Exercises

Development of the Atomic Theory

19. a. The composition of a substance depends on the numbers of atoms of each element making up the compound (i.e., the formula of the compound) and not on the composition of the mixture from which it was formed.

b. Avogadro’s hypothesis implies that volume ratios are equal to molecule ratios at constant temperature and pressure. \( \text{H}_2 + \text{Cl}_2 \rightarrow 2 \text{HCl} \). From the balanced equation, the volume of \( \text{HCl} \) produced will be twice the volume of \( \text{H}_2 \) (or \( \text{Cl}_2 \)) reacted.

20. From Avogadro’s hypothesis, volume ratios are equal to molecule ratios at constant temperature and pressure. Therefore, we can write a balanced equation using the volume data, \( \text{Cl}_2 + 3 \text{F}_2 \rightarrow 2 \text{X} \). Two molecules of \( \text{X} \) contain 6 atoms of \( \text{F} \) and two atoms of \( \text{Cl} \). The formula of \( \text{X} \) is \( \text{ClF}_3 \) for a balanced reaction.

\[
\frac{1.188}{1.188} = 1.000; \quad \frac{2.375}{1.188} = 1.999; \quad \frac{3.563}{1.188} = 2.999
\]

The masses of fluorine are simple ratios of whole numbers to each other, 1:2:3.

21. Hydroxylamine: \( 1.44 \times 10^{-1} \text{ g H/g N} \); Ammonia: \( 2.16 \times 10^{-1} \text{ g H/g N} \)

Hydrogen azide: \( 2.40 \times 10^{-2} \text{ g H/g N} \)

Let’s try all of the ratios:

\[
\frac{0.216}{0.144} = \frac{1.50}{2}; \quad \frac{0.144}{0.0240} = 6.00; \quad \frac{0.216}{0.0240} = 9.00
\]

All the masses of hydrogen in these three compounds can be expressed as simple whole number ratios. The g H/g N in hydrazine, ammonia, and hydrogen azide are in the ratios 6:9:1.

22. To get the atomic mass of H to be 1.00, we divide the mass of hydrogen that reacts with 1.00 g of oxygen by 0.126, i.e., \( \frac{0.126}{0.126} = 1.00 \). To get Na, Mg and O on the same scale, we do the same division.

\[
\text{Na: } \frac{2.875}{0.126} = 22.8; \quad \text{Mg: } \frac{1.500}{0.126} = 11.9; \quad \text{O: } \frac{1.00}{0.126} = 7.94
\]

<table>
<thead>
<tr>
<th></th>
<th>H</th>
<th>O</th>
<th>Na</th>
<th>Mg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relative Value</td>
<td>1.00</td>
<td>7.94</td>
<td>22.8</td>
<td>11.9</td>
</tr>
<tr>
<td>Accepted Value</td>
<td>1.008</td>
<td>16.00</td>
<td>22.99</td>
<td>24.31</td>
</tr>
</tbody>
</table>
The atomic masses of O and Mg are incorrect. The atomic masses of H and Na are close. Something must be wrong about the assumed formulas of the compounds. It turns out the correct formulas are \( \text{H}_2\text{O}, \text{Na}_2\text{O}, \) and \( \text{MgO}. \) The smaller discrepancies result from the error in the atomic mass of H.

24. If the formula was Be\(_2\)O\(_3\), then 2 times the atomic mass of Be would combine with three times the atomic mass of oxygen, or:

\[
\frac{2A}{3(16.00)} = \frac{0.5633}{1.000}
\]

Atomic mass of Be = A = 13.52. The accepted value is 9.01 and the discrepancy is due to the assumed formula. The actual formula is BeO.

The Nature of the Atom

25. Density of hydrogen nucleus (contains one proton only):

\[
V_{\text{nucleus}} = \frac{4}{3} \pi r^3 = \frac{4}{3} (3.14) (5 \times 10^{-14} \text{ cm})^3 = 5 \times 10^{-40} \text{ cm}^3
\]

\[
d = \frac{1.67 \times 10^{-24} \text{ g}}{5 \times 10^{-40} \text{ cm}^3} = 3 \times 10^{15} \text{ g/cm}^3
\]

Density of H-atom (contains one proton and one electron):

\[
V_{\text{atom}} = \frac{4}{3} (3.14) (1 \times 10^{-8} \text{ cm})^3 = 4 \times 10^{-24} \text{ cm}^3
\]

\[
d = \frac{1.67 \times 10^{-24} + 9 \times 10^{-28} \text{ g}}{4 \times 10^{-24} \text{ cm}^3} = 0.4 \text{ g/cm}^3
\]

26. Since electrons move about the nucleus at an average distance of about \( 1 \times 10^{-8} \text{ cm} \), then the diameter of an atom is about \( 2 \times 10^{-8} \text{ cm} \). Let’s set up a ratio:

\[
\frac{\text{diameter of nucleus}}{\text{diameter of atom}} = \frac{1 \text{ mm}}{\text{diameter of model}} = \frac{1 \times 10^{-13} \text{ cm}}{2 \times 10^{-8} \text{ cm}}, \text{ Solving:}
\]

\[
\text{diameter of model} = 2 \times 10^5 \text{ mm} = 200 \text{ m}
\]

27. \( 5.93 \times 10^{-18} \text{ C} \times \frac{1 \text{ electron charge}}{1.602 \times 10^{-19} \text{ C}} = 37 \) negative (electron) charges on the oil drop

28. First, divide all charges by the smallest quantity, \( 6.40 \times 10^{-13} \).

\[
\frac{2.56 \times 10^{-12}}{6.40 \times 10^{-13}} = 4.00; \quad \frac{7.68}{0.640} = 12.00; \quad \frac{3.84}{0.640} = 6.00
\]
Since all charges are whole number multiples of \(6.40 \times 10^{-19}\) zirkombs then the charge on one electron could be \(6.40 \times 10^{-19}\) zirkombs. However, \(6.40 \times 10^{-19}\) zirkombs could be the charge of two electrons (or three electrons, etc.). All one can conclude is that the charge of an electron is \(6.40 \times 10^{-19}\) zirkombs or an integer fraction of \(6.40 \times 10^{-19}\).

29. gold - Au; silver - Ag; mercury - Hg; potassium - K; iron - Fe; antimony - Sb; tungsten - W
30. sodium - Na; beryllium - Be; manganese - Mn; chromium - Cr; uranium - U
31. fluorine - F; chlorine - Cl; bromine - Br; sulfur - S; oxygen - O; phosphorus - P
32. titanium - Ti; selenium - Se; plutonium - Pu; nitrogen - N; silicon - Si
33. Sn - tin; Pt - platinum; Co - cobalt; Ni - nickel; Mg - magnesium; Ba - barium; K - potassium
34. As - arsenic; I - iodine; Xe - xenon; He - helium; C - carbon; Si - silicon
35. The noble gases are He, Ne, Ar, Kr, Xe, and Rn (helium, neon, argon, krypton, xenon, and radon). Radon has only radioactive isotopes. In the periodic table the whole number enclosed in parenthesis is the mass number of the longest lived isotope of the element.

36. promethium (Pm) and technetium (Tc)
37. a. Eight; Li to Ne
   b. Eight; Na to Ar
   c. Eighteen; K to Kr
   d. Five; N, P, As, Sb, Bi
38. a. Six; Be, Mg, Ca, Sr, Ba, Ra
   b. Five; O, S, Se, Te, Po
   c. Three; Ni, Pd, Pt
   d. Six; He, Ne, Ar, Kr, Xe, Rn
39. a. \(\frac{238}{94}\)Pu; 94 protons, 238 - 94 = 144 neutrons
   b. \(\frac{65}{29}\)Cu; 29 protons, 65 - 29 = 36 neutrons
   c. \(\frac{52}{24}\)Cr; 24 protons, 28 neutrons
   d. \(\frac{4}{2}\)He; 2 protons, 2 neutrons
   e. \(\frac{60}{27}\)Co; 27 protons, 33 neutrons
   f. \(\frac{54}{24}\)Cr; 24 protons, 30 neutrons
40. a. \(\frac{15}{7}\)N; 7 protons, 8 neutrons
   b. \(\frac{3}{1}\)H; 1 proton, 2 neutrons
   c. \(\frac{207}{82}\)Pb; 82 protons, 125 neutrons
   d. \(\frac{151}{63}\)Eu; 63 protons, 88 neutrons
   e. \(\frac{107}{47}\)Ag; 47 protons, 60 neutrons
   f. \(\frac{109}{47}\)Ag; 47 protons, 62 neutrons
41. 9 protons means the atomic number is 9. The mass number is 9 + 10 = 19; Symbol: \(\frac{19}{9}\)F
42. a. P b. I c. K d. Yb
43. Atomic number = 63 (Eu), Charge = +63 - 60 = +3; Mass number = 63 + 88 = 151; Symbol: \(\frac{151}{63}\)Eu\(^{3+}\)
44. Atomic number = 50 (Sn); Mass number = 50 + 68 = 118; Net charge = +50 - 48 = +2; The symbol is $^{118}_{50}$Sn$^{2+}$.

45. Atomic number = 16 (S); Charge = +16 - 18 = -2; Mass number = 16 + 18 = 34; Symbol: $^{34}_{16}$S$^{2-}$

46. Atomic number = 16 (S); Charge = +16 - 18 = -2; Mass number = 16 + 16 = 32; Symbol: $^{32}_{16}$S$^{2-}$

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Number of protons in nucleus</th>
<th>Number of neutrons in nucleus</th>
<th>Number of electrons</th>
<th>Net charge</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{75}_{33}$As$^{3+}$</td>
<td>33</td>
<td>42</td>
<td>30</td>
<td>3+</td>
</tr>
<tr>
<td>$^{128}_{52}$Te$^{2-}$</td>
<td>52</td>
<td>76</td>
<td>54</td>
<td>2-</td>
</tr>
<tr>
<td>$^{32}_{16}$S</td>
<td>16</td>
<td>16</td>
<td>16</td>
<td>0</td>
</tr>
<tr>
<td>$^{204}_{81}$Tl$^{+}$</td>
<td>81</td>
<td>123</td>
<td>80</td>
<td>1+</td>
</tr>
<tr>
<td>$^{195}_{78}$Pt</td>
<td>78</td>
<td>117</td>
<td>78</td>
<td>0</td>
</tr>
</tbody>
</table>

48.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Number of protons in nucleus</th>
<th>Number of neutrons in nucleus</th>
<th>Number of electrons</th>
<th>Net charge</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{238}_{92}$U</td>
<td>92</td>
<td>146</td>
<td>92</td>
<td>0</td>
</tr>
<tr>
<td>$^{40}_{20}$Ca$^{2+}$</td>
<td>20</td>
<td>20</td>
<td>18</td>
<td>2+</td>
</tr>
<tr>
<td>$^{51}_{23}$V$^{3+}$</td>
<td>23</td>
<td>28</td>
<td>20</td>
<td>3+</td>
</tr>
<tr>
<td>$^{89}_{39}$Y</td>
<td>39</td>
<td>50</td>
<td>39</td>
<td>0</td>
</tr>
<tr>
<td>$^{79}_{35}$Br$^{-}$</td>
<td>35</td>
<td>44</td>
<td>36</td>
<td>1-</td>
</tr>
<tr>
<td>$^{31}_{15}$P$^{3-}$</td>
<td>15</td>
<td>16</td>
<td>18</td>
<td>3-</td>
</tr>
</tbody>
</table>
49. Metals: Mg, Ti, Au, Bi, Ge, Eu, Am; Nonmetals: Si, B, At, Rn, Br

50. Si, Ge, B, At; The elements at the boundary between the metals and the non-metals: B, Si, Ge, As, Sb, Te, Po, At. Aluminum has mostly properties of metals.

51. a and d: A group is a vertical column of elements in the periodic table. Elements in the same family (group) have similar chemical properties.

52. b (Group 4A) and d (Group 2A)

53. Carbon is a nonmetal. Silicon and germanium are metalloids. Tin and lead are metals. Thus, metallic character increases as one goes down a family in the periodic table.

54. The metallic character decreases from left to right.

55. Metals lose electrons to form cations and nonmetals gain electrons to form anions. Group IA, IIA and IIA metals form stable +1, +2 and +3 charged cations, respectively. Group VA, VIA and VIIA nonmetals form -3, -2 and -1 charged anions, respectively.

   a. Lose 1 e\textsuperscript{-} to form Na\textsuperscript{+}.
   b. Lose 2 e\textsuperscript{-} to form Sr\textsuperscript{2+}.
   c. Lose two e\textsuperscript{-} to form Ba\textsuperscript{2+}.
   d. Gain 1 e\textsuperscript{-} to form I\textsuperscript{-}.
   e. Lose 3 e\textsuperscript{-} to form Al\textsuperscript{3+}.
   f. Gain 2 e\textsuperscript{-} to form S\textsuperscript{2-}.

56. a. Gain 1 e\textsuperscript{-} to form Cl\textsuperscript{-}.
   b. Lose 1 e\textsuperscript{-} to form Cs\textsuperscript{+}.
   c. Gain 2 e\textsuperscript{-} to form Se\textsuperscript{2-}.
   d. Gain 3 e\textsuperscript{-} to form N\textsuperscript{3-}.
   e. Gain 2 e\textsuperscript{-} to form O\textsuperscript{2-}.
   f. Lose 2 e\textsuperscript{-} to form Mg\textsuperscript{2+}.

Nomenclature

57. a. sodium chloride
   b. rubidium oxide
   c. calcium sulfide
   d. aluminum iodide
   58. a. cobalt(III) oxide
   b. copper(I) oxide
   c. iron(II) bromide
   d. lead(IV) sulfide
   59. a. chromium(VI) oxide
   b. chromium(III) oxide
   c. aluminum oxide
   d. sodium hydride
   e. calcium bromide
   f. zinc chloride (Zinc only forms +2 ions so no roman numerals are needed for zinc compounds.)

60. a. cesium fluoride
   b. lithium nitride
   c. silver sulfide (Silver only forms +1 ions so no roman numerals are needed.)
   d. manganese(IV) oxide
   e. titanium(IV) oxide
   f. strontium phosphide

61. a. potassium perchlorate
   b. calcium phosphate
   c. aluminum sulfate
   d. lead(II) nitrate

62. a. barium sulfide
   b. sodium nitrite
   c. potassium permanganate
   d. potassium dichromate
63. a. nitrogen triiodide  
   c. sulfur difluoride  
   b. phosphorus trichloride  
   d. dinitrogen tetrafluoride

64. a. silicon tetrafluoride  
   c. nitrogen monoxide  
   b. tetraphosphorus hexoxide  
   d. selenium trioxide

65. a. copper(I) iodide  
   d. sodium carbonate  
   f. tetrabulfur tetranitride  
   i. barium chromate  
   b. copper(II) iodide  
   e. sodium hydrogen carbonate or sodium bicarbonate  
   g. sulfur hexafluoride  
   j. ammonium nitrate  
   c. cobalt(II) iodide  
   h. sodium hypochlorite

66. a. nitric acid  
   d. nitrogen trifluoride  
   f. dichlorine heptoxide  
   i. ruthenium(III) nitrate  
   l. magnesium phosphate  
   b. nitrous acid  
   e. sodium hydrogen sulfate or sodium bisulfate (common name)  
   g. sodium bromate  
   j. vanadium(V) oxide  
   c. phosphoric acid  
   h. iron(III) periodate  
   i. Co(NO₃)₃

67. a. CsBr  
   b. BaSO₄  
   e. SiCl₄  
   f. ClF₃  
   c. NH₄Cl  
   d. ClO  
   g. BeO  
   h. MgF₂

68. a. SF₂  
   d. Li₃N  
   g. NH₄C₂H₅O₂  
   j. Hg₂Cl₂; Mercury(I) exists as Hg²⁺ ions.  
   b. SF₆  
   e. Cr₂(CO₃)₃  
   h. NH₄HSO₄  
   k. KClO₃  
   c. NaH₂PO₄  
   f. SnF₂  
   i. Co(NO₃)₃  
   l. NaH

69. a. NaOH  
   d. Na₂O₂  
   g. PbO  
   j. CuBr  
   b. Al(OH)₃  
   e. Cu(C₂H₅O₂)₂  
   h. PbO₂  
   k. H₂SO₃  
   c. HCN  
   f. CF₄  
   i. HC₂H₅O₂  
   l. GaAs (Ga³⁺ and As³⁻ ions)

70. a. (NH₄)₂HPO₄  
   d. Na₂SO₃  
   g. HBr  
   j. KHS  
   b. Hg₂S  
   e. Al(HSO₄)₃  
   h. HBrO₂  
   k. CaI₂  
   c. SiO₂  
   f. NCl₃  
   i. HBrO₄  
   l. CsClO₄

Additional Exercises

71. There should be no difference. The composition of insulin from both sources will be the same and therefore, it will have the same activity regardless of the source. As a practical note, trace contaminants in the two types of insulin may be different. These trace contaminates may be important.

72. a. $^{24}_{12}$Mg: 12 protons, 12 neutrons, 12 electrons
   b. $^{24}_{12}$Mg²⁺: 12 p, 12 n, 10 e  
   c. $^{59}_{27}$Co²⁺: 27 p, 32 n, 25 e
   d. $^{59}_{27}$Co³⁺: 27 p, 32 n, 24 e  
   e. $^{59}_{27}$Co: 27 p, 32 n, 27 e