CHAPTER 4

Chemical Foundations: Elements, Atoms, and Ions

CHAPTER ANSWERS

1. The alchemists discovered several new elements and learned how to prepare acids.
2. Robert Boyle
3. Boyle's most important contribution was his insistence that science should be firmly grounded in *experiment*. Boyle tried to limit the influence of any preconceptions about science and only accepted as fact what could be demonstrated.
4. There are at least 115 elements presently known; of these 88 occur naturally and the remainders are manmade. Table 4.1 lists the most common elements on the Earth.
5. Oxygen
6. Trace elements are those elements that are present in only tiny amounts in the body, but are critical for many bodily processes and functions.
7. **C:** cadmium, Cd; calcium, Ca; californium, Cf; carbon, C; cerium, Ce; cesium, Cs; chlorine, Cl; chromium, Cr; cobalt, Co; copper, Cu; curium, Cm

   S: samarium, Sm; scandium, Sc; seaborgium, Sg; selenium, Se; silicon, Si; silver, Ag; sodium, Na; sulfur, S

   T: tantalum, Ta; technetium, Tc; tellurium, Te; terbium, Tb; thallium, Tl; thorium, Th; thulium, Tm; tin, Sn; titanium, Ti; tungsten, W
8. The symbols for these elements are based upon their names in other languages.
9.
   a. 2
   b. 10
   c. 12
   d. 9
   e. 8
   f. 6
   g. 5
   h. 3
   i. 1
   j. 11

10.

a. 8
b. 5
c. 2
d. 9
e. 13
f. 12
g. 6
h. 11
i. 7
j. 1

11.

W	tungsten
Ge	germanium
Pd	palladium
Pt	platinum
Zr	zirconium
Ir	iridium

12.

praeseodymium	Pr
lawrencium	Lr
californium	Cf
nobelium	No
hafnium	Hf

13.

a. potassium
b. germanium
c. phosphorus
d. carbon
e. nitrogen
f. sodium
g. neon
h. iodine

14. **B**: barium, Ba; berkelium, Bk; beryllium, Be; bismuth, Bi; bohrium, Bh; boron, B; bromine, Br

N: neodymium, Nd; neon, Ne; neptunium, Np; nickel, Ni; niobium, Nb; nitrogen, N; nobelium, No

P: palladium, Pd; phosphorus, P; platinum, Pt; plutonium, Pu; polonium, Po; potassium, K; praseodymium, Pr; promethium, Pm; protactinium, Pa

S: samarium, Sm; scandium, Sc; seaborgium, Sg; selenium, Se; silicon, Si; silver, Ag; sodium, Na; strontium, Sr; sulfur, S

15. Elements are made of tiny particles called atoms. All atoms of a given element are identical. The atoms of a given element are different from those of any other element. Atoms of one element can combine with atoms of other elements to form compounds. A given compound always has the same relative numbers and types of atoms. Atoms are indivisible in chemical processes. Atoms are neither created nor destroyed in chemical processes. A chemical reaction simply changes the way the atoms are grouped together.

16.

a. Elements are made of tiny particles called atoms.

b. All the atoms of a given element are identical.

c. The atoms of a given element are different from those of any other element.

d. A given compound always has the same relative numbers and types of atoms,

e. Atoms are neither created nor destroyed in chemical processes. A chemical reaction simply changes the way the atoms are grouped together.

17. A compound is a distinct substance that is composed of two or more elements and always contains exactly the same relative masses of those elements.

18. According to Dalton all atoms of the same element are *identical*; in particular, every atom of a given element has the same *mass* as every other atom of that element. If a given compound always contains the *same relative numbers* of atoms of each kind, and those atoms always have the *same masses*, then it follows that the compound made from those elements would always contain the same relative masses of its elements.

19.

a. C_3H_8

b. N_2O

c. BaI_2

d. $AlCl_3$

e. $C_{12}H_{22}O_{11}$

f. K_2CO_3

20.

a. PbO_2

b. $CoCl_3$

c. $C_6H_{12}O_6$

d. Al_2O_3

e. Na_2CO_3

f. CaH_2

21.

a. J. J. Thomson discovered the electron. Thomson postulated that because negative particles had been detected in the atom there must also be positive particles to counterbalance the negative charge.

b. William Thomson (Lord Kelvin) described the atom as a uniform pudding of positive charge with electrons scattered throughout (like the raisins in a pudding) to balance the electrical charge.

22.

a. False; Rutherford's bombardment experiments with metal foil suggested that the alpha particles were being deflected by coming near a *dense, positively charged* atomic nucleus.

b. False; The proton and the electron have opposite charges, but the mass of the electron is *much smaller* than the mass of the proton.

c. True

23. Neutrons are found in the nucleus and carry no electrical charge.

24. The protons and neutrons are found in the nucleus. The protons are positively charged; the neutrons have no electrical charge. Protons and neutrons each have approximately the same mass.

25. The proton and the neutron have similar (but not identical) masses. Both of these particles have a mass approximately 2000 times greater than that of an electron. The combination of the protons and the neutrons makes up the bulk of the mass of an atom, but the electrons make the greatest contribution to the chemical properties of the atom.

26. neutron; electron

27. 10^{-13} cm = 10^{-15} m

28. Because they are located in the exterior regions of the atom, it is the electrons of an atom that most interact with other atoms and are therefore most responsible for the atom's chemical behavior.

29. Although all atoms of a given element contain the same number of protons in the nucleus, some atoms of a given element may have different numbers of neutrons. Isotopes are atoms of the same element with different mass numbers.

30. The atomic number represents the number of protons in the nucleus of the atom and makes the atom a particular element. The mass number represents the total number of protons and neutrons in the nucleus of an atom and distinguishes one isotope of an element from another.

31. the same

32. mass

33. Dalton's original assumption was reasonable for his time, but as mass determination techniques improved it was discovered that a given element may be composed of several isotopes. Isotopes have the same number of protons and electrons and so are chemically identical, but differ in the number of neutrons, which causes some physical differences.

34. Atoms of the same element (i.e., atoms with the same number of protons in the nucleus) may have different numbers of neutrons, and so will have different masses.

35.

a. 28

b. 29

c. 34

d. 48

e. 16

f. 14

g. 23

h. 54

36.

Atomic Number	Symbol	Name
14	Si	silicon
54	Xe	xenon
79	Au	gold
56	Ba	barium
53	I	iodine
50	Sn	tin
48	Cd	cadmium

37.

a. $^{17}_{8}O$

b. $^{37}_{17}Cl$

c. $^{60}_{27}Co$

d. $^{57}_{26}Fe$

e. $^{131}_{53}I$

f. $^{7}_{3}Li$

38.

a. $^{26}_{14}Si$

b. $^{30}_{15}P$

c. $^{47}_{24}Cr$

d. $^{60}_{27}Co$

e. $^{62}_{30}Zn$

f. $^{39}_{19}K$

39.

a. 94 protons, 150 neutrons, 94 electrons
b. 95 protons, 146 neutrons, 95 electrons
c. 89 protons, 138 neutrons, 89 electrons
d. 55 protons, 78 neutrons, 55 electrons
e. 77 protons, 116 neutrons, 77 electrons
f. 25 protons, 31 neutrons, 25 electrons

40.

a. 19 protons, 20 neutrons, 19 electrons
b. 24 protons, 29 neutrons, 24 electrons
c. 34 protons, 50 neutrons, 34 electrons
d. 33 protons, 43 neutrons, 33 electrons
e. 36 protons, 55 neutrons, 36 protons
f. 27 protons, 32 neutrons, 27 electrons

41.

Element	Symbol	Atomic Number	Mass Number	Number of neutrons
sodium	$^{23}_{11}Na$	11	23	12
nitrogen	$^{15}_{7}N$	7	15	8
barium	$^{136}_{56}Ba$	56	136	80
lithium	$^{9}_{3}Li$	3	9	6
boron	$^{11}_{5}B$	5	ll	6

42.

Element	Number of Neutrons	Atomic Number	Mass Number	Symbol
nitrogen	6	7	13	$^{13}_{7}N$
nitrogen	7	7	14	$^{14}_{7}N$
lead	124	82	206	$^{206}_{82}Pb$
iron	31	26	57	$^{57}_{26}Fe$
krypton	48	36	84	$^{84}_{36}Kr$

43. The elements are listed in the periodic table in order of increasing atomic number (number of protons in the nucleus) so that elements with similar properties form vertical groups.

44. Elements with similar chemical properties are aligned *vertically* in families known as *groups*.

45. Metals are excellent conductors of heat and electricity and are malleable, ductile, and generally shiny (lustrous) when a fresh surface is exposed.

46. Metallic elements are found towards the *left* and *bottom* of the periodic table; there are far more metallic elements than there are nonmetals.

47. Mercury is a liquid at room temperature.

48. The gaseous nonmetallic elements are hydrogen, nitrogen, oxygen, fluorine, chlorine, plus all the Group 8 elements (noble gases). There are no gaseous metallic elements under room conditions.

49. The only metal that ordinarily occurs as a liquid is mercury. The only nonmetallic element that occurs as a liquid at room temperature is bromine (elements such as oxygen and nitrogen are frequently obtainable as liquids, but these result from compression of the gases into cylinders at very low temperatures).

50. The metalloids are the elements found on either side of the "stairstep" region that is marked on most periodic tables. The metalloid elements show some properties of both metals and nonmetals.

51.

a. Group 1; alkali metals

b. Group 2; alkaline earth elements

c. Group 8; noble gases

d. Group 7; halogens

e. Group 2; alkaline earth elements

f. Group 8; noble gases

g. Group 1; alkali metals

52.

a. fluorine, chlorine, bromine, iodine, astatine

b. lithium, sodium, potassium, rubidium, cesium, francium

c. beryllium, magnesium, calcium, strontium, barium, radium

d. helium, neon, argon, krypton, xenon, radon

53.

a. Sr; $Z = 38$; Group 2; metal

b. I; $Z = 53$; Group 7; nonmetal

c. Si; $Z = 14$; Group 4; metalloid

d. Cs; $Z = 55$; Group 1; metal

e. S; $Z = 16$; Group 6; nonmetal

54.

Element	Symbol	Number	Group Number	Metal/Nonmetal
calcium	Ca	20	2	metal
radon	Rn	86	8	nonmetal
rubidium	Rb	37	1	metal
phosphorus	P	15	5	nonmetal
germanium	Ge	32	4	metalloid

55. compounds (and mixtures of compounds)
56. Most of the elements are too reactive to be found in the uncombined form in nature and are found only in compounds.
57. argon
58. These elements are found *uncombined* in nature and do not readily react with other elements. For many years it was thought that these elements formed no compounds at all, but this has now been shown to be untrue.
59. diatomic
60. diatomic gases: H_2, N_2, O_2, Cl_2, and F_2

    monatomic gases: He, Ne, Kr, Xe, Rn, and Ar
61. electricity
62. chlorine
63. liquids: bromine, mercury, gallium

    gases: hydrogen, nitrogen, oxygen, fluorine, chlorine, and the noble gases (helium, neon, argon, krypton, xenon, radon)
64. diamond
65. zero
66. electrons
67. loses three
68. 3+
69. cations, anions
70. *-ide*
71. The answer will depend on the student's selection of elements; in general, the metallic elements are the ones that form positively charged ions.
72. nonmetallic
73.
    a. 24
    b. 18
    c. 25
    d. 24
    e. 18
    f. 18
    g. 21
    h. 18

74.

a. 10
b. 22
c. 10
d. 10
e. 23
f. 54
g. 23
h. 2

75.

a.	Ca: 20 protons, 20 electrons	Ca^{2+}: 20 protons, 18 electrons
b.	P: 15 protons, 15 electrons	P^{3-}: 15 protons, 18 electrons
c.	Br: 35 protons, 35 electrons	Br^{-}: 35 protons, 36 electrons
d.	Fe: 26 protons, 26 electrons	Fe^{3+}: 26 protons, 23 electrons
e.	Al: 13 protons, 13 electrons	Al^{3+}: 13 protons, 10 electrons
f.	N: 7 protons, 7 electrons	N^{3-}: 7 protons, 10 electrons

76.

a. two electrons gained
b. three electrons gained
c. three electrons lost
d. two electrons lost
e. one electron lost
f. two electrons lost.

77.

a. I^{-}
b. Sr^{2+}
c. Cs^{+}
d. Ra^{2+}
e. F^{-}
f. Al^{3+}

78.

a. P^{3-}
b. Ra^{2+}
c. At

d. no ion

e. Cs

f. Se^{2-}

79. A compound that has a high melting point (many hundreds of degrees) and that conducts an electrical current when melted or dissolved in water almost certainly consists of ions.

80. Sodium chloride is an *ionic* compound consisting of Na^{1+} and Cl^{-} *ions*. When NaCl is dissolved in water, these ions are *set free* and can move independently to conduct the electrical current. Sugar crystals, although they may visually *appear* similar, contain *no* ions. When sugar is dissolved in water, it dissolves as uncharged *molecules*. There are no electrically charged species present in a sugar solution to carry the electrical current.

81. In the solid state ions are present, but they are rigidly held in fixed positions in the crystal of the substance. For ionic substances to be able to pass an electrical current, the ions must be able to *move*, which is possible when the solid is converted to the liquid state.

82. The total number of positive charges must equal the total number of negative charges so that there will be *no net charge* on the crystals of an ionic compound. A macroscopic sample of compound must ordinarily not have any net charge.

83.

a. One 3– ion is needed to balance one 3+ ion; FeP.

b. The smallest common multiple of three and two is six; three 2– ions are required to balance two 3+ ions; Fe_2S_3.***

c. Three 1– ions are required to balance one 3+ ion; $FeCl_3$.

d. Two 1–ions are required to balance one 2+ ion; $MgCl_2$.

e. One 2– ion balances one 2+ ion; MgO.

f. The smallest common multiple of two and three is six; two 3– ions are required to balance three 2+ ions; Mg_3N_2.

g. Three 1+ ions are required to balance one 3– ion; Na_3P.

h. Two 1+ ions are required to balance one 2– ion; Na_2S.

84.

a. The smallest common multiple of two and three is six; two 3+ ions are balanced by three 2– ions; Cr_2S_3

b. One 2+ ion balances one 2– ion; CrO

c. Three 1– ions are needed to balance one 3+ ion;: AlF_3

d. The smallest common multiple of two and three is six; two 3+ ions are balanced by three 2– ions; Al_2O_3

e. One 3+ ion balances one 3– ion; AlP

f. Three 1+ ions are needed to balance one 3– ion; Li_3N

85.

a. At; $Z = 85$

b. Xe; $Z = 54$

c. Ra; $Z = 88$

d. Sr; $Z = 38$

e. Pb; $Z = 82$

f. Se; $Z = 34$

g. Ar; $Z = 18$

h. Cs; $Z = 55$

86.

a. 7; halogens

b. 8; noble gases

c. 2; alkaline earth elements

d. 2; alkaline earth elements

e. 4

f. 6; (The members of Group 6 are sometimes called the chalcogens.)

g. 8; noble gases

h. 1; alkali metals

87.

	Element	Symbol	Atomic Number
Group 1	hydrogen	H	1
	lithium	Li	3
	sodium	Na	11
	potassium	K	19
Group 2	beryllium	Be	4
	magnesium	Mg	12
	calcium	Ca	20
	strontium	Sr	38
Group 6	oxygen	O	8
	sulfur	S	16
	selenium	Se	34
	tellurium	Te	52
Group 7	fluorine	F	9
	chlorine	Cl	17
	bromine	Br	35
	iodine	I	53

88.

	Element	Symbol	Atomic Number
Group 3	boron	B	5
	aluminum	Al	13
	gallium	Ga	31
	indium	In	49
Group 5	nitrogen	N	7
	phosphorus	P	15
	arsenic	As	33
	antimony	Sb	51
Group 6	oxygen	O	8
	sulfur	S	16
	selenium	Se	34
	tellurium	Te	52
Group 8	helium	He	2
	neon	Ne	10
	argon	Ar	18
	krypton	Kr	36

89. The atomic number represents the number of protons in the nucleus of an atom. The mass number represents the total number of protons and neutrons. No two different elements have the same atomic number. If the *total* number of protons and neutrons happens to be the same for two atoms, then the atoms will have the same mass number.

90. Most of the mass of an atom is concentrated in the nucleus; the *protons* and *neutrons* that constitute the nucleus have similar masses, and these particles are nearly two thousand times heavier than electrons. The chemical properties of an atom depend on the number and location of the *electrons* it possesses. Electrons are found in the outer regions of the atom and are the particles most likely to be involved in interactions among atoms.

91. Yes. For example, carbon and oxygen form carbon monoxide (CO) and carbon dioxide (CO_2). The existence of more than one compound composed of the same elements does not in any way contradict Dalton's theory. For example, the relative mass of carbon in different samples of CO is always the same, and the relative mass of carbon in different samples of CO_2 is also always the same. Dalton did not say, however, that two different compounds would have to have the same relative masses of the elements present. In fact, Dalton said that two different compounds of the same elements would have to have different relative masses of the elements.

92. $C_6H_{12}O_6$

93. FeO and Fe_2O_3

94.

a. 29 protons; 34 neutrons; 29 electrons

b. 35 protons; 45 neutrons; 35 electrons

c. 12 protons; 12 neutrons; 12 electrons

95.

Mass Number	Symbol	Number of neutrons
24	$^{24}_{13}Al$	11
25	$^{25}_{13}Al$	12
26	$^{26}_{13}Al$	13
28	$^{28}_{13}Al$	15
29	$^{29}_{13}Al$	16
30	$^{30}_{13}Al$	17

96. The chief use of gold in ancient times was as *ornamentation*, whether in statuary or in jewelry. Gold possesses an especially beautiful luster, and because it is relatively soft and malleable, it could be worked finely by artisans. Among the metals gold is particularly inert to attack by most substances in the environment.

97. Boyle defined a substance as an element if it could not be broken down into simpler substances by chemical means.

98.

a. I
b. Si
c. W
d. Fe
e. Cu
f. Co

99.

a. Ca
b. K
c. Cs
d. Pb
e. Pt
f. Au

100.

a. Br
b. Bi
c. Hg
d. V
e. F
f. Ca

101.

a. Ag
b. Al
c. Cd
d. Sb
e. Sn
f. As

102.

a. osmium
b. zirconium
c. rubidium
d. radon
e. uranium
f. manganese
g. nickel
h. bromine

103.

a. tellurium
b. palladium
c. zinc
d. silicon
e. cesium
f. bismuth
g. fluorine
h. titanium

104.

a. CO_2
b. $AlCl_3$
c. $HClO_4$
d. SCl_6

105.

a. nitrogen, N
b. neon, Ne
c. sodium, Na
d. nickel, Ni

e. titanium, Ti

f. argon, Ar

g. krypton, Kr

h. xenon, Xe

106.

a. $^{13}_{6}C$

b. $^{13}_{6}C$

c. $^{13}_{6}C$

d. $^{44}_{19}K$

e. $^{41}_{20}Ca$

f. $^{35}_{19}K$

107.

a. 22 protons, 19 neutrons, 22 electrons

b. 30 protons, 34 neutrons, 30 electrons

c. 32 protons, 44 neutrons, 32 electrons

d. 36 protons, 50 neutrons, 36 electrons

e. 33 protons, 42 neutrons, 33 electrons

f. 19 protons, 22 neutrons, 19 electrons

108.

Symbol	Number of Protons	Number of Neutrons	Mass Number
$^{41}_{20}Ca$	20	21	41
$^{55}_{25}Mn$	25	30	55
$^{109}_{47}Ag$	47	62	109
$^{45}_{21}Sc$	21	24	45

109.

a. C; Z = 6; nonmetal

b. Se; Z = 34; nonmetal

c. Rn; Z = 86; nonmetal; noble gases

d. Be; Z = 4; metal; alkaline earth elements