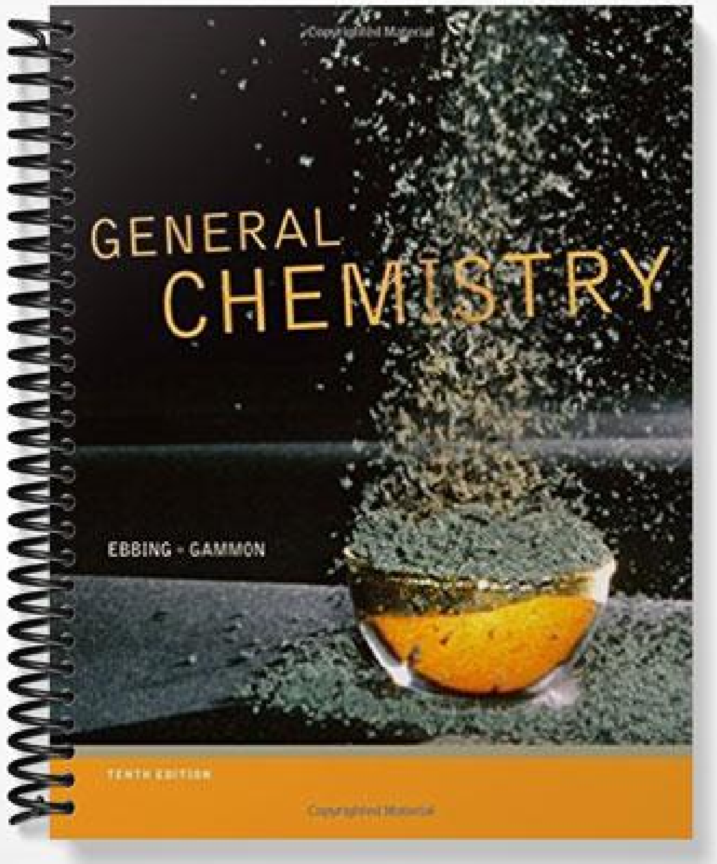
SOLUTIONS MANUAL



CHAPTER 2

Atoms, Molecules, and Ions

■ SOLUTIONS TO EXERCISES

Note on significant figures: If the final answer to a solution needs to be rounded off, it is given first with one nonsignificant figure, and the last significant figure is underlined. The final answer is then rounded to the correct number of significant figures. In multistep problems, intermediate answers are given with at least one nonsignificant figure; however, only the final answer has been rounded off.

2.1. The element with atomic number 17 (the number of protons in the nucleus) is chlorine, symbol Cl. The mass number is 17 + 18 = 35. The symbol is ${}^{35}_{17}Cl$.

2.2. Multiply each isotopic mass by its fractional abundance; then sum:

$34.96885 \text{ amu} \times 0.75771 = 26.49\underline{6}247$

$36.96590 \text{ amu} \times 0.24229 = \underline{8.956467}$

$35.45\underline{2}714 = 35.453 \text{ amu}$

The atomic mass of chlorine is 35.453 amu.

2.3.
a. Se: Group VIA, Period 4; nonmetal
b. Cs: Group IA, Period 6; metal
c. Fe: Group VIIIB, Period 4; metal
d. Cu: Group IB, Period 4; metal
e. Br: Group VIIA, Period 4; nonmetal

2.4. Take as many cations as there are units of charge on the anion and as many anions as there are units of charge on the cation. Two K^+ ions have a total charge of 2+, and one CrO_4^{2-} ion has a charge of 2–, giving a net charge of zero. The simplest ratio of K^+ to CrO_4^{2-} is 2:1, and the formula is K_2CrO_4.

2.5. a. CaO: Calcium, a Group IIA metal, is expected to form only a 2+ ion (Ca^{2+}, the calcium ion). Oxygen (Group VIA) is expected to form an anion of charge equal to the group number minus 8 (O^{2-}, the oxide ion). The name of the compound is calcium oxide.

b. $PbCrO_4$: Lead has more than one monatomic ion. You can find the charge on the Pb ion if you know the formula of the anion. From Table 2.5, the CrO_4 refers to the anion CrO_4^{2-} (the chromate ion). Therefore, the Pb cation must be Pb^{2+} to give electrical neutrality. The name of Pb^{2+} is lead(II) ion, so the name of the compound is lead(II) chromate.

2.6. Thallium(III) nitrate contains the thallium(III) ion, Tl^{3+}, and the nitrate ion, NO_3^-. The formula is $Tl(NO_3)_3$.

2.7. a. Dichlorine hexoxide

b. Phosphorus trichloride

c. Phosphorus pentachloride

2.8. a. CS_2 b. SO_3

2.9. a. Boron trifluoride b. Hydrogen selenide

2.10. When you remove one H^+ ion from $HBrO_4$, you obtain the BrO_4^- ion. You name the ion from the acid by replacing -*ic* with -*ate*. The anion is called the perbromate ion.

2.11. Sodium carbonate decahydrate

2.12. Sodium thiosulfate is composed of sodium ions (Na^+) and thiosulfate ions ($S_2O_3^{2-}$), so the formula of the anhydrous compound is $Na_2S_2O_3$. Since the material is a pentahydrate, the formula of the compound is $Na_2S_2O_3{\bullet}5H_2O$.

2.13. Balance O first in parts (a) and (b) because it occurs in only one product. Balance S first in part (c) because it appears in only one product. Balance H first in part (d) because it appears in just one reactant as well as in the product.

a. Write a 2 in front of $POCl_3$ for O; this requires a 2 in front of PCl_3 for final balance:

$$O_2 + 2PCl_3 \rightarrow 2POCl_3$$

b. Write a 6 in front of N_2O to balance O; this requires a 6 in front of N_2 for final balance:

$$P_4 + 6N_2O \rightarrow P_4O_6 + 6N_2$$

c. Write $2As_2S_3$ and $6SO_2$ to achieve an even number of oxygens on the right to balance what will always be an even number of oxygens on the left. The $2As_2S_3$ then requires $2As_2O_3$. Finally, to balance (6 + 12) O's on the right, write $9O_2$.

$$2As_2S_3 + 9O_2 \rightarrow 2As_2O_3 + 6SO_2$$

d. Write a 4 in front of H_3PO_4; this requires a 3 in front of $Ca(H_2PO_4)_2$ for twelve H's.

$$Ca_3(PO_4)_2 + 4H_3PO_4 \rightarrow 3Ca(H_2PO_4)_2$$

■ ANSWERS TO CONCEPT CHECKS

2.1. CO_2 is a compound that is a combination of 1 carbon atom and 2 oxygen atoms. Therefore, the chemical model must contain a chemical combination of 3 atoms stuck together with 2 of the atoms being the same (oxygen). Since each "ball" represents an individual atom, the three models on the left can be eliminated since they don't contain the correct number of atoms. Keeping in mind that balls of the same color represent the same element, only the model on the far right contains two elements with the correct ratio of atoms, 1:2; therefore, it must be CO_2.

2.2. If 7999 out of 8000 alpha particles deflected back at the alpha-particle source, this would imply that the atom was a solid, impenetrable mass. Keep in mind that this is in direct contrast to what was observed in the actual experiments, where the majority of the alpha particles passed through without being deflected.

2.3. Elements are listed together in groups because they have similar chemical and/or physical properties.

2.4. Statement (a) is the best statement regarding molecular compounds. Although you may have wanted to classify Br_2 as a molecular compound, it is an element and not a compound. Regarding statement (b), quite a few molecular compounds exit that don't contain carbon. Water and the nitrogen oxides associated with smog are prime examples. Statement (c) is false; ionic compounds consist of anions and cations. Statement (d) is very close to the right selection but it is too restrictive. Some molecular compounds containing both metal and nonmetal atoms are known to exist, e.g., cisplatin, $Ni(CO)_4$, etc. Because numerous molecular compounds are either solids or liquids at room temperature, statement (e) is false.

2.5. a. This compound is an ether because it has a functional group of an oxygen atom between two carbon atoms (–O–).

b. This compound is an alcohol because it has an –OH functional group.

c. This compound is a carboxylic acid because it has the –COOH functional group.

d. This compound is a hydrocarbon because it contains only carbon and hydrogen atoms.

2.6. The SO_4^{2-}, NO_2^-, and I_3^- are considered to be polyatomic ions. Statement (a) is true based on the prefix *poly*. By definition, any ion must have a negative or positive charge; thus, statement (b) is true. Bring that the triiodide ion has only iodine atoms bonded together, and no other elements present, statement (c) is false. There are numerous examples to show that statement (d) is true, e.g., chromate, dichromate, permanganate to name a few. Oxoanions are polyatomic ions containing a central characteristic element surrounded by a number of oxygen atoms, e.g., sulfate and nitrite given in this concept check's. Statement (e) is true.

2.7. A bottle containing a compound with the formula Al_2Q_3 would have an anion, Q, with a charge of 2−. The total positive charge in the compound due to the Al^{3+} is 6+ (2 x 3+), so the total negative charge must be 6−; therefore, each Q ion must have a charge of 2−. Thus, Q would probably be an element from Group VIA on the periodic table.

■ ANSWERS TO SELF-ASSESSMENT AND REVIEW QUESTIONS

2.1. Atomic theory is an explanation of the structure of matter in terms of different combinations of very small particles called atoms. Since compounds are composed of atoms of two or more elements, there is no limit to the number of ways in which the elements can be combined. Each compound has its own unique properties. A chemical reaction consists of the rearrangement of the atoms present in the reacting substances to give new chemical combinations present in the substances formed by the reaction.

2.2. Divide each amount of chlorine, 1.270 g and 1.904 g, by the lower amount, 1.270 g. This gives 1.000 and 1.499, respectively. Convert these to whole numbers by multiplying by 2, giving 2.000 and 2.998. The ratio of these amounts of chlorine is essentially 2:3. This is consistent with the law of multiple proportions because, for a fixed mass of iron (1 gram), the masses of chlorine in the other two compounds are in a ratio of small whole numbers.

2.3. A cathode-ray tube consists of a negative electrode, or cathode, and a positive electrode, or anode, in an evacuated tube. Cathode rays travel from the cathode to the anode when a high voltage is turned on. Some of the rays pass through the hole in the anode to form a beam, which is then bent toward positively charged electric plates in the tube. This implies that a cathode ray consists of a beam of negatively charged particles (or electrons) and that electrons are constituents of all matter.

2.4. Millikan performed a series of experiments in which he obtained the charge on the electron by observing how a charged drop of oil falls in the presence and in the absence of an electric field. An atomizer introduces a fine mist of oil drops into the top chamber (Figure 2.6). Several drops happen to fall through a small hole into the lower chamber, where the experimenter follows the motion of one drop with a microscope. Some of these drops have picked up one or more electrons as a result of friction in the atomizer and have become negatively charged. A negatively charged drop will be attracted upward when the experimenter turns on a current to the electric plates. The drop's upward speed (obtained by timing its rise) is related to its mass-to-charge ratio, from which you can calculate the charge on the electron.

2.5. The nuclear model of the atom is based on experiments of Geiger, Marsden, and Rutherford. Rutherford stated that most of the mass of an atom is concentrated in a positively charged center called the nucleus around which negatively charged electrons move. The nucleus, although it contains most of the mass, occupies only a very small portion of the space of the atom. Most of the alpha particles passed through the metal atoms of the foil undeflected by the lightweight electrons. When an alpha particle does happen to hit a metal-atom nucleus, it is scattered at a wide angle because it is deflected by the massive, positively charged nucleus (Figure 2.8).

2.6. The atomic nucleus consists of two kinds of particles, protons and neutrons. The mass of each is about the same, on the order of 1.67×10^{-27} kg, and about 1800 times that of the electron. An electron has a much smaller mass, on the order of 9.11×10^{-31} kg. The neutron is electrically neutral, but the proton is positively charged. An electron is negatively charged. The charges on the proton and the electron are equal in magnitude.

2.7. Protons (hydrogen nuclei) were discovered as products of experiments involving the collision of alpha particles with nitrogen atoms that resulted in a proton being knocked out of the nitrogen nucleus. Neutrons were discovered as the radiation product of collisions of alpha particles with beryllium atoms. The resulting radiation was discovered to consist of particles having a mass approximately equal to that of a proton and having no charge (neutral).

2.8. Oxygen consists of three different isotopes, each having 8 protons but a different number of neutrons.

2.9. The percentages of the different isotopes in most naturally occurring elements have remained essentially constant over time and in most cases are independent of the origin of the element. Thus, what Dalton actually calculated were average atomic masses (relative masses). He could not weigh individual atoms, but he could find the average mass of one atom relative to the average mass of another.

2.10. A mass spectrometer measures the mass-to-charge ratio of positively charged atoms (and molecules). It produces a mass spectrum, which shows the relative numbers of atoms (fractional abundances) of various masses (isotopic masses). The mass spectrum gives us all the information needed to calculate the atomic weight.

2.11. The atomic mass of an element is the average atomic mass for the naturally occurring element expressed in atomic mass units. The atomic mass would be different elsewhere in the universe if the percentages of isotopes in the element were different from those on earth. Recent research has shown that isotopic abundances actually do differ slightly depending on the location found on earth.

2.12. The element in Group IVA and Period 5 is tin (atomic number 50).

2.13. A metal is a substance or mixture that has characteristic luster, or shine, and is generally a good conductor of heat and electricity.

2.14. The formula for ethane is C_2H_6.

2.15. A molecular formula gives the exact number of different atoms of an element in a molecule. A structural formula is a chemical formula that shows how the atoms are bonded to one another in a molecule.

2.16. Organic molecules contain carbon combined with other elements such as hydrogen, oxygen, and nitrogen. An inorganic molecule is composed of elements other than carbon. Some inorganic molecules that contain carbon are carbon monoxide (CO), carbon dioxide (CO_2), carbonates, and cyanides.

2.17. An ionic binary compound: NaCl; a molecular binary compound: H_2O.

2.18. a. The elements are represented by B, F, and I.

b. The compounds are represented by A, E, and G.

c. The mixtures are represented by C, D, and H.

d. The ionic solid is represented by A.

e. The gas made up of an element and a compound is represented by C.

f. The mixtures of elements are represented by D and H.

g. The solid element is represented by F.

h. The solids are represented by A and F.

i. The liquids are represented by E, H, and I.

2.19. In the Stock system, CuCl is called copper(I) chloride, and $CuCl_2$ is called copper(II) chloride. One of the advantages of the Stock system is that more than two different ions of the same metal can be named with this system. In the former (older) system, a new suffix other than -*ic* and -*ous* must be established and/or memorized.

2.20. A balanced chemical equation has the numbers of atoms of each element equal on both sides of the arrow. The coefficients are the smallest possible whole numbers.

2.21. The answer is a: 50 p, 69 n, and 48 e^-.

2.22. The answer is d: 65%.

2.23. The answer is c: magnesium hydroxide, $Mg(OH)_2$.

2.24. The answer is b: Li.

■ ANSWERS TO CONCEPT EXPLORATIONS

2.25. **Part I**

a. $\text{Average mass} = \dfrac{2.00\text{ g} + 2.00\text{ g} + 2.00\text{ g} + 2.00\text{ g}}{4} = 2.00\text{ g}$

Part II

a. $\text{Average mass} = \dfrac{2.00\text{ g} + 1.75\text{ g} + 3.00\text{ g} + 1.25\text{ g}}{4} = 2.00\text{ g}$

b. The average mass of a sphere in the two samples is the same. The average does not represent the individual masses. Also, it does not indicate the variability in the individual masses.

Part III

a. $\dfrac{50\text{ blue spheres}}{1} \times \dfrac{2.00\text{ g}}{1\text{ blue sphere}} = 100.00\text{ g}$

b. If 50 spheres were removed at random, then 50 spheres would remain in the jar. You can use the average mass to calculate the total mass.

$\dfrac{50\text{ spheres}}{1} \times \dfrac{2.00\text{ g}}{1\text{ sphere}} = 100.00\text{ g}$

c. No, the average mass does not represent the mass of an individual sphere.

d. $\dfrac{80.0\text{ g}}{1} \times \dfrac{1\text{ blue sphere}}{2.00\text{ g}} = 40.0\text{ blue spheres}$

e. $\dfrac{60.0\text{ g}}{1} \times \dfrac{1\text{ sphere}}{2.00\text{ g}} = 30.0\text{ spheres}$

The assumption is that the average mass of a sphere (2.00 g) can be used in the calculation. Also, assume the sample is well mixed.

Part IV

a. For green spheres: $X = \dfrac{3\text{ green}}{3\text{ green} + 1\text{ blue}} = 0.750$

For blue spheres: $X = \dfrac{1\text{ blue}}{3\text{ green} + 1\text{ blue}} = 0.250$

b. $\text{Average mass} = (0.750) \times \dfrac{3.00\text{ g}}{1\text{ green sphere}} + (0.250) \times \dfrac{1.00\text{ g}}{1\text{ blue sphere}} = 2.50\text{ g}$

c. The atomic mass of an element is the weighted average calculated as in part (b) of Part IV above, using fractional abundances and individual masses.

2.26. a. Atom A has three protons.

b. The number of protons is the same as the atomic number for that element.

c. Lithium, Li, has atomic number 3.

d. The charge on element A is zero. There are three protons, each +1, and three electrons, each −1. This yields a net charge of zero.

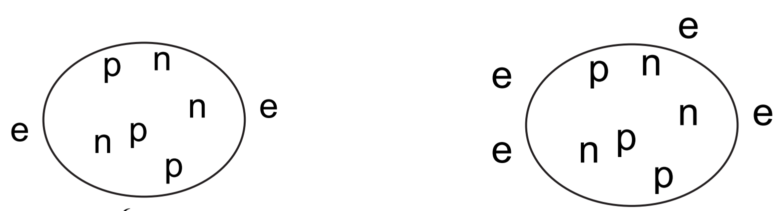
e. The nuclide symbol for A is $^{7}_{3}Li$.

f. Atom B has three protons and thus atomic number 3. It is lithium, with symbol Li.

g. Atom B has three protons and three neutrons. Its mass number is 6. This is different from the mass number of atom A, which is 7.

h. Atom B has three protons and three electrons and thus is neutral.

i. The nuclide symbol for B is $^{6}_{3}Li$. The atomic number is 3 and the mass number is 6 for both nuclides.

j. 

$^{6}_{3}Li^{+}$ $^{6}_{3}Li^{-}$

In both cases the mass number is 6 and the atomic number is 3

k. Two different lithium isotopes are depicted, lithium-6 and lithium-7.

l. The mass number of an isotope is the total number of protons and neutrons in its nucleus. Its value is an integer. It is related to the mass of the isotope but not related to the atomic mass, which is a weighted average over the fractional abundances and isotopic masses.

■ ANSWERS TO CONCEPTUAL PROBLEMS

2.27. If atoms were balls of positive charge with the electrons evenly distributed throughout, there would be no massive, positive nucleus to deflect the beam of alpha particles when it is shot at the gold foil.

2.28. Once the subscripts of the compounds in the original chemical equation are changed (the molecule N_2 was changed to the atom N), the substances reacting are no longer the same. Your friend may be able to balance the second equation, but it is no longer the same chemical reaction.

2.29. You could group elements by similar physical properties such as density, mass, color, conductivity, etc., or by chemical properties, such as reaction with air, reaction with water, etc.

2.30. You would name the ions with the formulas XO_4^{2-}, XO_3^{2-}, and XO^{2-} using the name for XO_2^{2-} (excite) as the example to determine the root name of the element X (exc). Thus XO_4^{2-}, with the greatest number of oxygen atoms in the group, would be perexcate; XO_3^{2-} would be excate; and XO^{2-}, with the fewest oxygen atoms in the group, would be hypoexcite.

2.31. a. In each case, the total positive charge and the total negative charge in the compounds must cancel. Therefore, the compounds with the cations X^+, X^{2+}, and X^{5+}, combined with the SO_4^{2-} anion, are X_2SO_4, XSO_4, and $X_2(SO_4)_5$, respectively.

b. You recognize the fact that whenever a cation can have multiple oxidation states (1+, 2+, and 5+ in this case), the name of the compound must indicate the charge. Therefore, the names of the compounds in part (a) would be exy(I) sulfate, exy(II) sulfate, and exy(V) sulfate, respectively.

2.32. a. This model contains three atoms of two different elements (H and O). Therefore, the model is of H_2O.

b. This model represents a crystal that contains two different elements in a 1:1 ratio (K^+ and Cl^-). Therefore, the model represents the ionic compound, KCl.

c. This model contains six atoms, four of which are the same (H), and two others (C and O). Therefore, the model is of CH_3OH.

d. This model contains four atoms of two different elements (N and H). Therefore, the model is of NH_3.

2.33. A potassium-39 atom in this case would contain 19 protons and 20 neutrons. If the charge of the proton were twice that of an electron, it would take twice as many electrons as protons, or 38 electrons, to maintain a charge of zero.

2.34. a. Since the mass of an atom is not due only to the sum of the masses of the protons, neutrons, and electrons, when you change the element in which you are basing the amu, the mass of the amu must change as well.

b. Since the amount of material that makes up a hydrogen atom doesn't change, when the amu gets larger, as in this problem, the hydrogen atom must have a smaller mass in amu.

2.35. a. $2Li + Cl_2 \rightarrow 2LiCl$

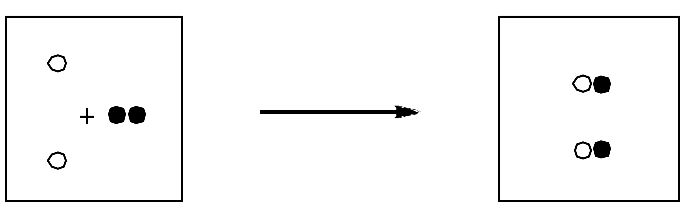
b. $16Na + S_8 \rightarrow 8Na_2S$

c. $2Al + 3I_2 \rightarrow 2AlI_3$

d. $3Ba + N_2 \rightarrow Ba_3N_2$

e. $12V + 5P_4 \rightarrow 4V_3P_5$

2.36.

a. 

b. $2A + B_2 \rightarrow 2AB$

c. Some possible real elements with formula B_2 are F_2, Cl_2, Br_2, and I_2.

■ SOLUTIONS TO PRACTICE PROBLEMS

Note on significant figures: If the final answer to a solution needs to be rounded off, it is given first with one nonsignificant figure, and the last significant figure is underlined. The final answer is then rounded to the correct number of significant figures. In multistep problems, intermediate answers are given with at least one nonsignificant figure; however, only the final answer has been rounded off.

2.37. a. Argon b. Zinc c. Silver d. Magnesium

2.38. a. Beryllium b. Silver c. Silicon d. Carbon

2.39. a. K b. S c. Fe d. Mn

2.40. a. Cu b. Ca c. Hg d. Sn

2.41. The mass of the electron is found by multiplying the two values:

$$1.602 \text{ x } 10^{-19}\text{ C} \times \frac{5.64 \times 10^{-12}\text{ kg}}{1\text{ C}} = 9.0\underline{3}5 \times 10^{-31}\text{ kg} = 9.04 \times 10^{-31}\text{ kg}$$

2.42. The mass of the fluorine atom is found by multiplying the two values:

$$1.602 \times 10^{-19}\text{ C} \times \frac{1.97 \times 10^{-7}\text{ kg}}{1\text{ C}} = 3.1\underline{5}5 \times 10^{-26}\text{ kg} = 3.16 \times 10^{-26}\text{ kg}$$

2.43. The isotope of atom A is the atom with 18 protons, atom C; the atom that has the same mass number as atom A (37) is atom D.

2.44. The isotope of atom A is the atom with 32 protons, atom D; the atom that has the same mass number as atom A (71) is atom B.

2.45. Each isotope of chlorine (atomic number 17) has 17 protons. Each neutral atom will also have 17 electrons. The number of neutrons for Cl-35 is 35 – 17 = 18 neutrons. The number of neutrons for Cl-37 is 37 – 17 = 20 neutrons.

2.46. Each isotope of nitrogen (atomic number 7) has seven protons. Each neutral atom will also have seven electrons. The number of neutrons for N-14 is 14 – 7 = 7 neutrons. The number of neutrons for N-15 is 15 – 7 = 8 neutrons.

2.47. The element with 14 protons in its nucleus is silicon (Si). The mass number = 14 + 14 = 28. The notation for the nucleus is ${}^{28}_{14}\text{Si}$.

2.48. The element with 34 protons in its nucleus is selenium (Se).
The mass number = 34 + 45 = 79. The notation for the nucleus is ${}^{79}_{34}\text{Se}$.

2.49. Since the atomic ratio of nitrogen to hydrogen is 1:3, divide the mass of N by one-third of the mass of hydrogen to find the relative mass of N.

$$\frac{\text{Atomic mass of N}}{\text{Atomic mass of H}} = \frac{7.933\text{ g}}{1/3 \text{ x } 1.712\text{ g}} = \frac{13.9\underline{0}1\text{ g N}}{1\text{ g H}} = \frac{13.90}{1}$$

2.50. Since the atomic ratio of hydrogen to sulfur is 2:1, divide the mass of S by one-half of the mass of hydrogen to find the relative mass of S.

$$\frac{\text{Atomic mass of S}}{\text{Atomic mass of H}} = \frac{9.330\text{ g}}{1/2 \times 0.587\text{ g}} = \frac{31.\underline{7}8\text{ g S}}{1\text{ g H}} = \frac{31.8}{1}$$

2.51. Multiply each isotopic mass by its fractional abundance, and then sum:

X-63: $62.930 \times 0.6909 = 43.4\underline{7}83$

X-65: $64.928 \times 0.3091 = \underline{20.0692}$

$63.5\underline{4}75 = 63.55$ amu

The element is copper, atomic mass 63.546 amu.

2.52. Multiply each isotopic mass by its fractional abundance, and then sum:

$49.9472 \times 0.002500 = 0.124868$

$50.9440 \times 0.9975 = \underline{50.81664}$

$= 50.9\underline{4}150 = 50.94$ amu

The atomic mass of this element is 50.94 amu. The element is vanadium (V).

2.53. Multiply each isotopic mass by its fractional abundance, and then sum:

$38.964 \times 0.9326 = 36.3\underline{3}78$

$39.964 \times 1.00 \times 10^{-4} = 0.00399\underline{6}4$

$40.962 \times 0.0673 = \underline{2.75674}$

$= 39.0\underline{9}853 = 39.10$ amu

The atomic mass of this element is 39.10 amu. The element is potassium (K).

2.54. Multiply each isotopic mass by its fractional abundance, and then sum:

$27.977 \times 0.9221 = 25.7\underline{9}8$

$28.976 \times 0.0470 = 1.3\underline{6}2$

$29.974 \times 0.0309 = \underline{0.9262}$

$= 28.0\underline{8}6 = 28.09$ amu

The atomic mass of this element is 28.09 amu. The element is silicon (Si).

2.55. According to the picture, there are 20 atoms, 5 of which are brown and 15 of which are green. Using the isotopic masses in the problem, the atomic mass of element X is

$$\frac{5}{20}(23.02\text{ amu}) + \frac{15}{20}(25.147\text{ amu}) = 5.75\underline{5} + 18.86\underline{0}2 = 24.61\underline{5}2 = 24.615\text{ amu}$$

2.56. According to the picture, there are 24 atoms, 8 of which are blue and 16 of which are orange. Using the isotopic masses in the problem, the atomic mass of element X is

$$\frac{8}{24}(47.621\text{ amu}) + \frac{16}{24}(51.217\text{ amu}) = 15.87\underline{3}7 + 34.14\underline{4}7 = 50.01\underline{8}4 = 50.018\text{ amu}$$

2.57. a. C: Group IVA, Period 2; nonmetal

b. Po: Group VIA, Period 6; metal

c. Cr: Group VIB, Period 4; metal

d. Mg: Group IIA, Period 3; metal

e. B: Group IIIA, Period 2; metalloid

2.58. a. V: Group VB, Period 4; metal

b. Rb: Group IA, Period 5; metal

c. B: Group IIIA, Period 2; metalloid

d. I: Group VIIA, Period 5; nonmetal

e. He: Group VIIIA, Period 1; nonmetal

2.59. a.Tellurium b. Aluminum

2.60. a. Bismuth b. Beryllium

2.61. Examples are:

a. O (oxygen)

b. F (fluorine)

c. Fe (iron)

d. Ce (cerium)

2.62. Examples are:

a. Ti (titanium)

b. Li (lithium)

c. S (sulfur)

d. U (uranium)

2.63. They are different in that the solid sulfur consists of S_8 molecules, whereas the hot vapor consists of S_2 molecules. The S_8 molecules are four times as heavy as the S_2 molecules. Hot sulfur is a mixture of S_8 and S_2 molecules, but at high enough temperatures only S_2 molecules are formed. Both hot sulfur and solid sulfur consist of molecules with only sulfur atoms.

2.64. They are different in that the solid phosphorus consists of P_4 molecules, whereas the hot vapor consists of P_2 molecules. The P_4 molecules are twice as heavy as the P_2 molecules. Hot phosphorus is a mixture of P_4 and P_2 molecules above the boiling point, but at high temperatures only P_2 molecules are formed. Both solid phosphorus and phosphorus vapor consist of molecules with only phosphorus atoms.

2.65. The number of nitrogen atoms in the 1.50-g sample of N_2O is

$$2.05 \times 10^{22}\ N_2O\ \text{molecules} \times \frac{2\ \text{N atoms}}{1\ N_2O\ \text{molecule}} = 4.10 \times 10^{22}\ \text{N atoms}$$

The number of nitrogen atoms in 44.0 g of N_2O is

$$44.0\ \text{g}\ N_2O \times \frac{4.10 \times 10^{22}\ \text{N atoms}}{1.50\ \text{g}\ N_2O} = 1.2\underline{0}3 \times 10^{24}\ \text{N atoms} = 1.20 \times 10^{24}\ \text{N atoms}$$

2.66. Since each HNO_3 molecule contains one N atom, in 4.30×10^{22} HNO_3 molecules there are 4.30 x 10^{22} N atoms. The number of oxygen atoms in 61.0 g of HNO_3 is obtained as follows.

$$61.0\ \text{g}\ HNO_3 \times \frac{4.30 \times 10^{22}\ HNO_3\ \text{molecules}}{4.50\ \text{g}\ HNO_3} \times \frac{3\ \text{O atoms}}{1\ HNO_3\ \text{molecule}}$$

$$= 1.7\underline{4}9 \times 10^{24}\ \text{O atoms} = 1.75 \times 10^{24}\ \text{O atoms}$$

2.67. $$3.3 \times 10^{21}\ \text{H atoms} \times \frac{1\ NH_3\ \text{molecule}}{3\ \text{H atoms}} = 1.1 \times 10^{21}\ NH_3\ \text{molecules}$$

2.68. $$4.2 \times 10^{23}\ \text{H atoms} \times \frac{1\ C_2H_5OH\ \text{molecule}}{6\ \text{H atoms}} = 7.0 \times 10^{22}\ C_2H_5OH\ \text{molecules}$$

2.69. a. N_2H_4

b. H_2O_2

c. C_3H_8O

d. PCl_3

2.70. a. $C_3H_8O_3$

b. Si_2H_6

c. NH_3O

d. SF_4

2.71. a. PCl_5

b. NO_2

c. $C_3H_6O_2$

2.72. a. H_2SO_4

b. C_6H_6

c. C_3H_6O

2.73. $$\frac{1\ \text{Fe atom}}{1\ Fe(NO_3)_2\ \text{unit}} \times \frac{1\ Fe(NO_3)_2\ \text{unit}}{2\ NO_3^-\ \text{ions}} \times \frac{1\ NO_3^-\ \text{ion}}{3\ \text{O atoms}} = \frac{1\ \text{Fe atom}}{6\ \text{O atoms}} = \frac{1}{6}$$

Thus, the ratio of iron atoms to oxygen atoms is one Fe atom to six O atoms.

2.74. $\frac{1\ PO_4^{3-}\ \text{ion}}{1\ (NH_4)_3PO_4\ \text{unit}} \times \frac{4\ \text{O atoms}}{1\ PO_4^{3-}\ \text{ion}} \times \frac{1\ (NH_4)_3PO_4\ \text{unit}}{3\ NH_4^+\ \text{units}} \times \frac{1\ NH_4^+\ \text{unit}}{1\ \text{N atom}} = \frac{4\ \text{O atoms}}{3\ \text{N atoms}} = \frac{4}{3}$

Thus, the ratio of oxygen atoms to nitrogen atoms is four O atoms to three N atoms.

2.75. a. $Fe(CN)_3$

b. K_2CO_3

c. Li_3N

d. Ca_3P_2

2.76. a. Co_3N_2

b. $(NH_4)_3PO_4$

c. Na_2SO_3

d. $Fe(OH)_3$

2.77. a. Na_2SO_4: sodium sulfate (Group IA forms only 1+ cations.)

b. Na_3N: sodium nitride (Group IIA forms only 1+ cations.)

c. CuCl: copper(I) chloride (Group IB forms 1+ and 2+ cations.)

d. Cr_2O_3: chromium(III) oxide (Group VIB forms numerous oxidation states.)

2.78. a. CaO: calcium oxide (Group IIA forms only 2+ cations.)

b. Mn_2O_3: manganese(III) oxide (Group VIIB forms numerous oxidation states.)

c. NH_4HCO_3: ammonium bicarbonate or ammonium hydrogen carbonate.

d. $Cu(NO_3)_2$: copper(II) nitrate (Group IB forms 1+ and 2+ cations.)

2.79. a. Lead(II) permanganate: $Pb(MnO_4)_2$ (Permanganate is in Table 2.6.)

b. Barium hydrogen carbonate: $Ba(HCO_3)_2$ (The HCO_3^- ion is in Table 2.6.)

c. Cesium sulfide: Cs_2S (Group 1A ions form 1+ cations.)

d. Iron(III) acetate: $Fe(C_2H_3O_2)_3$ (The acetate ion = 1– [from Table 2.6]; for the sum of charges to be zero, three must be used.)

2.80. a. Sodium thiosulfate: $Na_2S_2O_3$ (The $S_2O_3^{2-}$ is in Table 2.6.)

b. Copper(II) hydroxide: $Cu(OH)_2$ (Two OH^- ions must be used to balance Cu^{2+}.)

c. Calcium hydrogen carbonate: $Ca(HCO_3)_2$ (The HCO_3^- ion is in Table 2.6.)

d. Chromium(III) phosphide: CrP (Both ions have charges of 3-.)

2.81. a. Molecular

b. Ionic

c. Molecular

d. Ionic

2.82. a. Molecular
b. Molecular
c. Molecular
d. Ionic

2.83. a. Dinitrogen monoxide
b. Tetraphosphorus dec(a)oxide
c. Arsenic trichloride
d. Dichlorine hept(a)oxide

2.84. a. Dinitrogen difluoride
b. Carbon tetrafluoride
c. Dinitrogen pent(a)oxide
d. Tetr(a)arsenic hex(a)oxide

2.85. a. NBr_3
b. XeF_6
c. CO
d. Cl_2O_5

2.86. a. P_2O_5
b. NO_2
c. N_2F_4
d. BF_3

2.87. a. Selenium trioxide
b. Disulfur dichloride
c. Carbon monoxide

2.88. a. Nitrogen trifluoride
b. Diphosphorus tetrahydride
c. Oxygen difluoride

2.89. a. Sulfurous acid: H_2SO_3
b. Hyponitrous acid: $H_2N_2O_2$
c. Disulfurous acid: $H_2S_2O_5$
d. Arsenic acid: H_3AsO_4

2.90. a. Selenous acid: H_2SeO_3

b. Chlorous acid: $HClO_2$

c. Hypoiodous acid: HIO

d. Nitric acid: HNO_3

2.91. $Na_2SO_4 \bullet 10H_2O$ is sodium sulfate decahydrate.

2.92. $NiSO_4 \bullet 6H_2O$ is nickel(II) sulfate hexahydrate.

2.93. Iron(II) sulfate heptahydrate is $FeSO_4 \bullet 7H_2O$.

2.94. Cobalt(II) chloride hexahydrate is $CoCl_2 \bullet 6H_2O$.

2.95. $1\ PbCO_3 \times \frac{3\text{ O atoms}}{1\ PbCO_3\text{ unit}} + 2\ KNO_3 \times \frac{3\text{ O atoms}}{1\ KNO_3\text{ unit}} = 9\text{ O atoms}$

2.96. $2\ PbO \times \frac{1\text{ O atom}}{1\text{ PbO unit}} + 2\ SO_2 \times \frac{2\text{ O atoms}}{1\ SO_2\text{ unit}} = 6\text{ O atoms}$

The equation is not balanced as written. There are currently only 2 oxygen atoms on the left side.

2.97. a. Balance: $Sn + NaOH \rightarrow Na_2SnO_2 + H_2$

If Na is balanced first by writing a 2 in front of NaOH, the entire equation is balanced.

$Sn + 2NaOH \rightarrow Na_2SnO_2 + H_2$

b. Balance: $Al + Fe_3O_4 \rightarrow Al_2O_3 + Fe$

First balance O (it appears once on each side) by writing a 3 in front of Fe_3O_4 and a 4 in front of Al_2O_3:

$Al + 3Fe_3O_4 \rightarrow 4Al_2O_3 + Fe$

Now balance Al against the 8 Al's on the right and Fe against the 9 Fe's on the left:

$8Al + 3Fe_3O_4 \rightarrow 4Al_2O_3 + 9Fe$

c. Balance: $CH_3OH + O_2 \rightarrow CO_2 + H_2O$

First balance H (it appears once on each side) by writing a 2 in front of H_2O:

$CH_3OH + O_2 \rightarrow CO_2 + 2H_2O$

To avoid fractional coefficients for O, multiply the equation by 2:

$2CH_3OH + 2O_2 \rightarrow 2CO_2 + 4H_2O$

Finally, balance O by changing $2O_2$ to "$3O_2$"; this balances the entire equation:

$2CH_3OH + 3O_2 \rightarrow 2CO_2 + 4H_2O$

d. Balance: $P_4O_{10} + H_2O \rightarrow H_3PO_4$

First balance P (it appears once on each side) by writing a 4 in front of H_3PO_4:

$$P_4O_{10} + H_2O \rightarrow 4H_3PO_4$$

Finally, balance H by writing a 6 in front of H_2O; this balances the entire equation:

$$P_4O_{10} + 6H_2O \rightarrow 4H_3PO_4$$

e. Balance: $PCl_5 + H_2O \rightarrow H_3PO_4 + HCl$

First balance Cl (it appears once on each side) by writing a 5 in front of HCl:

$$PCl_5 + H_2O \rightarrow H_3PO_4 + 5HCl$$

Finally, balance H by writing a 4 in front of H_2O; this balances the entire equation:

$$PCl_5 + 4H_2O \rightarrow H_3PO_4 + 5HCl$$

2.98. a. Balance: $Ca_3(PO_4)_2 + H_3PO_4 \rightarrow Ca(H_2PO_4)_2$

First balance Ca (appears only once on each side) by writing a 3 in front of $Ca(H_2PO_4)_2$;

$$Ca_3(PO_4)_2 + H_3PO_4 \rightarrow 3Ca(H_2PO_4)_2$$

Finally, balance P by writing a 4 in front of H_3PO_4; this balances the entire equation:

$$Ca_3(PO_4)_2 + 4H_3PO_4 \rightarrow 3Ca(H_2PO_4)_2$$

b. Balance: $MnO_2 + HCl \rightarrow MnCl_2 + Cl_2 + H_2O$

First balance O (appears only once on each side) by writing a 2 in front of H_2O:

$$MnO_2 + HCl \rightarrow MnCl_2 + Cl_2 + 2H_2O$$

Finally, balance H and Cl by writing a 4 in front of HCl to balance the entire equation:

$$MnO_2 + 4HCl \rightarrow MnCl_2 + Cl_2 + 2H_2O$$

c. Balance: $Na_2S_2O_3 + I_2 \rightarrow NaI + Na_2S_4O_6$

First balance S by writing a 2 in front of $Na_2S_2O_3$:

$$2Na_2S_2O_3 + I_2 \rightarrow NaI + Na_2S_4O_6$$

Finally, balance Na by writing a 2 in front of NaI; this balances the entire equation:

$$2Na_2S_2O_3 + I_2 \rightarrow 2NaI + Na_2S_4O_6$$

d. Balance: $Al_4C_3 + H_2O \rightarrow Al(OH)_3 + CH_4$

First balance Al with a 4 in front of $Al(OH)_3$, and balance C with a 3 in front of CH_4:

$$Al_4C_3 + H_2O \rightarrow 4Al(OH)_3 + 3CH_4$$

Finally, balance H and O with a 12 in front of H_2O; this balances the entire equation:

$$Al_4C_3 + 12H_2O \rightarrow 4Al(OH)_3 + 3CH_4$$

e. Balance: $NO_2 + H_2O \rightarrow HNO_3 + NO$

First balance H with a 2 in front of HNO_3:

$$NO_2 + H_2O \rightarrow 2HNO_3 + NO$$

Finally, balance N with a 3 in front of NO_2; this balances the entire equation:

$$3NO_2 + H_2O \rightarrow 2HNO_3 + NO$$

2.99. Balance: $Ca_3(PO_4)_2(s) + H_2SO_4(aq) \rightarrow CaSO_4(s) + H_3PO_4(aq)$

Balance Ca first with a 3 in front of $CaSO_4$:

$$Ca_3(PO_4)_2(s) + H_2SO_4(aq) \rightarrow 3CaSO_4(s) + H_3PO_4(aq)$$

Next, balance the P with a 2 in front of H_3PO_4:

$$Ca_3(PO_4)_2(s) + H_2SO_4(aq) \rightarrow 3CaSO_4(s) + 2H_3PO_4(aq)$$

Finally, balance the S with a 3 in front of H_2SO_4; this balances the equation:

$$Ca_3(PO_4)_2(s) + 3H_2SO_4(aq) \rightarrow 3CaSO_4(s) + 2H_3PO_4(aq)$$

2.100. Balance: $Na(s) + H_2O(l) \rightarrow NaOH(aq) + H_2(g)$

Balance H first with a 2 in front of H_2O and NaOH:

$$Na + 2H_2O \rightarrow 2NaOH + H_2$$

Then, balance Na with a 2 in front of Na; this balances the equation:

$$2Na(s) + 2H_2O(l) \rightarrow 2NaOH(aq) + H_2(g)$$

2.101. Balance: $NH_4Cl(aq) + Ba(OH)_2(aq) \rightarrow NH_3(g) + BaCl_2(aq) + H_2O(l)$

Balance O first with a 2 in front of H_2O:

$$NH_4Cl + Ba(OH)_2 \rightarrow NH_3 + BaCl_2 + 2H_2O$$

Balance H with a 2 in front of NH_4Cl and a 2 in front of NH_3; this balances the equation:

$$2NH_4Cl(aq) + Ba(OH)_2(aq) \xrightarrow{\Delta} 2NH_3(g) + BaCl_2(aq) + 2H_2O(l)$$

2.102. Balance: $PbS(s) + PbSO_4(s) \rightarrow Pb(l) + SO_2(g)$

Balance S first with a 2 in front of SO_2:

$$PbS + PbSO_4 \rightarrow Pb + 2SO_2$$

Balance Pb with a 2 in front of Pb; this balances the equation:

$$PbS(s) + PbSO_4(s) \xrightarrow{\Delta} 2Pb(l) + 2SO_2(g)$$

■ SOLUTIONS TO GENERAL PROBLEMS

2.103. Calculate the ratio of oxygen for 1 g (fixed amount) of nitrogen in both compounds:

$$\text{A:}\quad \frac{2.755\text{ g O}}{1.206\text{ g N}} = \frac{2.28\underline{4}4\text{ g O}}{1\text{ g N}} \qquad \text{B:}\quad \frac{4.714\text{ g O}}{1.651\text{ g N}} = \frac{2.85\underline{5}2\text{ g O}}{1\text{ g N}}$$

Next, find the ratio of oxygen per gram of nitrogen for the two compounds.

$$\frac{\text{g O in B/1 g N}}{\text{g O in A/1 g N}} = \frac{2.85\underline{5}2\text{ g O}}{2.28\underline{4}4\text{ g O}} = \frac{1.24\underline{9}8\text{ g O}}{1\text{g O}}$$

B contains 1.25 times as many O atoms as A does (there are five O's in B for every four O's in A).

2.104. Calculate the ratio of oxygen for 1 g (fixed amount) of sulfur in both compounds:

$$\text{A:}\quad \frac{1.811\text{ g O}}{1.210\text{ g S}} = \frac{1.49\underline{6}6\text{ g O}}{1\text{ g S}} \qquad \text{B:}\quad \frac{1.779\text{ g O}}{1.783\text{ g S}} = \frac{0.997\underline{7}5\text{ g O}}{1\text{ g S}}$$

Next, find the ratio of oxygen per gram of sulfur for the two compounds.

$$\frac{\text{g O in A/1 g S}}{\text{g O in B/1 g S}} = \frac{1.49\underline{6}6\text{ g O}}{0.997\underline{7}5\text{ g O}} = \frac{1.49\underline{9}9\text{ g O}}{1\text{g O}}$$

A contains 1.50 times as many O atoms as B does (there are three O's in A for every two O's in B).

2.105. The smallest difference is between -1.12×10^{-18} C and 9.60×10^{-19} C and is equal to -1.6×10^{-19} C. If this charge is equivalent to one electron, the number of excess electrons on a drop may be found by dividing the negative charge by the charge of one electron.

$$\text{Drop 1:}\quad \frac{-3.20 \times 10^{-19}\text{ C}}{-1.6 \times 10^{-19}\text{ C}} = 2.\underline{0} \cong 2\text{ electrons}$$

$$\text{Drop 2:}\quad \frac{-6.40 \times 10^{-19}\text{ C}}{-1.6 \times 10^{-19}\text{ C}} = 4.\underline{0} \cong 4\text{ electrons}$$

$$\text{Drop 3:}\quad \frac{-9.60 \times 10^{-19}\text{ C}}{-1.6 \times 10^{-19}\text{ C}} = 6.\underline{0} \cong 6\text{ electrons}$$

$$\text{Drop 4:}\quad \frac{-1.12 \times 10^{-18}\text{ C}}{-1.6 \times 10^{-19}\text{ C}} = 7.\underline{0} \cong 7\text{ electrons}$$

2.106. The smallest difference in charge for the oil drop is $-1.85 \text{ x } 10^{-19}$; assume this is the fundamental unit of negative charge. Use this to divide into each drop's charge:

$$\text{Drop 1:}\quad \frac{-5.55 \times 10^{-19}\text{ C}}{-1.85 \times 10^{-19}\text{ C}} = 3.\underline{0} \cong 3\text{ electrons}$$

$$\text{Drop 2:}\quad \frac{-9.25 \times 10^{-19}\text{ C}}{-1.85 \times 10^{-19}\text{ C}} = 5.\underline{0} \cong 5\text{ electrons}$$

$$\text{Drop 3:}\quad \frac{-1.11 \times 10^{-18}\text{ C}}{-1.85 \times 10^{-19}\text{ C}} = 6.\underline{0} \cong 6\text{ electrons}$$

Drop 4: $\dfrac{-1.48 \times 10^{-18}\ \text{C}}{-1.85 \times 10^{-19}\ \text{C}} = 8.\underline{0} \cong 8$ electrons

2.107. For the Eu atom to be neutral, the number of electrons must equal the number of protons, so a neutral europium atom has 63 electrons. The 3+ charge on the Eu^{3+} indicates there are three more protons than electrons, so the number of electrons is 63 – 3 = 60.

2.108. For the Cs atom to be neutral, the number of electrons must equal the number of protons, so a neutral cesium atom has 55 electrons. The 1+ charge on the Cs^+ indicates there is one more proton than electrons, so the number of electrons is 55 – 1 = 54.

2.109. The number of protons = mass number – number of neutrons = 81 – 46 = 35. The element with Z = 35 is bromine (Br).

The ionic charge = number of protons – number of electrons = 35 – 36 = –1.

Symbol: ${}^{81}_{35}Br^-$.

2.110. The number of protons = mass number – number of neutrons = 74 – 51 = 23. The element with Z = 23 is vanadium (V).

The ionic charge = number of protons – number of electrons = 23 – 18 = +5.

Symbol: ${}^{74}_{23}V^{5+}$.

2.111. The sum of the fractional abundances must equal 1. Let y equal the fractional abundance of ${}^{63}Cu$. Then the fractional abundance of ${}^{65}Cu$ equals $(1 - y)$. We write one equation in one unknown:

$$\text{Atomic mass} = 63.546 = 62.9298y + 64.9278(1 - y)$$

$$63.546 = 64.9278 - 1.9980y$$

$$y = \frac{64.9278 - 63.546}{1.9980} = 0.691\underline{5}9$$

The fractional abundance of ${}^{63}Cu$ = 0.691$\underline{5}$9 = 0.6916.

The fractional abundance of ${}^{65}Cu$ = 1 – 0.69159 = 0.308$\underline{4}$1 = 0.3084.

2.112. As in the previous problem, the sum of the fractional abundances must equal 1. Thus, the abundance of one isotope can be expressed in terms of the other. Let y equal the fractional abundance of Ag-107. Then the fractional abundance of Ag-109 equals $(1 - y)$. We can write one equation in one unknown:

$$\text{Atomic mass} = 107.87 = 106.91y + 108.90(1 - y)$$

$$107.87 = 108.90 - 1.99y$$

$$y = \frac{108.90 - 107.87}{1.99} = 0.51\underline{7}58$$

The fractional abundance of Ag-107 = 0.51$\underline{7}$58 = 0.518.

The fractional abundance of Ag-109 = 1 – 0.51$\underline{7}$58 = 0.48$\underline{2}$41 = 0.482.

2.113. a. Bromine, Br

b. Hydrogen, H

c. Niobium, Nb

d. Fluorine, F

2.114. a. Bromine, Br

b. Mercury, Hg

c. Aluminum, Al

d. Potassium, K

2.115. a. Chromium(III) ion

b. Lead(IV) ion

c. Titanium(II) ion

d. Copper(II) ion

2.116. a. Manganese(II) ion

b. Nickel(II) ion

c. Cobalt(II) ion

d. Iron(III) ion

2.117. All possible ionic compounds: Na_2SO_4, NaCl, $CoSO_4$, and $CoCl_2$.

2.118. All possible ionic compounds: MgS, $Mg(NO_3)_2$, Cr_2S_3, and $Cr(NO_3)_3$.

2.119. a. Tin(II) phosphate

b. Ammonium nitrite

c. Magnesium hydroxide

d. Nickel(II) sulfite

2.120. a. Copper(II) nitrite

b. Ammonium phosphide

c. Potassium sulfite

d. Mercury(II) nitride

2.121. a. Hg_2S [Mercury(I) exists as the polyatomic Hg_2^{2+} ion (Table 2.6).]

b. $Co_2(SO_3)_3$

c. $(NH_4)_2Cr_2O_7$

d. AlF_3

2.122. a. H_2O_2

b. $Mg_3(PO_4)_2$

c. Pb_3P_4

d. $CaCO_3$

2.123. a. Arsenic tribromide

b. Hydrogen telluride (dihydrogen telluride)

c. Diphosphorus pent(a)oxide

d. Silicon dioxide

2.124. a. Chlorine tetrafluoride

b. Carbon disulfide

c. Phosphorus trifluoride

d. Sulfur hexafluoride

2.125. a. Balance the C and H first:

$$C_2H_6 + O_2 \rightarrow 2CO_2 + 3H_2O$$

Avoid a fractional coefficient for O on the left by doubling all coefficients except O_2's, and then balance the O's:

$$2C_2H_6 + 7O_2 \rightarrow 4CO_2 + 6H_2O$$

b. Balance the P first:

$$P_4O_6 + H_2O \rightarrow 4H_3PO_3$$

Then balance the O (or H), which also gives the H (or O) balance:

$$P_4O_6 + 6H_2O \rightarrow 4H_3PO_3$$

c. Balancing the O first is the simplest approach. (Starting with K and Cl and then proceeding to O will cause the initial coefficient for $KClO_3$ to be changed in balancing O last.)

$$4KClO_3 \rightarrow KCl + 3KClO_4$$

d. Balance the N first:

$$(NH_4)_2SO_4 + NaOH \rightarrow 2NH_3 + H_2O + Na_2SO_4$$

Then balance the Na, followed by O; this also balances the H:

$$(NH_4)_2SO_4 + 2NaOH \rightarrow 2NH_3 + 2H_2O + Na_2SO_4$$

e. Balance the N first:

$$2NBr_3 + NaOH \rightarrow N_2 + NaBr + HOBr$$

Note that NaOH and HOBr each have one O and that NaOH and NaBr each have one Na; thus the coefficients of all three are equal; from $2NBr_3$, this coefficient must be 6Br/2 = 3:

$$2NBr_3 + 3NaOH \rightarrow N_2 + 3NaBr + 3HOBr$$

2.126. a. Balance the Na first:

$$2NaOH + H_2CO_3 \rightarrow Na_2CO_3 + H_2O$$

Then balance the H; this also balances the O:

$$2NaOH + H_2CO_3 \rightarrow Na_2CO_3 + 2H_2O$$

b. Balance the Cl with a 4 in front of the HCl; then balance the O's with a 2 in front of H_2O:

$$SiCl_4 + 2H_2O \rightarrow SiO_2 + 4HCl$$

c. Balance the O first with an 8 in front of CO; then balance the C with an 8 in front of C:

$$Ca_3(PO_4)_2 + 8C \rightarrow Ca_3P_2 + 8CO$$

d. Balance the O by multiplying O_2 by 3 and doubling both products to give a total of six O's on both sides of the equation:

$$H_2S + 3O_2 \rightarrow 2SO_2 + 2H_2O$$

Then balance H and S with a 2 in front of H_2S:

$$2H_2S + 3O_2 \rightarrow 2SO_2 + 2H_2O$$

e. Since the reaction has two N's on the left and one N on the right, try a tentative N-balancing by writing a 2 in front of NO_2:

$$N_2O_5 \rightarrow 2NO_2 + O_2$$

Now there are five O's on the left and six O's on the right. Balance the O's with a ½ in front of O_2; this gives

$$N_2O_5 \rightarrow 2NO_2 + \tfrac{1}{2}\,O_2$$

Because it is customary to balance chemical equations with whole number coefficients, multiplying each of the reactant and product coefficients by 2 yields the desired result:

$$2N_2O_5 \rightarrow 4NO_2 + O_2$$

2.127. Let: x = number of protons. Then $1.21x$ is the number of neutrons. Since the mass number is 62, you get

$$62 = x + 1.21x = 2.21x$$

Thus, $x = 2\underline{8}.054$, or 28. The element is nickel (Ni). Since the ion has a +2 charge, there are 26 electrons.

2.128. Let: x = number of protons. Then $1.30x$ is the number of neutrons. Since the mass number is 85, you get

$$85 = x + 1.30x = 2.30x$$

Thus, $x = 36.95$, or 37. The element is rubidium (Rb). Since the ion has a +1 charge, there are 36 electrons.

2.129. The average atomic mass would be

Natural carbon: $12.011 \times 1/2 = 6.00\underline{5}500$

Carbon-13: $13.00335 \times 1/2 = \underline{6.501675}$

Average $= 12.50\underline{7}175$

The average atomic mass of the sample is 12.507 amu.

2.130. The average atomic mass would be

Natural chlorine: 35.4527 × 1/2 = 17.7263500

Chlorine-35: 34.96885 × 1/2 = 17.4844250

Average = 35.2107750

The average atomic mass of the sample is 35.2108 amu.

2.131. The island of stability is a region of the periodic table where a relatively stable super-heavy nuclide is at the peak of stability and is surrounded by foothills consisting of less stable nuclides. It is centered around the most stable nuclide, which is predicted to have an atomic number of 114 and a mass number of 298.

2.132. ${}^{70}_{30}\text{Zn} + {}^{208}_{82}\text{Pb} \rightarrow {}^{277}_{112}\text{Uub} + {}^{1}_{0}\text{n}$

■ SOLUTIONS TO STRATEGY PROBLEMS

2.133. SO_3, sulfur trioxide; NO_2, nitrogen dioxide; PO_4^{3-}, phosphate ion;

N_2, nitrogen; $Mg(OH)_2$, magnesium hydroxide

2.134. The unknown metal, M, is a cation with a 2+ charge. An example is magnesium.

2.135. The name of the product is aluminum oxide. The reaction is

$4Al(s) + 3O_2(g) \rightarrow 2Al_2O_3(s)$

2.136. $4NH_3(g) + 5O_2(g) \rightarrow 4NO(g) + 6H_2O(l)$

2.137. (0.7721)(37.24 amu) + (1 – 0.7721)(x) = 37.45 amu

$$x = \frac{37.45 - (0.7721)(37.24)}{(1 - 0.7721)} = 38.161 \text{ amu} = 38.2 \text{ amu}$$

2.138. Sulfur has atomic number 16, so S^{2+} has 16 minus 2 or 14 electrons, which is the number of neutrons in the unknown ion. The number of protons is 27 minus 14 = 13, which is the atomic number, so the element is aluminum. The number of electrons is 13 – 3 = 10.

2.139. 6.5×10^{20} formula units $CaCl_2 \times \frac{3 \text{ ions}}{1 \text{ formula unit}} = 1.95 \times 10^{21}$ ions

2.140. $MgCO_3$, magnesium carbonate

Mg_3N_2, magnesium nitride

$Cr_2(CO_3)_3$, chromium(III) carbonate

CrN, chromium(III) nitride

2.141. SO_3, sulfur trioxide

HNO_2, nitrous acid

Mg_3N_2, magnesium nitride

HI(*aq*), hydroiodic acid

$Cu_3(PO_4)_2$, copper(II) phosphate

$CuSO_4 \bullet 5H_2O$, copper(II) sulfate pentahydrate

2.142. HIO_3, iodic acid

$NaIO_4$, sodium periodate

$Mg(IO_2)_2$, magnesium iodite

$Fe(IO_2)_3$, iron(III) iodite

2.143. a. An aqueous solution of lead(II) chloride is mixed with an aqueous solution of sodium sulfide to form an aqueous solution of sodium chloride and a lead(II) sulfide precipitate.

b. When gaseous sulfur trioxide is passed into liquid water an aqueous solution of sulfuric acid is formed.

c. Graphite is combusted in an oxygen atmosphere to form gaseous carbon dioxide.

d. Gaseous hydrogen iodide forms when hydrogen gas and gaseous iodine are mixed.

2.144. $Cl_2(g) + 2K(s) \rightarrow 2KCl(s)$

2.145. Each $^{1}H_2{}^{16}O$ molecule contains 8 neutrons, 10 protons, and 10 electrons.

neutrons in 6.0×10^{23} molecules = $8 \times (6.0 \times 10^{23}) = 4.8 \times 10^{24}$ neutrons

protons in 6.0×10^{23} molecules = $10 \times (6.0 \times 10^{23}) = 6.0 \times 10^{24}$ protons

Because the water molecules are neutrally charged there must also be 6.0×10^{24} electrons.

2.146. a. hydrogen chloride

b. hydrobromic acid

c. hydrogen fluoride

d. nitric acid

2.147. We are told that a ^{238}U nucleus decays by emitting a ^{4}He atom while the remaining subatomic particles remain intact. In equation form, we can write this as follows:

$$^{238}_{92}U \rightarrow {}^{4}_{2}He + {}^{y}_{z}X$$

Such nuclear decay processes must follow conservation laws. In this regard, the total mass number of the reactants must equal that of the products. It follows that if 238 = 4 + y, then y = 234. Likewise, the total atomic number of the reactants must equal that of the products. Again, if 92 = 2 + z, then z = 90. The symbol for the other nuclide being produced in this decay process is $^{234}_{90}Th$. Thorium (Th) is produced.

2.148. $2\ H_3PO_4(aq) + 3\ Mg(OH)_2(s) \rightarrow 6\ H_2O(l) + Mg_3(PO_4)_2(s)$

■ SOLUTIONS TO CUMULATIVE-SKILLS PROBLEMS

2.149. The spheres occupy a diameter of 2 × 1.86 Å = 3.72 Å. The line of sodium atoms would stretch a length of

$$\text{Length} = \frac{3.72\ \text{Å}}{1\ \text{Na atom}} \times 2.619 \times 10^{22}\ \text{Na atoms} = 9.7\underline{4}2 \times 10^{22}\ \text{Å}$$

Now, convert this to miles.

$$9.7\underline{4}2 \times 10^{22}\ \text{Å} \times \frac{10^{-10}\ \text{m}}{1\ \text{Å}} \times \frac{1\ \text{mile}}{1.609 \times 10^{3}\ \text{m}} = 6.0\underline{5}5 \times 10^{9}\ \text{miles} = 6.06 \times 10^{9}\ \text{miles}$$

2.150. The spheres occupy a diameter of 2 × 0.99 Å = 1.98 Å. The line of chlorine atoms would stretch a length of

$$\text{Length} = \frac{1.98\ \text{Å}}{1\ \text{Cl atom}} \times \frac{1.699 \text{ x } 10^{22}\ \text{Cl atoms}}{1.000\ \text{g Cl}} \times 0.\underline{5}\ \text{g Cl} = \underline{1}.682 \times 10^{22}\ \text{Å}$$

Now, convert this to miles.

$$\underline{1}.682 \times 10^{22}\ \text{Å} \times \frac{10^{-10}\ \text{m}}{1\ \text{Å}} \times \frac{1\ \text{mile}}{1.609 \times 10^{3}\ \text{m}} = \underline{1}.045 \times 10^{9}\ \text{miles} = 1 \times 10^{9}\ \text{miles}$$

2.151. $NiSO_4{\bullet}7H_2O(s) \rightarrow NiSO_4{\bullet}6H_2O(s) + H_2O(g)$

[8.753 g] = [8.192 g + (8.753 – 8.192 = 0.561 g)]

The 8.192 g of $NiSO_4{\bullet}6H_2O$ must contain 6 × 0.561 = 3.366 g H_2O.

Mass of anhydrous $NiSO_4$ = 8.192 g $NiSO_4{\bullet}6H_2O$ – 3.366 g $6H_2O$ = 4.826 g $NiSO_4$

2.152. The formula for cobalt(II) sulfate heptahydrate is $CoSO_4{\bullet}7H_2O$ and the formula for cobalt(II) sulfate monohydrate is $CoSO_4{\bullet}H_2O$. The equation for the described heating process is

$CoSO_4{\bullet}7H_2O(s) \rightarrow CoSO_4{\bullet}H_2O(s) + 6H_2O(g)$

Using the law of conservation of mass with the data provided,

[3.548 g heptahydrate] = [2.184 g monohydrate + (3.548 – 2.184 = 1.364 g H_2O)]

Mass of one H_2O unit per 3.548 g of $CoSO_4{\bullet}7H_2O$ = 1.364 g ÷ 6 = 0.22733 g

Mass of anhydrous $CoSO_4$ = 2.184 g $CoSO_4{\bullet}H_2O$ – 0.22733 g H_2O = 1.95$\underline{6}$7 g = 1.957 g $CoSO_4$

2.153. $\text{Mass of O} = 0.6015\ \text{L} \times \frac{1.330\ \text{g O}}{1\ \text{L}} = 0.799\underline{9}95\ \text{g} = 0.8000\ \text{g oxygen}$

$$15.9994\ \text{amu O} \times \frac{3.177\ \text{g X}}{0.799\underline{9}95\ \text{g O}} = 63.5\underline{3}8\ \text{amu X} = 63.54\ \text{amu}$$

The atomic mass of X is 63.54 amu; X is copper.

2.154. Mass of Cl = $0.4810\text{ L} \times \dfrac{2.948\text{ g Cl}}{1\text{ L}} = 1.41\underline{7}99\text{ g} = 1.418\text{ g chlorine}$

$$35.453\text{ amu Cl} \times \dfrac{4.315\text{ g X}}{1.41\underline{7}99\text{ g Cl}} = 107.\underline{8}8\text{ amu X} = 107.9\text{ amu}$$

The atomic mass of X is 107.9 amu; X is silver.