2	?	6	2	6	10	2	6		2
Y	39	2	2	6	2	6	10	2	6	1	2
Zr	40	2	2	6	2	6	10	2	6	2	2
Cb	41	2	2	6	2	6	10	2	6	4	1
Mo	42	2	2	6	2	6	10	2	6	5	1
Tc	43	2	2	6	2	6	10	2	6	6	1
Ru	44	2	2	6	2	6	10	2	6	7	1
Rh	45	2	2	6	2	6	10	2	6	8	1
Pd	46	2	2	6	2	6	10	2	6	10	
Ag	47	2	2	6	2	6	10	2	6	10	1
Cd	48	2	2	6	2	6	10	2	6	10	2

TABLE 1.—ELECTRONIC DISTRIBUTIONS—(*Continued*)

Element	*Atomic No.*	1s	2s	2p	3s	3p	3d	4s	4p	4d	4f	5s	5p	5d	5f	6s	6p	6d	7s
In	49	2	2	6	2	6	10	2	6	10		2	1						
Sn	50	2	2	6	2	6	10	2	6	10		2	2						
Sb	51	2	2	6	2	6	10	2	6	10		2	3						
Te	52	2	2	6	2	6	10	2	6	10		2	4						
I	53	2	2	6	2	6	10	2	6	10		2	5						
Xe	54	2	2	6	2	6	10	2	6	10		2	6						
Cs	55	2	2	6	2	6	10	2	6	10		2	6			1			
Ba	56	2	2	6	2	6	10	2	6	10		2	6			2			
La	57	2	2	6	2	6	10	2	6	10		2	6	1		2			
Ce	58	2	2	6	2	6	10	2	6	10	2	2	6			2			
Pr	59	2	2	6	2	6	10	2	6	10	3	2	6			2			
Nd	60	2	2	6	2	6	10	2	6	10	4	2	6			2			
Pm	61	2	2	6	2	6	10	2	6	10	5	2	6			2			
Sm	62	2	2	6	2	6	10	2	6	10	6	2	6			2			
Eu	63	2	2	6	2	6	10	2	6	10	7	2	6			2			
Gd	64	2	2	6	2	6	10	2	6	10	7	2	6	1		2			
Tb	65	2	2	6	2	6	10	2	6	10	9	2	6			2			
Dy	66	2	2	6	2	6	10	2	6	10	10	2	6			2			
Ho	67	2	2	6	2	6	10	2	6	10	11	2	6			2			
Er	68	2	2	6	2	6	10	2	6	10	12	2	6			2			
Tm	69	2	2	6	2	6	10	2	6	10	13	2	6			2			
Yb	70	2	2	6	2	6	10	2	6	10	14	2	6			2			
Lu	71	2	2	6	2	6	10	2	6	10	14	2	6	1		2			
Hf	72	2	2	6	2	6	10	2	6	10	14	2	6	2		2			
Ta	73	2	2	6	2	6	10	2	6	10	14	2	6	3		2			
W	74	2	2	6	2	6	10	2	6	10	14	2	6	4		2			
Re	75	2	2	6	2	6	10	2	6	10	14	2	6	5		2			
Os	76	2	2	6	2	6	10	2	6	10	14	2	6	6		2			
Ir	77	2	2	6	2	6	10	2	6	10	14	2	6	9					
Pt	78	2	2	6	2	6	10	2	6	10	14	2	6	9		1			
Au	79	2	2	6	2	6	10	2	6	10	14	2	6	10		1			
Hg	80	2	2	6	2	6	10	2	6	10	14	2	6	10		2			
Tl	81	2	2	6	2	6	10	2	6	10	14	2	6	10		2	1		
Pb	82	2	2	6	2	6	10	2	6	10	14	2	6	10		2	2		
Bi	83	2	2	6	2	6	10	2	6	10	14	2	6	10		2	3		
Po	84	2	2	6	2	6	10	2	6	10	14	2	6	10		2	4		
At	85	2	2	6	2	6	10	2	6	10	14	2	6	10		2	5		
Rn	86	2	2	6	2	6	10	2	6	10	14	2	6	10		2	6		
Fr	87	2	2	6	2	6	10	2	6	10	14	2	6	10		2	6		1
Ra	88	2	2	6	2	6	10	2	6	10	14	2	6	10		2	6		2
Ac	89	2	2	6	2	6	10	2	6	10	14	2	6	10		2	6	1	2
*Th	90	2	2	6	2	6	10	2	6	10	14	2	6	10		2	6	2	2
*Pa	91	2	2	6	2	6	10	2	6	10	14	2	6	10	2	2	6	1	2
*U	92	2	2	6	2	6	10	2	6	10	14	2	6	10	3	2	6	1	2
*Np	93	2	2	6	2	6	10	2	6	10	14	2	6	10	4	2	6	1	2
*Pu	94	2	2	6	2	6	10	2	6	10	14	2	6	10	5	2	6	1	2
*Am	95	2	2	6	2	6	10	2	6	10	14	2	6	10	6	2	6	1	2
*Cm	96	2	2	6	2	6	10	2	6	10	14	2	6	10	7	2	6	1	2
*Bk	97	2	2	6	2	6	10	2	6	10	14	2	6	10	8	2	6	1	2
*Cf	98	2	2	6	2	6	10	2	6	10	14	2	6	10	9	2	6	1	2

* Probable structures.

(Inorganic Chemistry by Therald Moeller, John Wiley & Sons, Inc., pp. 98–101, 1952.)

Periodic Table. The one given as Table 2 suits explanations in pharmaceutical chemistry quite well.

In examining the Periodic Table note that there are eight groups or, that after every eighth element (for Periods II and III) the properties begin repeating themselves which necessitates listing sodium under lithium, magnesium under beryllium, etc., thus "building" the Periodic Table. The name implies that the properties of elements occur in periods.

With each increase in atomic number (a like increase in electrons) the valence possibilities of the elements change. Every so often (Group O or the inert gases) an element appears with no chemical properties (will not form compounds). These are always preceded by an element with seven electrons in the outer shell and succeeded by an element with one electron in the outer shell. The atoms of the elements in each group in the Periodic Table nearly always have the same number of electrons in the outer shell. This fact accounts for the similarity in chemical properties for elements in the same group.

Beyond Argon (2–8–8) the electron structure becomes more complicated and necessitates a division into A and B subgroups. The horizontal periods II and III are called the "typical elements." Within these the elements in each vertical group show some similarity. In the following periods, IV to VII, the subgroups are expressed as A and B. In following through with the atomic numbers it will be noted that elements in A come first and in B come later in their respective periods. Group VIII elements in the center of the table bring together the subgroups A and B. The complexity of the larger elements allows grouping elements of atomic number 58 to 71 which all resemble lanthanum 57 into Group IIIA (Period VI). Likewise, the elements of atomic number 89–101 are similar to actinium 89 and are arranged as part of Group IIIA (Period VII).

It may easily be seen that the elements within a group, in general, possess the same number of electrons in their outer shell. Likewise, across a period the elements progressively increase by one electron. Chemical activity in general increases for the listed elements in descending order for a group except for Group IB and the halogens.

In a given period metallic properties decrease as the atomic number increases. In a group the metallic properties increase downward. This change in metallic character is gradual and there are certain intermediate elements possessing both metallic and nonmetallic character which are termed *metalloids* (*e.g.*, germanium and arsenic).

Valence and Chemical Combination.—Much has been learned in recent years about how and why chemical combinations occur. Valence is concerned with the combination of elements and how the attraction is maintained. It explains the completely ionic compounds

TABLE 2.—THE LONG PERIODIC TABLE

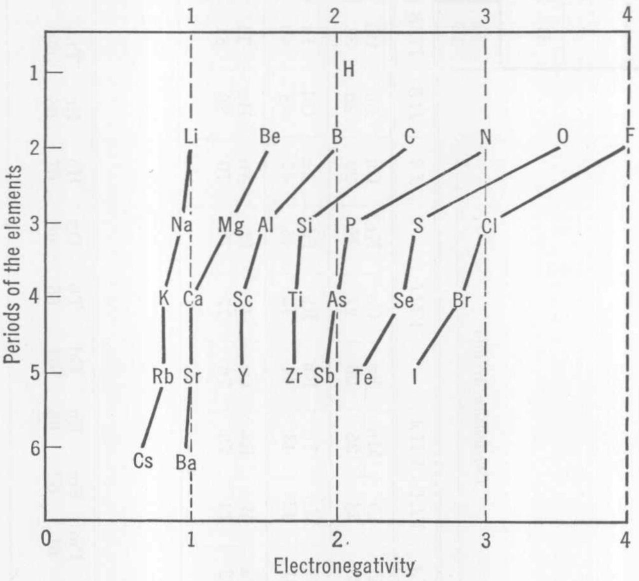
	Metals												Nonmetals					
Group	*I*	*II*											*III*	*IV*	*V*	*VI*	*VII*	*O*
Period I	H 1																	He 2
Period II	Li 3	Be 4											B 5	C 6	N 7	O 8	F 9	Ne 10
Period III	Na 11	Mg 12						*Transition Metals*					Al 13	Si 14	P 15	S 16	Cl 17	A 18
Subgroups	*IA*	*IIA*	*IIIA*	*IVA*	*VA*	*VIA*	*VIIA*	*VIII*			*IB*	*IIB*	*IIIB*	*IVB*	*VB*	*VIB*	*VIIB*	*O*
Period IV	K 19	Ca 20	Sc 21	Ti 22	V 23	Cr 24	Mn 25	Fe 26	Co 27	Ni 28	Cu 29	Zn 30	Ga 31	Ge 32	As 33	Se 34	Br 35	Kr 36
Period V	Rb 37	Sr 38	Y 39	Zr 40	Cb 41	Mo 42	Tc 43	Ru 44	Rh 45	Pd 46	Ag 47	Cd 48	In 49	Sn 50	Sb 51	Te 52	I 53	Xe 54
Period VI	Cs 55	Ba 56	57–71	Hf 72	Ta 73	W 74	Re 75	Os 76	Ir 77	Pt 78	Au 79	Hg 80	Tl 81	Pb 82	Bi 83	Po 84	At 85	Rn 86
Period VII	Fr 87	Ra 88	89–96															

Elements 57–71	La 57	Ce 58	Pr 59	Nd 60	Pm 61	Sm 62	Eu 63	Gd 64	Tb 65	Dy 66	Ho 67	Er 68	Tm 69	Yb 70	Lu 71
Elements 89–101	Ac 89	Th 90	Pa 91	U 92	Np 93	Pu 94	Am 95	Cm 96	Bk 97	Cf 98	Es 99	Fm 100	Mv 101	— 102	— 103

(NaCl), partly ionized compounds ($MgSO_4$), non-ionized compounds (CCl_4) and complex compounds ($Ag(NH_3)_2NO_3$).

Valence is difficult to define in that atoms unite in different ways but in all cases there is an electrostatic attraction. Perhaps it is simply best to consider it the power or ability of elements to combine with one another. A chemical bond is more definite because we visualize two chemical units as being held together by some force. Going back to Table 1 of electron distribution we note that the ability of elements to combine depends upon their extranuclear

TABLE 3.—ELECTRONEGATIVITIES OF THE ELEMENTS,* ACCORDING TO PAULING (Nature of the Chemical Bond, Cornell University Press)



(General Chemistry by A. W. Laubengayer, Rinehart & Co., Inc., New York, p. 174, 1953.)

* Electropositivity is another term, usually used in referring to the relative tendency of metals to give up an electron and thus go to a more electropositive condition.

structural arrangement and the number of electrons. Generally speaking, the electrons in the outer shell of an element determine much of its valence characteristics.

Valency may be considered under the following four categories: (*1*) electrovalency, (*2*) covalency, (*3*) co-ordinate covalency, and (*4*) other bonding forces.

(*1*) *Electrovalence* exists between two chemical entities of opposite charge. This situation occurs when electrons are taken up or surrendered by the uniting particles. Valence of this type is present particularly between the strongly metallic (Group I and IA) or strongly electropositive elements (see Table 3) and the strongly