Chapter 2
Atoms, Molecules, and Ions

INSTRUCTOR'S NOTES

Although much of this chapter will be review for many students who have taken high school chemistry, the ideas included are so central to later study that class coverage will probably be necessary. Key topics are the structure of the atom and related information (atomic number, isotopes), the mole unit, the periodic table, chemical formulas and names, and the relationships between formulas and composition. Three to five class periods will probably be necessary in order to address the essentials in this chapter unless your students are well-versed in some of these topics.

Some points on which students have some problems or questions are:

(a) The rule of determining the charges on transition metal cations tells students that they can assume such ions usually have 2+ or 3+ charges (with 2+ charges especially prominent). They are often uneasy about being given this choice. We certainly emphasize that they will see other possibilities (and that even negative charges are possible but that they will not see them in the general chemistry course).

(b) Students have to be convinced that they have no choice but to learn the language of chemistry by memorizing the names and charges of polyatomic ions. They can be reminded that correct names and formulas are required to prevent serious consequences, such as the use of the wrong medicine which can have tragic results or the purchase of the wrong substance which leads to wasted resources.

(c) A very common problem students have is recognizing that $MgBr_2$, for example, is composed of Mg^{2+} and two Br^- ions. We have seen such combinations as Mg^{2+} and Br_2^{2-}.

SUGGESTED DEMONSTRATIONS

1. Properties of Elements
   - Take as many samples of elements as possible to your lecture on the elements and the periodic table.
   - See the series by Alton Banks in the *Journal of Chemical Education* titled "What's the Use?" This series describes a different element each month and gives references to the *Periodic Table Videodisc*.
   - Pinto, G. "Using Balls from Different Sports to Model the Variation of Atomic Sizes," *Journal of Chemical Education* **1998**, *75*, 725.
2. Atomic Structure
   - Hohman, J. R. "Introduction of the Scientific Method and Atomic Theory to Liberal Arts Chemistry Students," *Journal of Chemical Education* **1998**, *75*, 1578.
3. Elements That Form Molecules in Their Natural States
   - Use samples of H_2, O_2, N_2, and Br_2 to illustrate elements that are molecules.

4. Formation of Compounds from Elements and Decomposition of a Compound into Its Elements
   - Bring many samples of compounds to your lecture. Ignite H_2 in a balloon or burn Mg in O_2 to show how elements are turned into compounds. Also burn Mg in CO_2 to show CO_2 is made of C and that MgO can be made another way.
5. Ionic Compounds
   - Bring a number of common, ionic compounds to class.
6. The Mole Concept
   - To illustrate the mole, take 1 molar quantities of elements such as Mg, Al, C, Sn, Pb, Fe, and Cu to the classroom.
   - When doing examples in lecture, it is helpful to have a sample of the element available. For example, hold up a pre-weighed sample of magnesium wire and ask how many moles of metal it contains. Or, drop a pre-weighed piece of sodium metal into a dish of water on the overhead projector, and ask how many moles of sodium reacted.
7. Molar Quantities
   - Display molar quantities of NaCl, H_2O, sugar, and common ionic compounds. Especially show some hydrated salts to emphasize the inclusion of H_2O in their molar mass.
   - Display a teaspoon of water and ask how many moles, how many molecules, and how many total atoms are contained.
   - Display a piece of $CaCO_3$ and ask how many moles are contained in the piece and then how many total atoms.
8. Weight Percent of Elements
   - When talking about weight percent of elements, use NO_2 as an example and then make NO_2 from Cu and nitric acid.
9. Determine the Formula of a Hydrated Compound
   - Heat samples of hydrated $CoSO_4$ or $CuSO_4$ to illustrate analysis of hydrated compounds and the color change that can occur when water is released and evaporated.
   - For the discussion of analysis, heat a sample of $CoCl_2 \cdot 6\ H_2O$ in a crucible to illustrate how to determine the number of waters of hydration and also discuss the distinctive color change observed during this process.

SOLUTIONS TO STUDY QUESTIONS

2.1 Atoms contain the fundamental particles protons (+1 charge), neutrons (zero charge), and electrons (–1 charge). Protons and neutrons are in the nucleus of an atom. Electrons are the least massive of the three particles.

2.2 Mass number is the sum of the number of protons and number of neutrons for an atom. Atomic mass is the mass of an atom. When the mass is expressed in u, the mass of a proton and of a neutron are both approximately one. Because the mass of electrons is small relative to that of a proton or neutron, the mass number approximates the atomic mass.

2.3 Ratio of diameter of nucleus to diameter of electron cloud is 2×10^{-3} m (2 mm) to 200 m or $1{:}10^5$. For the diameter of the atom (i.e., the electron cloud) = 1×10^{-10} m (1×10^{-8} cm), the diameter of the nucleus is $1 \times 10^{-10}\text{ m}/10^5 = 1 \times 10^{-15}\text{ m} = 1 \times 10^{-13}\text{ cm} = 1\text{ fm}$.

2.4 Each gold atom has a diameter of 2 × 145 pm = 290. pm

$$36\text{ cm} \cdot \frac{1\text{ m}}{100\text{ cm}} \cdot \frac{10^{12}\text{ pm}}{1\text{ m}} \cdot \frac{1\text{ Au atom}}{290.\text{ pm}} = 1.2 \times 10^9\text{ Au atoms}$$

2.5 (a) ${}^{27}_{12}\text{Mg}$ (b) ${}^{48}_{22}\text{Ti}$ (c) ${}^{62}_{30}\text{Zn}$

2.6 (a) ${}^{59}_{28}\text{Ni}$ (b) ${}^{244}_{94}\text{Pu}$ (c) ${}^{184}_{74}\text{W}$

2.7

	electrons	protons	neutrons
(a)	12	12	12
(b)	50	50	69
(c)	90	90	142
(d)	6	6	7
(e)	29	29	34
(f)	83	83	122

2.8 (a) Number of protons = number of electrons = 43; number of neutrons = 56

(b) Number of protons = number of electrons = 95; number of neutrons = 146

2.9 $$\frac{\text{mass electron}}{\text{mass proton}} = \frac{9.109383 \times 10^{-28}\text{ g}}{1.672622 \times 10^{-24}\text{ g}} = 5.446170 \times 10^{-4}$$

The proton is 1834 times more massive than an electron. Dalton’s estimate was off by a factor of about 2.

2.10 Negatively charged electrons in the cathode-ray tube collide with He atoms, splitting the atom into an electron and a He^+ cation. The electrons continued to be attracted to the anode while the cations passed through the perforated cathode.

2.11 Alpha particles are positively charged, beta particles are negatively charged, and gamma particles are neutral. Alpha particles have more mass than beta particles.

2.12 Atoms are not solid, hard, or impenetrable. They have mass (an important aspect of Dalton's hypothesis), and we now know that atoms are in rapid motion at all temperatures above absolute zero (the kinetic-molecular theory).

2.13 $^{16}O/^{12}C$ = 15.995 u/12.000 u = 1.3329

2.14 15.995 u · 1.661 × 10^{-24} g/u = 2.657 x 10^{-23} g

2.15 $^{57}_{27}Co$ (30 neutrons), $^{58}_{27}Co$ (31 neutrons), and $^{60}_{27}Co$ (33 neutrons)

2.16 Atomic number of Ag is 47; both isotopes have 47 protons and 47 electrons.

^{107}Ag 107 – 47 = 60 neutrons

^{109}Ag 109 – 47 = 62 neutrons

2.17 $^{1}_{1}H$, protium: one proton, one electron

$^{2}_{1}H$, deuterium: one proton, one electron, one neutron

$^{3}_{1}H$, tritium: one proton, one electron, two neutrons

2.18 $^{19}_{9}X$, $^{20}_{9}X$, and $^{21}_{9}X$ are isotopes of X

2.19 The atomic weight of thallium is 204.3833. The fact that this weight is closer to 205 than 203 indicates that the 205 isotope is the more abundant.

2.20 Strontium has an atomic weight of 87.62 so ^{88}Sr is the most abundant.

2.21 (^{6}Li mass)(% abundance) + (^{7}Li mass)(% abundance) = atomic weight of Li

(6.015121 u)(0.0750) + (7.016003 u)(0.9250) = 6.94 u

2.22 (^{24}Mg mass)(% abundance) + (^{25}Mg mass)(% abundance) + (^{26}Mg mass)(% abundance)

= atomic weight of Mg

(23.985 u)(0.7899) + (24.986 u)(0.1000) + (25.983 u)(0.1101)

= 24.31 u

2.23 Let x represent the abundance of ^{69}Ga and $(1 – x)$ represent the abundance of ^{71}Ga.

69.723 u = (x)(68.9257 u) + $(1 – x)$(70.9249 u)

x = 0.6012; ^{69}Ga abundance is 60.12%, ^{71}Ga abundance is 39.88%

2.24 Let x represent the abundance of ^{151}Eu and $(1 – x)$ represent the abundance of ^{153}Eu.

151.965 u = (x)(150.9197 u) + $(1 – x)$(152.9212 u)

x = 0.4777; ^{151}Eu abundance is 47.77%, ^{153}Eu abundance is 52.23%

2.25

	titanium	thallium
symbol	Ti	Tl
atomic number	22	81
atomic weight	47.867	204.3833
period	4	6
group	4B	3A
	metal	metal

2.26

	silicon	tin	antimony	sulfur	selenium
symbol	Si	Sn	Sb	S	Se
atomic number	14	50	51	16	34
period	3	5	5	3	4
group	4A	4A	5A	6A	6A
	metalloid	metal	metalloid	nonmetal	nonmetal

2.27 Periods 2 and 3 have 8 elements, Periods 4 and 5 have 18 elements, and Period 6 has 32 elements.

2.28 There are 26 elements in the seventh period, the majority of them are called the Actinides, and many of them are man-made elements.

2.29 (a) C, Cl
(b) C, Cl, Cs, Ca
(c) Ce
(d) Cr, Co, Cd, Cu, Ce, Cf, Cm
(e) Cm, Cf
(f) Cl

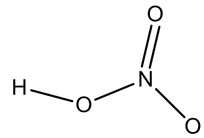
2.30 There are many correct answers for parts (a) and (d). Possible answers are shown below.
(a) C, carbon
(b) Rb, rubidium
(c) Cl, chlorine
(d) Ne, neon

2.31 Metals: Na, Ni, Np
Nonmetals: N, Ne

2.32 (a) Bk
(b) Br
(c) B
(d) Ba
(e) Bi

2.33 Molecular formula for nitric acid: HNO_3

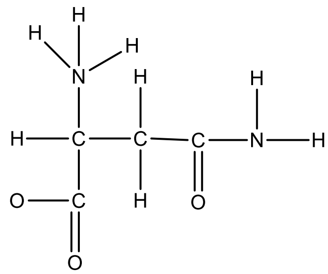
Structural formula:



The molecule is planar.

2.34 Molecular formula for asparagine: $C_4H_8N_2O_3$

Structural formula:



2.35 (a) Mg^{2+} (b) Zn^{2+} (c) Ni^{2+} (d) Ga^{3+}

2.36 (a) Se^{2-} (b) F^{-} (c) Fe^{2+}, Fe^{3+} (d) N^{3-}

2.37 (a) Ba^{2+} (e) S^{2-}
(b) Ti^{4+} (f) ClO_4^{-}
(c) PO_4^{3-} (g) Co^{2+}
(d) HCO_3^{-} (h) SO_4^{2-}

2.38 (a) MnO_4^{-} (d) NH_4^{+}
(b) NO_2^{-} (e) PO_4^{3-}
(c) $H_2PO_4^{-}$ (f) SO_3^{2-}

2.39 Potassium loses 1 electron when it becomes a monatomic ion. Argon has the same number of electrons as the K^+ ion.

2.40 They both gain two electrons. O^{2-} has the same number of electrons as Ne and S^{2-} has the same number of electrons as Ar.

2.41 Ba^{2+}, Br^{-} $BaBr_2$

2.42 Co^{3+}, F^{-} CoF_3

2.43 (a) 2 K^+ ions, 1 S^{2-} ion (d) 3 NH_4^+ ions, 1 PO_4^{3-} ion
(b) 1 Co^{2+} ion, 1 SO_4^{2-} ion (e) 1 Ca^{2+} ion, 2 ClO^- ions
(c) 1 K^+ ion, 1 MnO_4^- ion (f) 1 Na^+ ion, 1 $CH_3CO_2^-$ ion

2.44 (a) 1 Mg^{2+} ion, 2 $CH_3CO_2^-$ ions (d) 1 Ti^{4+} ion, 2 SO_4^{2-} ions
(b) 1 Al^{3+} ion, 3 OH^- ions (e) 1 K^+ ion, 1 $H_2PO_4^-$ ion
(c) 1 Cu^{2+} ion, 1 CO_3^{2-} ion (f) 1 Ca^{2+} ion, 1 HPO_4^{2-} ion

2.45 Co^{2+}: CoO Co^{3+} Co_2O_3

2.46 (a) Pt^{2+}: $PtCl_2$ Pt^{4+}: $PtCl_4$
(b) Pt^{2+}: PtS Pt^{4+}: PtS_2

2.47 (a) incorrect, $AlCl_3$ (c) correct
(b) incorrect, KF (d) correct

2.48 (a) incorrect, CaO (c) incorrect, Fe_2O_3 or FeO
(b) correct (d) correct

2.49 (a) potassium sulfide (c) ammonium phosphate
(b) cobalt(II) sulfate (d) calcium hypochlorite

2.50 (a) calcium acetate (c) aluminum hydroxide
(b) nickel(II) phosphate (d) potassium dihydrogen phosphate

2.51 (a) $(NH_4)_2CO_3$ (d) $AlPO_4$
(b) CaI_2 (e) $AgCH_3CO_2$
(c) $CuBr_2$

2.52 (a) $Ca(HCO_3)_2$ (d) K_2HPO_4
(b) $KMnO_4$ (e) Na_2SO_3
(c) $Mg(ClO_4)_2$

2.53

Na_2CO_3	sodium carbonate	NaI	sodium iodide
$BaCO_3$	barium carbonate	BaI_2	barium iodide

2.54

$Mg_3(PO_4)_2$	magnesium phosphate	$Mg(NO_3)_2$	magnesium nitrate
$FePO_4$	iron(III) phosphate	$Fe(NO_3)_3$	iron(III) nitrate

2.55 The force of attraction is stronger in NaF than in NaI because the distance between ion centers is smaller in NaF (235 pm) than in NaI (322 pm).

2.56 The attractive forces are stronger in CaO because the ion charges are greater (+2/–2 in CaO and +1/–1 in NaCl).

2.57 (a) nitrogen trifluoride (c) boron triiodide
(b) hydrogen iodide (d) phosphorus pentafluoride

2.58 (a) dinitrogen pentaoxide (c) oxygen difluoride
(b) tetraphosphorus trisulfide (d) xenon tetrafluoride

2.59 (a) SCl_2 (b) N_2O_5 (c) $SiCl_4$ (d) B_2O_3

2.60 (a) BrF_3 (d) P_2F_4
(b) XeF_2 (e) C_4H_{10}
(c) N_2H_4

2.61 (a) $2.5 \text{ mol Al} \cdot \dfrac{27.0 \text{ g Al}}{1 \text{ mol Al}} = 68 \text{ g Al}$

(b) $1.25 \times 10^{-3} \text{ mol Fe} \cdot \dfrac{55.85 \text{ g Fe}}{1 \text{ mol Fe}} = 0.0698 \text{ g Fe}$

(c) $0.015 \text{ mol Ca} \cdot \dfrac{40.1 \text{ g Ca}}{1 \text{ mol Ca}} = 0.60 \text{ g Ca}$

(d) $653 \text{ mol Ne} \cdot \dfrac{20.18 \text{ g Ne}}{1 \text{ mol Ne}} = 1.32 \times 10^{4} \text{ g Ne}$

2.62 (a) $4.24 \text{ mol Au} \cdot \dfrac{197.0 \text{ g Au}}{1 \text{ mol Au}} = 835 \text{ g Au}$

(b) $15.6 \text{ mol He} \cdot \dfrac{4.003 \text{ g He}}{1 \text{ mol He}} = 62.4 \text{ g He}$

(c) $0.063 \text{ mol Pt} \cdot \dfrac{195 \text{ g Pt}}{1 \text{ mol Pt}} = 12 \text{ g Pt}$

(d) $3.63 \times 10^{-4} \text{ mol Pu} \cdot \dfrac{244.7 \text{ g Pu}}{1 \text{ mol Pu}} = 0.0888 \text{ g Pu}$

2.63 (a) $127.08 \text{ g Cu} \cdot \dfrac{1 \text{ mol Cu}}{63.546 \text{ g Cu}} = 1.9998 \text{ mol Cu}$

(b) $0.012 \text{ g Li} \cdot \dfrac{1 \text{ mol Li}}{6.94 \text{ g Li}} = 1.7 \times 10^{-3} \text{ mol Li}$

(c) $5.0 \text{ mg Am} \cdot \dfrac{1 \text{ g}}{10^{3} \text{ mg}} \cdot \dfrac{1 \text{ mol Am}}{243 \text{ g Am}} = 2.1 \times 10^{-5} \text{ mol Am}$

(d) $6.75 \text{ g Al} \cdot \dfrac{1 \text{ mol Al}}{26.98 \text{ g Al}} = 0.250 \text{ mol Al}$

2.64 (a) $16.0 \text{ g Na} \cdot \dfrac{1 \text{ mol Na}}{22.99 \text{ g Na}} = 0.696 \text{ mol Na}$

(b) $0.876 \text{ g Sn} \cdot \dfrac{1 \text{ mol Sn}}{118.7 \text{ g Sn}} = 7.38 \times 10^{-3} \text{ mol Sn}$

(c) $0.0034 \text{ g Pt} \cdot \dfrac{1 \text{ mol Pt}}{195 \text{ g Pt}} = 1.7 \times 10^{-5} \text{ mol Pt}$

(d) $0.983 \text{ g Xe} \cdot \dfrac{1 \text{ mol Xe}}{131.3 \text{ g Xe}} = 7.49 \times 10^{-3} \text{ mol Xe}$

2.65 Helium has the smallest molar mass and will have the largest number of atoms. Iron has the largest molar mass and the smallest number of atoms.

$$1.0 \text{ g He} \cdot \frac{1 \text{ mol He}}{4.00 \text{ g He}} \cdot \frac{6.02 \times 10^{23} \text{ He atoms}}{1 \text{ mol He}} = 1.5 \times 10^{23} \text{ He atoms}$$

$$1.0 \text{ g Fe} \cdot \frac{1 \text{ mol Fe}}{55.8 \text{ g Fe}} \cdot \frac{6.02 \times 10^{23} \text{ Fe atoms}}{1 \text{ mol Fe}} = 1.1 \times 10^{22} \text{ Fe atoms}$$

2.66 $$0.10 \text{ g K} \cdot \frac{1 \text{ mol K}}{39.0983 \text{ g K}} = 0.0026 \text{ mol K}$$

$$0.10 \text{ g Mo} \cdot \frac{1 \text{ mol Mo}}{95.96 \text{ g Mo}} = 0.0010 \text{ mol Mo}$$

$$0.10 \text{ g Cr} \cdot \frac{1 \text{ mol Cr}}{51.9961 \text{ g Cr}} = 0.0019 \text{ mol Cr}$$

$$0.10 \text{ g Al} \cdot \frac{1 \text{ mol Al}}{26.9815 \text{ g}} = 0.0037 \text{ mol Al}$$

0.0010 mol Mo < 0.0019 mol Cr < 0.0026 mol K < 0.0037 mol Al

2.67 $$3.99 \text{ g Ca} \cdot \frac{1 \text{ mol Ca}}{40.078 \text{ g Ca}} = 0.0996 \text{ mol Ca}$$

$$1.85 \text{ g P} \cdot \frac{1 \text{ mol P}}{30.9737 \text{ g}} = 0.0597 \text{ mol P}$$

$$4.14 \text{ g O} \cdot \frac{1 \text{ mol O}}{15.9994 \text{ g O}} = 0.259 \text{ mol O}$$

$$0.02 \text{ g H} \cdot \frac{1 \text{ mol H}}{1.00794 \text{ g H}} = 0.02 \text{ mol H}$$

0.02 mol H < 0.0597 mol P < 0.0996 mol Ca < 0.259 mol O

2.68 $$52 \text{ g Ga} \cdot \frac{1 \text{ mol Ga}}{69.7 \text{ g Ga}} \cdot \frac{6.02 \times 10^{23} \text{ Ga atoms}}{1 \text{ mol Ga}} = 4.5 \times 10^{23} \text{ Ga atoms}$$

$$9.5 \text{ g Al} \cdot \frac{1 \text{ mol Al}}{27.0 \text{ g Al}} \cdot \frac{6.02 \times 10^{23} \text{ Al atoms}}{1 \text{ mol Al}} = 2.1 \times 10^{23} \text{ Al atoms}$$

$$112 \text{ g As} \cdot \frac{1 \text{ mol As}}{74.92 \text{ g As}} \cdot \frac{6.022 \times 10^{23} \text{ As atoms}}{1 \text{ mol As}} = 9.00 \times 10^{23} \text{ As atoms}$$

Arsenic has the largest number of atoms in the mixture.

2.69 (a) Fe_2O_3 159.69 g/mol

(b) BCl_3 117.17 g/mol

(c) $C_6H_8O_6$ 176.13 g/mol

2.70 (a) $Fe(C_6H_{11}O_7)_2$ 446.14 g/mol

(b) $CH_3CH_2CH_2CH_2SH$ 90.19 g/mol

(c) $C_{20}H_{24}N_2O_2$ 324.42 g/mol

2.71 (a) $Ni(NO_3)_2 \cdot 6H_2O$ 290.79 g/mol

(b) $CuSO_4 \cdot 5H_2O$ 249.69 g/mol

2.72 (a) $H_2C_2O_4 \cdot 2H_2O$ 126.07 g/mol

(b) $MgSO_4 \cdot 7H_2O$ 246.48 g/mol

2.73 (a) $0.0255 \text{ mol } C_3H_7OH \cdot \dfrac{60.10 \text{ g } C_3H_7OH}{1 \text{ mol } C_3H_7OH} = 1.53 \text{ g } C_3H_7OH$

(b) $0.0255 \text{ mol } C_{11}H_{16}O_2 \cdot \dfrac{180.2 \text{ g } C_{11}H_{16}O_2}{1 \text{ mol } C_{11}H_{16}O_2} = 4.60 \text{ g } C_{11}H_{16}O_2$

(c) $0.0255 \text{ mol } C_9H_8O_4 \cdot \dfrac{180.2 \text{ g } C_9H_8O_4}{1 \text{ mol } C_9H_8O_4} = 4.60 \text{ g } C_9H_8O_4$

(d) $0.0255 \text{ mol } (CH_3)_2CO \cdot \dfrac{58.08 \text{ g } (CH_3)_2CO}{1 \text{ mol } (CH_3)_2CO} = 1.48 \ (CH_3)_2CO$

2.74 (a) $0.123 \text{ mol } C_{14}H_{10}O_4 \cdot \dfrac{242.2 \text{ g } C_{14}H_{10}O_4}{1 \text{ mol } C_{14}H_{10}O_4} = 29.8 \text{ g } C_{14}H_{10}O_4$

(b) $0.123 \text{ mol } C_4H_8N_2O_2 \cdot \dfrac{116.2 \text{ g } C_4H_8N_2O_2}{1 \text{ mol } C_4H_8N_2O_2} = 14.3 \text{ g } C_4H_8N_2O_2$

(c) $0.123 \text{ mol } C_5H_{10}S \cdot \dfrac{102.2 \text{ g } C_5H_{10}S}{1 \text{ mol } C_5H_{10}S} = 12.6 \text{ g } C_5H_{10}S$

(d) $0.123 \text{ mol } C_{12}H_{17}NO \cdot \dfrac{191.3 \text{ g } C_{12}H_{17}NO}{1 \text{ mol } C_{12}H_{17}NO} = 23.5 \text{ g } C_{12}H_{17}NO$

2.75 $1.00 \text{ kg } SO_3 \cdot \dfrac{10^3 \text{ g}}{1 \text{ kg}} \cdot \dfrac{1 \text{ mol } SO_3}{80.06 \text{ g } SO_3} = 12.5 \text{ mol } SO_3$

$12.5 \text{ mol } SO_3 \cdot \dfrac{6.022 \times 10^{23} \text{ molecules}}{1 \text{ mol } SO_3} = 7.52 \times 10^{24} \text{ molecules } SO_3$

$7.52 \times 10^{24} \text{ molecules } SO_3 \cdot \dfrac{1 \text{ S atom}}{1 \ SO_3 \text{ molecule}} = 7.52 \times 10^{24} \text{ S atoms}$

$7.52 \times 10^{24} \text{ molecules } SO_3 \cdot \dfrac{3 \text{ O atoms}}{1 \ SO_3 \text{ molecule}} = 2.26 \times 10^{25} \text{ O atoms}$

2.76 $0.20 \text{ mol } (NH_4)_2SO_4 \cdot \frac{2 \text{ mol } NH_4^+}{1 \text{ mol } (NH_4)_2SO_4} \cdot \frac{6.022 \times 10^{23} \; NH_4^+ \text{ ions}}{1 \text{ mol } NH_4^+} = 2.4 \times 10^{23} \; NH_4^+ \text{ ions}$

$0.20 \text{ mol } (NH_4)_2SO_4 \cdot \frac{1 \text{ mol } SO_4^{2-}}{1 \text{ mol } (NH_4)_2SO_4} \cdot \frac{6.022 \times 10^{23} \; SO_4^{2-} \text{ ions}}{1 \text{ mol } NH_4^+} = 1.2 \times 10^{23} \; SO_4^{2-} \text{ ions}$

$0.20 \text{ mol } (NH_4)_2SO_4 \cdot \frac{2 \text{ mol N}}{1 \text{ mol } (NH_4)_2SO_4} \cdot \frac{6.022 \times 10^{23} \text{ N atoms}}{1 \text{ mol N}} = 2.4 \times 10^{23} \text{ N atoms}$

$0.20 \text{ mol } (NH_4)_2SO_4 \cdot \frac{8 \text{ mol H}}{1 \text{ mol } (NH_4)_2SO_4} \cdot \frac{6.022 \times 10^{23} \text{ H atoms}}{1 \text{ mol H}} = 9.6 \times 10^{23} \text{ H atoms}$

$0.20 \text{ mol } (NH_4)_2SO_4 \cdot \frac{1 \text{ mol S}}{1 \text{ mol } (NH_4)_2SO_4} \cdot \frac{6.022 \times 10^{23} \text{ S atoms}}{1 \text{ mol S}} = 1.2 \times 10^{23} \text{ S atoms}$

$0.20 \text{ mol } (NH_4)_2SO_4 \cdot \frac{4 \text{ mol O}}{1 \text{ mol } (NH_4)_2SO_4} \cdot \frac{6.022 \times 10^{23} \text{ O atoms}}{1 \text{ mol O}} = 4.8 \times 10^{23} \text{ O atoms}$

2.77 Formula: $C_8H_9N_1O_2$

Molar mass: 151.16 g/mol

1 dose = 2 · 500 mg = 1×10^3 mg

$1 \times 10^3 \text{ mg} \cdot \frac{1 \text{ g}}{1000 \text{ mg}} \cdot \frac{1 \text{ mol}}{151.16 \text{ g}} \cdot \frac{6.022 \times 10^{23} \text{ molecules}}{1 \text{ mol}} \cdot = 4 \times 10^{21} \text{ molecules}$

2.78 (a) $324 \text{ mg } C_9H_8O_4 \cdot \frac{1 \text{ g}}{10^3 \text{ mg}} \cdot \frac{1 \text{ mol } C_9H_8O_4}{180.2 \text{ g } C_9H_8O_4} = 1.80 \times 10^{-3} \text{ mol } C_9H_8O_4$

$1904 \text{ mg } NaHCO_3 \cdot \frac{1 \text{ g}}{10^3 \text{ mg}} \cdot \frac{1 \text{ mol } NaHCO_3}{84.007 \text{ g } NaHCO_3} = 0.02266 \text{ mol } NaHCO_3$

$1000. \text{ mg } C_6H_8O_7 \cdot \frac{1 \text{ g}}{10^3 \text{ mg}} \cdot \frac{1 \text{ mol } C_6H_8O_7}{192.13 \text{ g } C_6H_8O_7} = 5.205 \times 10^{-3} \text{ mol } C_6H_8O_7$

(b) $1.80 \times 10^{-3} \text{ mol } C_9H_8O_4 \cdot \frac{6.022 \times 10^{23} \text{ molecules}}{1 \text{ mol } C_9H_8O_4} = 1.08 \times 10^{21} \text{ molecules } C_9H_8O_4$

2.79 (a) $\frac{207.2 \text{ g Pb}}{239.3 \text{ g PbS}} \cdot 100\% = 86.59\% \text{ Pb}$ $\quad \frac{32.07 \text{ g S}}{239.3 \text{ g PbS}} \cdot 100\% = 13.40\% \text{ S}$

(b) $\frac{(3)(12.01) \text{ g C}}{44.096 \text{ g } C_3H_8} \cdot 100\% = 81.71\% \text{ C}$ $\quad \frac{(8)(1.008) \text{ g H}}{44.096 \text{ g } C_3H_8} \cdot 100\% = 18.29\% \text{ H}$

(c) $\frac{(10)(12.01) \text{ g C}}{150.21 \text{ g } C_{10}H_{14}O} \cdot 100\% = 79.95\% \text{ C}$ $\frac{(14)(1.008) \text{ g H}}{150.21 \text{ g } C_{10}H_{14}O} \cdot 100\% = 9.395\% \text{ H}$

$\frac{16.00 \text{ g O}}{150.21 \text{ g } C_{10}H_{14}O} \cdot 100\% = 10.65\% \text{ O}$

2.80 (a) $\frac{(8)(12.01) \text{ g C}}{166.18 \text{ g } C_8H_{10}N_2O_2} \cdot 100\% = 57.82\% \text{ C}$ $\frac{(10)(1.008) \text{ g H}}{166.18 \text{ g } C_8H_{10}N_2O_2} \cdot 100\% = 6.066\% \text{ H}$

$\frac{(2)(14.01) \text{ g N}}{166.18 \text{ g } C_8H_{10}N_2O_2} \cdot 100\% = 16.86\% \text{ N}$ $\frac{(2)(16.00) \text{ g O}}{166.18 \text{ g } C_8H_{10}N_2O_2} \cdot 100\% = 19.26\% \text{ O}$

(b) $\frac{(10)(12.01) \text{ g C}}{156.26 \text{ g } C_{10}H_{20}O} \cdot 100\% = 76.86\% \text{ C}$ $\frac{(20)(1.008) \text{ g H}}{156.26 \text{ g } C_{10}H_{20}O} \cdot 100\% = 12.90\% \text{ H}$

$\frac{16.00 \text{ g O}}{156.26 \text{ g } C_{10}H_{20}O} \cdot 100\% = 10.24\% \text{ O}$

(c) $\frac{58.93 \text{ g Co}}{237.93 \text{ g } CoCl_2 \cdot 6\, H_2O} \cdot 100\% = 24.77\% \text{ Co}$ $\frac{(2)(35.45) \text{ g Cl}}{237.93 \text{ g } CoCl_2 \cdot 6\, H_2O} \cdot 100\% = 29.80\% \text{ Cl}$

$\frac{(12)(1.008) \text{ g H}}{237.93 \text{ g } CoCl_2 \cdot 6\, H_2O} \cdot 100\% = 5.084\% \text{ H}$ $\frac{(6)(16.00) \text{ g O}}{237.93 \text{ g } CoCl_2 \cdot 6\, H_2O} \cdot 100\% = 40.35\% \text{ O}$

2.81 $\frac{63.55 \text{ g Cu}}{95.62 \text{ g CuS}} \cdot 100\% = 66.46\% \text{ Cu}$

$10.0 \text{ g Cu} \cdot \frac{100.00 \text{ g CuS}}{66.46 \text{ g Cu}} = 15.0 \text{ g CuS}$

2.82 $\frac{47.87 \text{ g Ti}}{151.71 \text{ g } FeTiO_3} \cdot 100\% = 31.55\% \text{ Ti}$

$750 \text{ g Ti} \cdot \frac{100.00 \text{ g } FeTiO_3}{30.35 \text{ g Ti}} = 2.4 \times 10^3 \text{ g } FeTiO_3$

2.83 Empirical formula mass = 59.04 g/mol $\frac{118.1 \text{ g/mol}}{59.04 \text{ g/mol}} = 2$

The molecular formula is $(C_2H_3O_2)_2$, or $C_4H_6O_4$

2.84 Empirical formula mass = 58.06 g/mol $\frac{116.1 \text{ g/mol}}{58.06 \text{ g/mol}} = 2$

The molecular formula is $(C_2H_4NO)_2$, or $C_4H_8N_2O_2$

2.85

	Empirical formula	Molar mass (g/mol)	Molecular formula	
(a)	CH	26.0	26.0/13.0 = 2	C_2H_2
(b)	CHO	116.1	116.1/29.0 = 4	$C_4H_4O_4$
(c)	CH_2	112.2	$(CH_2)_8$ =	C_8H_{16}

2.86

	Empirical formula	Molar mass (g/mol)	Molecular formula	
(a)	$C_2H_3O_3$	150.1	150.1/75.0 = 2	$C_4H_6O_6$
(b)	C_3H_8	44.1	44.1/44.1 = 1	C_3H_8
(c)	B_2H_5	53.3	$(B_2H_5)_2$ =	B_4H_{10}

2.87 Assume 100.00 g of compound.

$$92.26 \text{ g C} \cdot \frac{1 \text{ mol C}}{12.011 \text{ g C}} = 7.681 \text{ mol C} \qquad 7.74 \text{ g H} \cdot \frac{1 \text{ mol H}}{1.008 \text{ g H}} = 7.68 \text{ mol H}$$

$$\frac{7.681 \text{ mol C}}{7.68 \text{ mol H}} = \frac{1 \text{ mol C}}{1 \text{ mol H}}$$ The empirical formula is CH

$$\frac{26.02 \text{ g/mol}}{13.02 \text{ g/mol}} = 2$$ The molecular formula is C_2H_2

2.88 The compound is 88.5% B and 11.5% H. Assume 100.0 g of compound.

$$88.5 \text{ g B} \cdot \frac{1 \text{ mol B}}{10.81 \text{ g B}} = 8.19 \text{ mol B} \qquad 11.5 \text{ g H} \cdot \frac{1 \text{ mol H}}{1.008 \text{ g H}} = 11.4 \text{ mol H}$$

$$\frac{11.4 \text{ mol H}}{8.19 \text{ mol B}} = \frac{1.39 \text{ mol H}}{1 \text{ mol B}} = \frac{7/5 \text{ mol H}}{1 \text{ mol B}} = \frac{7 \text{ mol H}}{5 \text{ mol B}}$$ The empirical formula is B_5H_7

2.89 The compound is 89.94% C and 10.06% H. Assume 100.00 g of compound.

$$89.94 \text{ g C} \cdot \frac{1 \text{ mol C}}{12.011 \text{ g C}} = 7.488 \text{ mol C} \qquad 10.06 \text{ g H} \cdot \frac{1 \text{ mol H}}{1.0079 \text{ g H}} = 9.981 \text{ mol H}$$

$$\frac{9.981 \text{ mol H}}{7.488 \text{ mol C}} = \frac{1.33 \text{ mol H}}{1 \text{ mol C}} = \frac{4/3 \text{ mol H}}{1 \text{ mol C}} = \frac{4 \text{ mol H}}{3 \text{ mol C}}$$ The empirical formula is C_3H_4

$$\frac{120.2 \text{ g/mol}}{40.07 \text{ g/mol}} = 3$$ The molecular formula is C_9H_{12}

2.90 Assume 100.00 g of compound.

$$57.17 \text{ g S} \cdot \frac{1 \text{mol S}}{32.065 \text{ g S}} = 1.783 \text{ mol S} \qquad 42.83 \text{ g C} \cdot \frac{1 \text{mol C}}{12.011 \text{ g C}} = 3.566 \text{ mol C}$$

$$\frac{3.566 \text{ mol C}}{1.783 \text{ mol S}} = \frac{2 \text{ mol C}}{1 \text{ mol S}}$$ The empirical formula is C_2S

$$\frac{448.70 \text{ g/mol}}{56.087 \text{ g/mol}} = 8$$ The molecular formula is $C_{16}S_8$

2.91 Assume 100.00 g of compound.

$$63.15 \text{ g C} \cdot \frac{1 \text{ mol C}}{12.011 \text{ g C}} = 5.258 \text{ mol C} \qquad 5.30 \text{ g H} \cdot \frac{1 \text{ mol H}}{1.008 \text{ g H}} = 5.26 \text{ mol H}$$

$$31.55 \text{ g O} \cdot \frac{1 \text{ mol O}}{15.999 \text{ g O}} = 1.972 \text{ mol O}$$

$$\frac{5.258 \text{ mol C}}{1.972 \text{ mol O}} = \frac{2.667 \text{ mol C}}{1 \text{ mol O}} = \frac{8 \text{ mol C}}{3 \text{ mol O}} \qquad \frac{5.26 \text{ mol H}}{1.972 \text{ mol O}} = \frac{2.667 \text{ mol H}}{1 \text{ mol O}} = \frac{8 \text{ mol H}}{3 \text{ mol O}}$$

The empirical formula is $C_8H_8O_3$

The molar mass is equal to the empirical formula mass, so the molecular formula is also $C_8H_8O_3$

2.92 Assume 100.0 g of compound.

$$74.0 \text{ g C} \cdot \frac{1 \text{ mol C}}{12.01 \text{ g C}} = 6.16 \text{ mol C} \qquad 8.65 \text{ g H} \cdot \frac{1 \text{ mol H}}{1.008 \text{ g H}} = 8.58 \text{ mol H}$$

$$17.35 \text{ g N} \cdot \frac{1 \text{ mol N}}{14.007 \text{ g N}} = 1.239 \text{ mol N}$$

$$\frac{6.16 \text{ mol C}}{1.239 \text{ mol N}} = \frac{5 \text{ mol C}}{1 \text{ mol N}} \qquad \frac{8.58 \text{ mol H}}{1.239 \text{ mol N}} = \frac{7 \text{ mol H}}{1 \text{ mol N}}$$

The empirical formula is C_5H_7N

$$\frac{162 \text{ g/mol}}{81.1 \text{ g/mol}} = 2$$

The molecular formula is $C_{10}H_{14}N_2$

2.93 0.678 g compound – 0.526 g Xe = 0.152 g F

$$0.526 \text{ g Xe} \cdot \frac{1 \text{ mol Xe}}{131.3 \text{ g Xe}} = 0.00401 \text{ mol Xe} \qquad 0.152 \text{ g F} \cdot \frac{1 \text{ mol F}}{19.00 \text{ g F}} = 0.00800 \text{ mol F}$$

$$\frac{0.00800 \text{ mol F}}{0.00401 \text{ mol Xe}} = \frac{2 \text{ mol F}}{1 \text{ mol Xe}}$$

The empirical formula is XeF_2

2.94 5.722 g compound – 1.256 g S = 4.466 g F

$$1.256 \text{ g S} \cdot \frac{1 \text{ mol S}}{32.066 \text{ g S}} = 0.03917 \text{ mol S} \qquad 4.466 \text{ g F} \cdot \frac{1 \text{ mol F}}{18.998 \text{ g F}} = 0.2351 \text{ mol F}$$

$$\frac{0.2351 \text{ mol F}}{0.03917 \text{ mol S}} = \frac{6 \text{ mol F}}{1 \text{ mol S}}$$

The empirical formula is SF_6; $x = 6$

2.95 1.394 g $MgSO_4 \cdot 7H_2O$ – 0.885 g $MgSO_4$ xH_2O = 0.509 g H_2O

(0.509 g H_2O)(1 mol H_2O/18.02 g) = 0.0282 mol H_2O lost

(1.394 g $MgSO_4 \cdot 7H_2O$)(1 mol $MgSO_4 \cdot 7H_2O$ /246.48 g) = 0.005656 mol

0.0282 mol/0.005656 mol = 4.99 ~ 5

7 H_2O – 5 H_2O = 2 H_2O left per $MgSO_4$

2.96 3.69 g product – 1.25 g Ge = 2.44 g Cl

$$1.25 \text{ g Ge} \cdot \frac{1 \text{ mol Ge}}{72.61 \text{ g Ge}} = 0.0172 \text{ mol Ge} \qquad 2.44 \text{ g Cl} \cdot \frac{1 \text{ mol Cl}}{35.45 \text{ g Cl}} = 0.0688 \text{ mol Cl}$$

$$\frac{0.0688 \text{ mol Cl}}{0.0172 \text{ mol Ge}} = \frac{4 \text{ mol Cl}}{1 \text{ mol Ge}}$$

The empirical formula is $GeCl_4$

2.97

Symbol	^{58}Ni	^{33}S	^{20}Ne	^{55}Mn
Number of protons	28	16	10	25
Number of neutrons	30	17	10	30
Number of electrons	28	16	10	25
Name of element	nickel	sulfur	neon	manganese

2.98 The atomic weight of potassium is 39.0983 u, so the lighter isotope, ^{39}K is more abundant than ^{41}K.

2.99 *Crossword Puzzle*

S	N
B	I

2.100 (a) Mg is the most abundant main group metal.

(b) H is the most abundant nonmetal.

(c) Si is the most abundant metalloid.

(d) Fe is the most abundant transition element.

(e) F and Cl are the halogens included ,and of these Cl is the most abundant.

2.101 (a) $\frac{63.546 \text{ g}}{1 \text{ mol Cu}} \cdot \frac{1 \text{ mol Cu}}{6.0221 \times 10^{23} \text{ Cu atoms}} = 1.0552 \times 10^{-22}$ g/Cu atom

(b) $\frac{\$41.70}{7.0 \text{ g wire}} \cdot \frac{1 \text{ g wire}}{0.99999 \text{ g Cu}} \cdot \frac{1.0552 \times 10^{-22} \text{ g}}{1 \text{ Cu atom}} = \$6.3 \times 10^{-22}$/Cu atom

2.102 (d) 3.43×10^{-27} mol S_8 is impossible. This amount is less than one molecule of S_8.

2.103 (a) Sr, strontium

(b) Zr, zirconium

(c) C, carbon

(d) As, arsenic

(e) I, iodine

(f) Mg, magnesium

(g) Kr, krypton

(h) S, sulfur

(i) As, arsenic or Ge, germanium

2.104 Carbon has three allotropes. Graphite consists of flat sheets of carbon atoms, diamond has carbon atoms attached to four other others in a tetrahedron, and buckminsterfullerene is a 60-atom cage of carbon atoms. Oxygen has two allotropes. Diatomic oxygen consists of molecules containing two oxygen atoms and ozone consists of molecules containing three oxygen atoms.

2.105 (a) One mole of Na has a mass of approximately 23 g, a mole of Si has a mass of 28 g, and a mole of U has a mass of 238 g. A 0.25 mol sample of U therefore represents a greater mass.

(b) A 0.5 mol sample of Na has a mass of approximately 12.5 g, and 1.2×10^{22} atoms of Na is approximately 0.02 moles of Na. Therefore 0.50 mol Na represents a greater mass.

(c) The molar mass of K is approximately 39 g/mol while that of Fe is approximately 56 g/mol. A single atom of Fe has a greater mass than an atom of K, so 10 atoms of Fe represents more mass.

2.106 $15\ \text{mg} \cdot \dfrac{1\ \text{g}}{10^3\ \text{mg}} \cdot \dfrac{1\ \text{mol Fe}}{55.85\ \text{g Fe}} = 2.7 \times 10^{-4}\ \text{mol Fe}$

$2.7 \times 10^{-4}\ \text{mol Fe} \cdot \dfrac{6.02 \times 10^{23}\ \text{atoms Fe}}{1\ \text{mol Fe}} = 1.6 \times 10^{20}\ \text{atoms Fe}$

2.107 (a) $3.79 \times 10^{24}\ \text{atoms Fe} \cdot \dfrac{1\ \text{mol Fe}}{6.022 \times 10^{23}\ \text{atoms Fe}} \cdot \dfrac{55.85\ \text{g Fe}}{1\ \text{mol Fe}} = 351\ \text{g Fe}$

(b) $19.921\ \text{mol } H_2 \cdot \dfrac{2.0158\ \text{g } H_2}{1\ \text{mol } H_2} = 40.157\ \text{g } H_2$

(c) $8.576\ \text{mol C} \cdot \dfrac{12.011\ \text{g C}}{1\ \text{mol C}} = 103.0\ \text{g C}$

(d) $7.4\ \text{mol Si} \cdot \dfrac{28.1\ \text{g Si}}{1\ \text{mol Si}} = 210\ \text{g Si}$

(e) $9.221\ \text{mol Na} \cdot \dfrac{22.990\ \text{g Na}}{1\ \text{mol Na}} = 212.0\ \text{g Na}$

(f) $4.07 \times 10^{24}\ \text{atoms Al} \cdot \dfrac{1\ \text{mol Al}}{6.022 \times 10^{23}\ \text{atoms Al}} \cdot \dfrac{26.98\ \text{g Al}}{1\ \text{mol Al}} = 182\ \text{g Al}$

(g) $9.2\ \text{mol } Cl_2 \cdot \dfrac{70.9\ \text{g } Cl_2}{1\ \text{mol } Cl_2} = 650\ \text{g } Cl_2$

(b) < (c) < (f) < (d) < (e) < (a) < (g)

2.108 0.744 g phosphorus combined with (1.704 g – 0.744 g) = 0.960 g O

$$\dfrac{(0.744/4)\ \text{g P}}{(0.960/10)\ \text{g O}} = \dfrac{1.94\ \text{g P}}{1\ \text{g O}}$$

$16.000\ \text{u O} \cdot \dfrac{1.94\ \text{g P}}{1\ \text{g O}} = 31.0\ \text{u P}$

2.109 (a) Use current values to determine the atomic mass of oxygen if H = 1.0000 u

$1.0000\ \text{u H} \cdot \dfrac{15.9994\ \text{u O}}{1.00794\ \text{u H}} = 15.873\ \text{u O}$

The value of Avogadro's number is based on the atomic mass of carbon.

$$1.0000 \text{ u H} \cdot \frac{12.011 \text{ u C}}{1.00794 \text{ u H}} = 11.916 \text{ u C}$$

$$11.916 \text{ u C} \cdot \frac{6.02214199 \times 10^{23} \text{ particles}}{12.0000 \text{ u C}} = 5.9802 \times 10^{23} \text{ particles}$$

(b) $$16.0000 \text{ u O} \cdot \frac{1.00794 \text{ u H}}{15.9994 \text{ u O}} = 1.00798 \text{ u H}$$

$$16.0000 \text{ u O} \cdot \frac{12.011 \text{ u C}}{15.9994 \text{ u O}} = 12.011 \text{ u C}$$

$$12.011 \text{ u C} \cdot \frac{6.02214199 \times 10^{23} \text{ particles}}{12.0000 \text{ u C}} = 6.0279 \times 10^{23} \text{ particles}$$

2.110 $$68 \text{ atoms K} \cdot \frac{1 \text{ mol K}}{6.02 \times 10^{23} \text{ atoms K}} \cdot \frac{39.1 \text{ g K}}{1 \text{ mol K}} = 4.4 \times 10^{-21} \text{ g K}$$

$$32 \text{ atoms Na} \cdot \frac{1 \text{ mol Na}}{6.02 \times 10^{23} \text{ atoms Na}} \cdot \frac{23.0 \text{ g Na}}{1 \text{ mol Na}} = 1.2 \times 10^{-21} \text{ g Na}$$

$$\text{weight \% K} = \frac{4.4 \times 10^{-21} \text{ g K}}{4.4 \times 10^{-21} \text{ g K} + 1.2 \times 10^{-21} \text{ g Na}} \cdot 100\% = 78\% \text{ K}$$

2.111 $(NH_4)_2CO_3$ $(NH_4)_2SO_4$ $NiCO_3$ $NiSO_4$

2.112 A strontium atom has 38 electrons. When an atom of strontium forms an ion, it loses two electrons, forming an ion having the same number of electrons as the noble gas krypton.

2.113 All five compounds contain three chlorine atoms. The compound with the lowest molar mass, (a) BCl_3, has the highest weight percent of chlorine.

$$\frac{(3)(35.45) \text{ g Cl}}{117.16 \text{ g BCl}_3} \cdot 100\% = 90.77\% \text{ Cl}$$

2.114 (a) $$1.0 \text{ g BeCl}_2 \cdot \frac{1 \text{ mol BeCl}_2}{79.9 \text{ g BeCl}_2} \cdot \frac{3 \text{ mol atoms}}{1 \text{ mol BeCl}_2} \cdot \frac{6.02 \times 10^{23} \text{ atoms}}{1 \text{ mol atoms}} = 2.3 \times 10^{22} \text{ atoms}$$

(b) $$1.0 \text{ g MgCl}_2 \cdot \frac{1 \text{ mol MgCl}_2}{95.2 \text{ g MgCl}_2} \cdot \frac{3 \text{ mol atoms}}{1 \text{ mol MgCl}_2} \cdot \frac{6.02 \times 10^{23} \text{ atoms}}{1 \text{ mol atoms}} = 1.9 \times 10^{22} \text{ atoms}$$

(c) $$1.0 \text{ g CaS} \cdot \frac{1 \text{ mol CaS}}{72.1 \text{ g CaS}} \cdot \frac{2 \text{ mol atoms}}{1 \text{ mol CaS}} \cdot \frac{6.02 \times 10^{23} \text{ atoms}}{1 \text{ mol atoms}} = 1.7 \times 10^{22} \text{ atoms}$$

(d) $1.0\text{ g SrCO}_3 \cdot \dfrac{1\text{ mol SrCO}_3}{148\text{ g SrCO}_3} \cdot \dfrac{5\text{ mol atoms}}{1\text{ mol SrCO}_3} \cdot \dfrac{6.02 \times 10^{23}\text{ atoms}}{1\text{ mol atoms}} = 2.0 \times 10^{22}\text{ atoms}$

(e) $1.0\text{ g BaSO}_4 \cdot \dfrac{1\text{ mol BaSO}_4}{233\text{ g BaSO}_4} \cdot \dfrac{6\text{ mol atoms}}{1\text{ mol BaSO}_4} \cdot \dfrac{6.02 \times 10^{23}\text{ atoms}}{1\text{ mol atoms}} = 1.6 \times 10^{22}\text{ atoms}$

The 1.0-g sample of (a) $BeCl_2$ has the largest number of atoms.

2.115 3.0×10^{23} molecules represents 0.50 mol of adenine. The molar mass of adenine ($C_5H_5N_5$) is 135.13 g/mol, so 0.5 mol of adenine has a mass of 67 g. A 40.0-g sample of adenine therefore has less mass than 0.5 mol of adenine.

2.116 (a) BaF_2: barium fluoride $SiCl_4$: silicon tetrachloride $NiBr_2$: nickel(II) bromide

(b) BaF_2 and $NiBr_2$ are ionic; $SiCl_4$ is molecular

(c) $0.50\text{ mol BaF}_2 \cdot \dfrac{175\text{ g}}{1\text{ mol BaF}_2} = 88\text{ g BaF}_2$

$0.50\text{ mol SiCl}_4 \cdot \dfrac{170.\text{ g}}{1\text{ mol SiCl}_4} = 85\text{ g SiCl}_4$

$1.0\text{ mol NiBr}_2 \cdot \dfrac{219\text{ g}}{1\text{ mol NiBr}_2} = 219\text{ g NiBr}_2$ 1.0 mol $NiBr_2$has the largest mass

2.117 $0.050\text{ mL H}_2\text{O} \cdot \dfrac{1\text{ cm}^3}{1\text{ mL}} \cdot \dfrac{1.00\text{ g}}{1\text{ cm}^3} \cdot \dfrac{1\text{ mol H}_2\text{O}}{18.0\text{ g}} \cdot \dfrac{6.02 \times 10^{23}\text{ molecules}}{1\text{ mol}} = 1.7 \times 10^{21}\text{ molecules H}_2\text{O}$

2.118 (a) Molar mass = 305.42 g/mol

(b) $55\text{ mg C}_{18}\text{H}_{27}\text{NO}_3 \cdot \dfrac{1\text{ g}}{10^3\text{ mg}} \cdot \dfrac{1\text{ mol C}_{18}\text{H}_{27}\text{NO}_3}{305.42\text{ g}} = 1.8 \times 10^{-4}\text{ mol C}_{18}\text{H}_{27}\text{NO}_3$

(c) $\dfrac{(18)(12.01)\text{ g C}}{305.42\text{ g C}_{18}\text{H}_{27}\text{NO}_3} \cdot 100\% = 70.78\%\text{ C}$ $\dfrac{(27)(1.008)\text{ g H}}{305.42\text{ g C}_{18}\text{H}_{27}\text{NO}_3} \cdot 100\% = 8.911\%\text{ H}$

$\dfrac{14.01\text{ g N}}{305.42\text{ g C}_{18}\text{H}_{27}\text{NO}_3} \cdot 100\% = 4.587\%\text{ N}$ $\dfrac{(3)(16.00)\text{ g O}}{305.42\text{ g C}_{18}\text{H}_{27}\text{NO}_3} \cdot 100\% = 15.72\%\text{ O}$

(d) $55\text{ mg C}_{18}\text{H}_{27}\text{NO}_3 \cdot \dfrac{70.78\text{ mg C}}{100.00\text{ mg C}_{18}\text{H}_{27}\text{NO}_3} = 39\text{ mg C}$

2.119 Molar mass = 245.77 g/mol

$\dfrac{63.55\text{ g Cu}}{245.77\text{ g Cu(NH}_3)_4\text{SO}_4\cdot\text{H}_2\text{O}} \cdot 100\% = 25.86\%\text{ Cu}$

$\dfrac{(4)(14.01)\text{ g N}}{245.77\text{ g Cu(NH}_3)_4\text{SO}_4\cdot\text{H}_2\text{O}} \cdot 100\% = 22.80\%\text{ N}$

$\dfrac{(14)(1.008)\text{ g H}}{245.77\text{ g Cu(NH}_3)_4\text{SO}_4\cdot\text{H}_2\text{O}} \cdot 100\% = 5.742\%\text{ H}$

$$\frac{32.07 \text{ g S}}{245.77 \text{ g Cu(NH}_3)_4\text{SO}_4\cdot\text{H}_2\text{O}} \cdot 100\% = 13.05\% \text{ S}$$

$$\frac{(5)(16.00) \text{ g O}}{245.77 \text{ g Cu(NH}_3)_4\text{SO}_4\cdot\text{H}_2\text{O}} \cdot 100\% = 32.55\% \text{ O}$$

$$10.5 \text{ g Cu(NH}_3)_4\text{SO}_4\cdot\text{H}_2\text{O} \cdot \frac{25.86 \text{ g Cu}}{100.00 \text{ g Cu(NH}_3)_4\text{SO}_4\cdot\text{H}_2\text{O}} = 2.72 \text{ g Cu}$$

$$10.5 \text{ g Cu(NH}_3)_4\text{SO}_4\cdot\text{H}_2\text{O} \cdot \frac{18.02 \text{ g H}_2\text{O}}{245.77 \text{ g Cu(NH}_3)_4\text{SO}_4\cdot\text{H}_2\text{O}} = 0.770 \text{ g H}_2\text{O}$$

2.120 (a) Ethylene glycol $C_2H_6O_2$ Molar mass = 62.07 g/mol

$$\frac{(2)(12.01) \text{ g C}}{62.07 \text{ g C}_2\text{H}_6\text{O}_2} \cdot 100\% = 38.70\% \text{ C} \qquad \frac{(2)(16.00) \text{ g O}}{62.07 \text{ g C}_2\text{H}_6\text{O}_2} \cdot 100\% = 51.55\% \text{ O}$$

(b) Dihydroxyacetone $C_3H_6O_3$ Molar mass = 90.08 g/mol

$$\frac{(3)(12.01) \text{ g C}}{90.08 \text{ g C}_3\text{H}_6\text{O}_3} \cdot 100\% = 40.00\% \text{ C} \qquad \frac{(3)(16.00) \text{ g O}}{90.08 \text{ g C}_3\text{H}_6\text{O}_3} \cdot 100\% = 53.29\% \text{ O}$$

(c) Ascorbic acid $C_6H_8O_6$ Molar mass = 176.13 g/mol

$$\frac{(6)(12.01) \text{ g C}}{176.13 \text{ g C}_6\text{H}_8\text{O}_6} \cdot 100\% = 40.91\% \text{ C} \qquad \frac{(6)(16.00) \text{ g O}}{176.13 \text{ g C}_6\text{H}_8\text{O}_6} \cdot 100\% = 54.51\% \text{ O}$$

Ascorbic acid has a larger percentage of carbon and of oxygen.

2.121

$$\frac{1.5 \text{ mol H}}{1 \text{ mol C}} = \frac{3/2 \text{ mol H}}{1 \text{ mol C}} = \frac{3 \text{ mol H}}{2 \text{ mol C}} = \frac{6 \text{ mol H}}{4 \text{ mol C}}$$

$$\frac{1.25 \text{ mol O}}{1 \text{ mol C}} = \frac{5/4 \text{ mol O}}{1 \text{ mol C}} = \frac{5 \text{ mol O}}{4 \text{ mol C}}$$

The empirical formula is $C_4H_6O_5$.

2.122

$$\frac{55.85 \text{ g Fe}}{151.92 \text{ g FeSO}_4} \cdot 100\% = 36.76\% \text{ Fe} \qquad \frac{55.85 \text{ g Fe}}{446.15 \text{ g Fe(C}_6\text{H}_{11}\text{O}_7)_2} \cdot 100\% = 12.52\% \text{ Fe}$$

The tablet containing $FeSO_4$ will deliver more atoms of iron.

2.123 Assume 100.00 g of compound.

$$30.70 \text{ g Fe} \cdot \frac{1 \text{ mol Fe}}{55.845 \text{ g}} = 0.5497 \text{ mol Fe} \qquad 69.30 \text{ g CO} \cdot \frac{1 \text{ mol CO}}{28.010 \text{ g}} = 2.474 \text{ mol CO}$$

$$\frac{2.474 \text{ mol CO}}{0.5497 \text{ mol Fe}} = \frac{4.5 \text{ mol CO}}{1 \text{ mol Fe}} = \frac{9 \text{ mol CO}}{2 \text{ mol Fe}}$$

The empirical formula is $Fe_2(CO)_9$

2.124 (a) $C_{10}H_{15}NO$ Molar mass = 165.23 g/mol

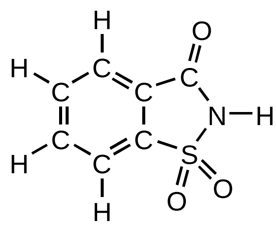
(b) $$\frac{(10)(12.01) \text{ g C}}{165.23 \text{ g C}_{10}\text{H}_{15}\text{NO}} \cdot 100\% = 72.69\% \text{ C}$$

(c) $$0.125 \text{ g C}_{10}\text{H}_{15}\text{NO} \cdot \frac{1 \text{ mol C}_{10}\text{H}_{15}\text{NO}}{165.23 \text{ g}} = 7.57 \times 10^{-4} \text{ mol C}_{10}\text{H}_{15}\text{NO}$$

(d) 7.57×10^{-4} mol $C_{10}H_{15}NO \cdot \dfrac{6.022 \times 10^{23} \text{ molecules}}{1 \text{ mol } C_{10}H_{15}NO} = 4.56 \times 10^{20}$ molecules

4.56×10^{20} molecules $\cdot \dfrac{10 \text{ C atoms}}{1 \text{ molecule}} = 4.56 \times 10^{21}$ C atoms

2.125 (a) $C_7H_5NO_3S$



(b) $125 \text{ mg } C_7H_5NO_3S \cdot \dfrac{1 \text{ g}}{10^3 \text{ mg}} \cdot \dfrac{1 \text{ mol } C_7H_5NO_3S}{183.19 \text{ g}} = 6.82 \times 10^{-4} \text{ mol } C_7H_5NO_3S$

(c) $125 \text{ mg } C_7H_5NO_3S \cdot \dfrac{32.07 \text{ mg S}}{183.19 \text{ mg } C_7H_5NO_3S} = 21.9 \text{ mg S}$

2.126 (a) chlorine trifluoride
(b) nitrogen trichloride
(c) strontium sulfate, ionic
(d) calcium nitrate, ionic
(e) xenon tetrafluoride
(f) oxygen difluoride
(g) potassium iodide, ionic
(h) aluminum sulfide, ionic
(i) phosphorus trichloride
(j) potassium phosphate, ionic

2.127 (a) NaOCl, ionic
(b) BI_3
(c) $Al(ClO_4)_3$, ionic
(d) $Ca(CH_3CO_2)_2$, ionic
(e) $KMnO_4$, ionic
(f) $(NH_4)_2SO_3$, ionic
(g) KH_2PO_4, ionic
(h) S_2Cl_2
(i) ClF_3
(j) PF_3

2.128

Cation	Anion	Name	Formula
NH_4^+	Br^-	ammonium bromide	NH_4Br
Ba^{2+}	S^{2-}	barium sulfide	BaS
Fe^{2+}	Cl^-	iron(II) chloride	$FeCl_2$
Pb^{2+}	F^-	lead(II) fluoride	PbF_2
Al^{3+}	CO_3^{2-}	aluminum carbonate	$Al_2(CO_3)_3$
Fe^{3+}	O^{2-}	iron(III) oxide	Fe_2O_3

2.129 (a) Assume 100.0 g of compound.

$14.6 \text{ g C} \cdot \dfrac{1 \text{ mol C}}{12.01 \text{ g C}} = 1.22 \text{ mol C}$ $\quad$ $39.0 \text{ g O} \cdot \dfrac{1 \text{ mol O}}{16.00 \text{ g O}} = 2.44 \text{ mol O}$

$$46.3 \text{ g F} \cdot \frac{1 \text{ mol F}}{19.00 \text{ g F}} = 2.44 \text{ mol F}$$

$$\frac{2.44 \text{ mol O}}{1.22 \text{ mol C}} = \frac{2 \text{ mol O}}{1 \text{ mol C}} \qquad \frac{2.44 \text{ mol F}}{1.22 \text{ mol C}} = \frac{2 \text{ mol F}}{1 \text{ mol C}}$$

The empirical formula is CO_2F_2. The empirical formula mass is equal to the molar mass, so the molecular formula is also CO_2F_2.

(b) Assume 100.00 g of compound.

$$93.71 \text{ g C} \cdot \frac{1 \text{ mol C}}{12.011 \text{ g C}} = 7.802 \text{ mol C} \qquad 6.29 \text{ g H} \cdot \frac{1 \text{ mol H}}{1.008 \text{ g H}} = 6.24 \text{ mol H}$$

$$\frac{7.802 \text{ mol C}}{6.24 \text{ mol H}} = \frac{1.25 \text{ mol C}}{1 \text{ mol H}} = \frac{5 \text{ mol C}}{4 \text{ mol H}}$$

The empirical formula is C_5H_4

$$\frac{128.16 \text{ g/mol}}{64.08 \text{ g/mol}} = 2$$

The molecular formula is $C_{10}H_8$

2.130 Assume 100.00 g of compound.

$$22.88 \text{ g C} \cdot \frac{1 \text{ mol C}}{12.011 \text{ g C}} = 1.905 \text{ mol C} \qquad 5.76 \text{ g H} \cdot \frac{1 \text{ mol H}}{1.008 \text{ g H}} = 5.71 \text{ mol H}$$

$$71.36 \text{ g As} \cdot \frac{1 \text{ mol As}}{74.922 \text{ g As}} = 0.9525 \text{ mol As}$$

$$\frac{1.905 \text{ mol C}}{0.9525 \text{ mol As}} = \frac{2 \text{ mol C}}{1 \text{ mol As}} \qquad \frac{5.71 \text{ mol H}}{0.9525 \text{ mol As}} = \frac{6 \text{ mol H}}{1 \text{ mol As}}$$

The empirical formula is C_2H_6As

$$\frac{210 \text{ g/mol}}{105.0 \text{ g/mol}} = 2$$

The molecular formula is $C_4H_{12}As_2$

2.131 Assume 100.00 g of compound.

$$58.77 \text{ g C} \cdot \frac{1 \text{ mol C}}{12.011 \text{ g C}} = 4.893 \text{ mol C} \qquad 13.81 \text{ g H} \cdot \frac{1 \text{ mol H}}{1.0079 \text{ g H}} = 13.70 \text{ mol H}$$

$$27.40 \text{ g N} \cdot \frac{1 \text{ mol N}}{14.007 \text{ g N}} = 1.956 \text{ mol N}$$

$$\frac{4.893 \text{ mol C}}{1.956 \text{ mol N}} = \frac{2.5 \text{ mol C}}{1 \text{ mol N}} = \frac{5 \text{ mol C}}{2 \text{ mol N}} \qquad \frac{13.70 \text{ mol H}}{1.956 \text{ mol N}} = \frac{7 \text{ mol H}}{1 \text{ mol N}} = \frac{14 \text{ mol H}}{2 \text{ mol N}}$$

The empirical formula is $C_5H_{14}N_2$. The empirical formula mass is equal to the molecular mass, so the molecular formula is also $C_5H_{14}N_2$.

2.132 $0.364 \text{ g Ni(CO)}_x - 0.125 \text{ g Ni} = 0.239 \text{ g CO}$

$0.239 \text{ g CO} \cdot \dfrac{1 \text{ mol CO}}{28.01 \text{ g CO}} = 0.00853 \text{ mol CO}$ $\quad$ $0.125 \text{ g Ni} \cdot \dfrac{1 \text{ mol Ni}}{58.69 \text{ g Ni}} = 0.00213 \text{ mol Ni}$

$\dfrac{0.00853 \text{ mol CO}}{0.00213 \text{ mol Ni}} = \dfrac{4 \text{ mol CO}}{1 \text{ mol Ni}}$ $\quad$ The compound formula is $Ni(CO)_4$ ($x = 4$)

2.133 Assume 100.0 g of compound.

$49.5 \text{ g C} \cdot \dfrac{1 \text{ mol C}}{12.01 \text{ g C}} = 4.12 \text{ mol C}$ $\quad$ $3.2 \text{ g H} \cdot \dfrac{1 \text{ mol H}}{1.01 \text{ g H}} = 3.2 \text{ mol H}$

$22.0 \text{ g O} \cdot \dfrac{1 \text{ mol O}}{16.00 \text{ g O}} = 1.38 \text{ mol O}$ $\quad$ $25.2 \text{ g Mn} \cdot \dfrac{1 \text{ mol Mn}}{54.94 \text{ g Mn}} = 0.459 \text{ mol Mn}$

$\dfrac{4.12 \text{ mol C}}{0.459 \text{ mol Mn}} = \dfrac{9 \text{ mol C}}{1 \text{ mol Mn}}$ $\quad$ $\dfrac{3.2 \text{ mol H}}{0.459 \text{ mol Mn}} = \dfrac{7 \text{ mol H}}{1 \text{ mol Mn}}$

$\dfrac{1.38 \text{ mol O}}{0.459 \text{ mol Mn}} = \dfrac{3 \text{ mol O}}{1 \text{ mol Mn}}$ $\quad$ The empirical formula is $C_9H_7MnO_3$

2.134 $\dfrac{(2)(30.97) \text{ g P}}{310.18 \text{ g Ca}_3(\text{PO}_4)_2} \cdot 100\% = 19.97\% \text{ P}$

$15.0 \text{ kg P} \cdot \dfrac{100.00 \text{ kg Ca}_3(\text{PO}_4)_2}{19.97 \text{ kg P}} = 75.1 \text{ kg Ca}_3(\text{PO}_4)_2$

2.135 $\dfrac{(2)(52.00) \text{ kg Cr}}{152.00 \text{ kg Cr}_2\text{O}_3} \cdot 100\% = 68.42\% \text{ Cr}$

$850 \text{ kg Cr} \cdot \dfrac{100.00 \text{ kg Cr}_2\text{O}_3}{68.42 \text{ kg Cr}} = 1200 \text{ kg Cr}_2\text{O}_3$

2.136 $\dfrac{(2)(121.8) \text{ g Sb}}{339.8 \text{ g Sb}_2\text{S}_3} \cdot 100\% = 71.69\% \text{ Sb}$

$1.00 \text{ kg ore} \cdot \dfrac{10^3 \text{ g}}{1 \text{ kg}} \cdot \dfrac{10.6 \text{ g Sb}}{100.0 \text{ g ore}} \cdot \dfrac{100.00 \text{ g Sb}_2\text{S}_3}{71.69 \text{ g Sb}} = 148 \text{ g Sb}_2\text{S}_3$

2.137 $1.246 \text{ g I}_x\text{Cl}_y - 0.678 \text{ g I} = 0.568 \text{ g Cl}$

$0.678 \text{ g I} \cdot \dfrac{1 \text{ mol I}}{126.9 \text{ g I}} = 0.00534 \text{ mol I}$ $\quad$ $0.568 \text{ g Cl} \cdot \dfrac{1 \text{ mol Cl}}{35.45 \text{ g Cl}} = 0.0160 \text{ mol Cl}$

$\dfrac{0.0160 \text{ mol Cl}}{0.00534 \text{ mol I}} = \dfrac{3 \text{ mol Cl}}{1 \text{ mol I}}$ $\quad$ The empirical formula is ICl_3

$\dfrac{467 \text{ g/mol}}{233.3 \text{ g/mol}} = 2$ $\quad$ The molecular formula is I_2Cl_6

2.138 $2.04 \text{ g V} \cdot \frac{1 \text{ mol V}}{50.94 \text{ g V}} = 0.0400 \text{ mol V}$ $1.93 \text{ g S} \cdot \frac{1 \text{ mol S}}{32.07 \text{ g S}} = 0.0602 \text{ mol S}$

$\frac{0.0602 \text{ mol S}}{0.0400 \text{ mol V}} = \frac{1.5 \text{ mol S}}{1 \text{ mol V}} = \frac{3 \text{ mol S}}{2 \text{ mol V}}$ The empirical formula is V_2S_3

2.139 $15.8 \text{ kg } FeS_2 \cdot \frac{55.85 \text{ kg Fe}}{119.99 \text{ kg } FeS_2} = 7.35 \text{ kg Fe}$

2.140 (a) True. $0.500 \text{ mol } C_8H_{18} \cdot \frac{114.2 \text{ g } C_8H_{18}}{1 \text{ mol } C_8H_{18}} = 57.1 \text{ g } C_8H_{18}$

(b) True. $\frac{(8)(12.01) \text{ g C}}{114.2 \text{ g } C_8H_{18}} \cdot 100\% = 84.1\% \text{ C}$

(c) True.

(d) False. $57.1 \text{ g } C_8H_{18} \cdot \frac{(18)(1.008) \text{ g H}}{114.2 \text{ g } C_8H_{18}} = 9.07 \text{ g H}$

2.141 (d) Na_2MoO_4

2.142 $\frac{74.75 \text{ g Cl}}{100.00 \text{ g } MCl_4} = \frac{(4)(35.453) \text{ g Cl}}{\text{molar mass } MCl_4}$

Molar mass MCl_4 = 189.7 g

Atomic weight M = 189.7 g MCl_4 – (4)(35.453) g Cl = 47.9 g

M is Ti, titanium

2.143 $2 \text{ tablets} \cdot \frac{300. \text{ mg}}{1 \text{ tablet}} \cdot \frac{1 \text{ g}}{10^3 \text{ mg}} \cdot \frac{1 \text{ mol } C_{21}H_{15}Bi_3O_{12}}{1086 \text{ g } C_{21}H_{15}Bi_3O_{12}} = 5.52 \times 10^{-4} \text{ mol } C_{21}H_{15}Bi_3O_{12}$

$5.52 \times 10^{-4} \text{ mol } C_{21}H_{15}Bi_3O_{12} \cdot \frac{3 \text{ mol Bi}}{1 \text{ mol } C_{21}H_{15}Bi_3O_{12}} \cdot \frac{209.0 \text{ g Bi}}{1 \text{ mol Bi}} = 0.346 \text{ g Bi}$

2.144 $\frac{15.2 \text{ g O}}{100 \text{ g } MO_2} = \frac{(2)(16.00) \text{ g O}}{\text{molar mass } MO_2}$ Molar mass MO_2 = 211 g

Atomic weight M = 211 g MO_2 – (2)(16.00) g O = 179 g M is Hf, hafnium

2.145 Molar mass of compound = $\frac{385 \text{ g}}{2.50 \text{ mol}} = 154 \text{ g/mol}$

154 g/mol = (molar mass of E) + [4 × (molar mass of Cl)] = M_E + 4(35.45 g/mol)

M_E = 12

E is C, carbon.

2.146 $\frac{15.9 \text{ g}}{0.15 \text{ mol}} = 106 \text{ g/mol } A_2Z_3$ $\frac{9.3 \text{ g}}{0.15 \text{ mol}} = 62 \text{ g/mol } AZ_2$

For AZ_2: (atomic mass A) + (2)(atomic mass Z) = 62

For A_2Z_3: (2)(atomic mass A) + (3)(atomic mass Z) = 106

(2)[62 – (2)(atomic mass Z)] + (3)(atomic mass Z) = 106

atomic mass Z = 18 g/mol

atomic mass A = 26 g/mol

2.147 $$\frac{(3)(79.904\text{ g Br})}{\text{molar mass } Br_3C_6H_3(C_8H_8)_x} \cdot 100\% = 0.105\ \%\text{ Br}$$

molar mass $Br_3C_6H_3(C_8H_8)_x = 2.28 \times 10^5$ g/mol

2.28×10^5 g/mol = (3)(79.904) g Br + (6)(12.011) g C + (3)(1.0079) g H + (x)(104.15) g C_8H_8

$x = 2.19 \times 10^3$

2.148 $$\frac{55.85\text{ g Fe}}{\text{molar mass hemoglobin}} \cdot 100\% = 0.335\%\text{ Fe}$$

molar mass hemoglobin = 1.67×10^4 g/mol

$$\frac{(4)(55.85)\text{ g Fe}}{\text{molar mass hemoglobin}} \cdot 100\% = 0.335\%\text{ Fe}$$

molar mass hemoglobin = 6.67×10^4 g/mol

2.149 (a) mass of nucleus = 1.06×10^{-22} g (electron mass is negligible)

$$\text{nuclear radius} = 4.8 \times 10^{-6}\text{ nm} \cdot \frac{10^{-9}\text{ m}}{1\text{ nm}} \cdot \frac{100\text{ cm}}{1\text{ m}} = 4.8 \times 10^{-13}\text{ cm}$$

volume of nucleus = $(^4/_3)(\pi)(4.8 \times 10^{-13}\text{ cm})^3 = 4.6 \times 10^{-37}\text{ cm}^3$

$$\text{density of nucleus} = \frac{1.06\times10^{-22}\text{ g}}{4.6\times10^{-37}\text{ cm}^3} = 2.3 \times 10^{14}\text{ g/cm}^3$$

(b) $$\text{atomic radius} = 0.125\text{ nm} \cdot \frac{10^{-9}\text{ m}}{1\text{ nm}} \cdot \frac{100\text{ cm}}{1\text{ m}} = 1.25 \times 10^{-8}\text{ cm}$$

volume of Zn atom = $(^4/_3)(\pi)(1.25 \times 10^{-8}\text{ cm})^3 = 8.18 \times 10^{-24}\text{ cm}^3$

volume of space occupied by electrons = $8.18 \times 10^{-24}\text{ cm}^3 - 4.6 \times 10^{-37}\text{ cm}^3$

$= 8.18 \times 10^{-24}\text{ cm}^3$

$$\text{density of space occupied by electrons} = \frac{(30)\left(9.11\times10^{-28}\text{ g}\right)}{8.18\times10^{-24}\text{ cm}^3} = 3.34 \times 10^{-3}\text{ g/cm}^3$$

(c) The nucleus is much more dense than the space occupied by the electrons.

2.150 (a) Volume of cube = $(1.000\text{ cm})^3 = 1.000\text{ cm}^3$

$$1.000\text{ cm}^3\text{ Pb} \cdot \frac{11.35\text{ g Pb}}{1\text{ cm}^3} \cdot \frac{1\text{ mol Pb}}{207.2\text{ g Pb}} \cdot \frac{6.0221 \times 10^{23}\text{ atoms Pb}}{1\text{ mol Pb}} = 3.299 \times 10^{22}\text{ atoms Pb}$$

(b) Volume of one lead atom = $\dfrac{(0.60)(1.000\ \text{cm}^3)}{3.299 \times 10^{22}\ \text{atoms Pb}}$ = $1.819 \times 10^{-23}\ \text{cm}^3$

$1.819 \times 10^{-23}\ \text{cm}^3 = (^4/_3)(\pi)(\text{Pb radius})^3$

Pb radius = 1.631×10^{-8} cm

2.151 (a) volume = $(0.0550\ \text{cm})(1.25\ \text{cm})^2 = 0.0859\ \text{cm}^3$ Ni

$0.0859\ \text{cm}^3\ \text{Ni} \cdot \dfrac{8.902\ \text{g Ni}}{1\ \text{cm}^3}$ = 0.765 g Ni (0.765 g Ni)(1 mol Ni/58.69 g Ni) = 0.0130 mol Ni

(b) 1.261 g compound – 0.765 g Ni = 0.496 g F

$0.765\ \text{g Ni} \cdot \dfrac{1\ \text{mol Ni}}{58.69\ \text{g Ni}} = 0.0130\ \text{mol Ni}$

$0.496\ \text{g F} \cdot \dfrac{1\ \text{mol F}}{19.00\ \text{g F}} = 0.0261\ \text{mol F}$

$\dfrac{0.0261\ \text{mol F}}{0.0130\ \text{mol Ni}} = \dfrac{2\ \text{mol F}}{1\ \text{mol Ni}}$ The empirical formula is NiF_2

(c) NiF_2, nickel(II) fluoride

2.152 (a) 0.199 g U_xO_y – 0.169 g U = 0.030 g O

$0.169\ \text{g U} \cdot \dfrac{1\ \text{mol U}}{238.0\ \text{g U}} = 7.10 \times 10^{-4}\ \text{mol U}$

$0.030\ \text{g O} \cdot \dfrac{1\ \text{mol O}}{16.0\ \text{g O}} = 1.9 \times 10^{-3}\ \text{mol O}$

$$\frac{1.9 \times 10^{-3}\ \text{mol O}}{7.10 \times 10^{-4}\ \text{mol U}} = \frac{2.68\ \text{mol O}}{1\ \text{mol U}} = \frac{8\ \text{mol O}}{3\ \text{mol U}}$$

The empirical formula is U_3O_8, a mixture of uranium(IV) oxide and uranium(VI) oxide.

$7.10 \times 10^{-4}\ \text{mol U} \cdot \dfrac{1\ \text{mol}\ U_3O_8}{3\ \text{mol U}} = 2.37 \times 10^{-4}\ \text{mol}\ U_3O_8$

(b) The atomic weight of U is 238.029 u, implying that the isotope ^{238}U is the most abundant.

(c) 0.865 g – 0.679 g = 0.186 g H_2O lost upon heating

$0.186\ \text{g}\ H_2O \cdot \dfrac{1\ \text{mol}\ H_2O}{18.02\ \text{g}\ H_2O} = 0.0103\ \text{mol}\ H_2O$

$0.679\ \text{g}\ UO_2(NO_3)_2 \cdot \dfrac{1\ \text{mol}\ UO_2(NO_3)_2}{394.0\ \text{g}\ UO_2(NO_3)_2} = 0.00172\ \text{mol}\ UO_2(NO_3)_2$

$$\frac{0.0103\ \text{mol}\ H_2O}{0.00172\ \text{mol}\ UO_2(NO_3)_2} = \frac{6\ \text{mol}\ H_2O}{1\ \text{mol}\ UO_2(NO_3)_2}$$

The formula of the hydrated compound is $UO_2(NO_3)_2 \cdot 6\ H_2O$

2.153 $0.125\ \text{mol Na} \cdot \dfrac{22.99\ \text{g Na}}{1\ \text{mol Na}} \cdot \dfrac{1\ \text{cm}^3}{0.97\ \text{g Na}} = 3.0\ \text{cm}^3$

Edge = $\sqrt[3]{3.0\ \text{cm}^3}$ = 1.4 cm

2.154 Assume 100.0 g of sample.

$$54.0 \text{ g C} \cdot \frac{1 \text{ mol C}}{12.01 \text{ g C}} = 4.50 \text{ mol C} \qquad 6.00 \text{ g H} \cdot \frac{1 \text{ mol H}}{1.008 \text{ g H}} = 5.95 \text{ mol H}$$

$$40.0 \text{ g O} \cdot \frac{1 \text{ mol O}}{16.00 \text{ g O}} = 2.50 \text{ mol O}$$

$$\frac{4.50 \text{ mol C}}{2.50 \text{ mol O}} = \frac{1.8 \text{ mol C}}{1 \text{ mol O}} = \frac{9 \text{ mol C}}{5 \text{ mol O}} \qquad \frac{5.95 \text{ mol H}}{2.50 \text{ mol O}} = \frac{2.38 \text{ mol H}}{1 \text{ mol O}} = \frac{12 \text{ mol H}}{5 \text{ mol O}}$$

Answer (d) $C_9H_{12}O_5$ is correct. The other students apparently did not correctly calculate the number of moles of material in 100.0 g or they improperly calculated the ratio of those moles in determining their empirical formula.

2.155 (a) The most abundant isotopes of C, H, and Cl are ^{12}C, ^{1}H, and ^{35}Cl. The peak at 50 *m/z* is due to ions with the makeup $^{12}C^{1}H_3{}^{35}Cl^+$ while the peak at 52 m/z is due to $^{12}C^{1}H_3{}^{37}Cl^+$ ions. The peak at 52 *m/z* is about 1/3 the height of the 50 m/z peak because the abundance of ^{37}Cl is about $^1/_3$ that of ^{35}Cl.

(b) The species at 51 *m/z* are $^{13}C^{1}H_3{}^{35}Cl^+$ and $^{12}C^{1}H_2{}^{2}H_1{}^{35}Cl^+$.

2.156 (a) *m/Z* 158 $^{79}Br_2$

m/Z 160 $^{79}Br^{81}Br$

m/Z 162 $^{81}Br_2$

(b) The abundances are close enough to assume an equal abundance of ^{79}Br and ^{81}Br. Two atoms from the two isotopes can be combined in four different manners to form Br_2: $^{79}Br_2$, $^{79}Br^{81}Br$, $^{81}Br^{79}Br$, and $^{81}Br_2$. Thus, the peak at *m/Z* 160 should have twice the intensity of the peaks at *m/Z* 158 and 162.

2.157 1.687 g hydrated compound – 0.824 g $MgSO_4$ = 0.863 g H_2O

$$0.863 \text{ g } H_2O \cdot \frac{1 \text{ mol } H_2O}{18.02 \text{ g } H_2O} = 0.0479 \text{ mol } H_2O$$

$$0.824 \text{ g } MgSO_4 \cdot \frac{1 \text{ mol } MgSO_4}{120.4 \text{ g } MgSO_4} = 0.00684 \text{ mol } MgSO_4$$

$$\frac{0.0479 \text{ mol } H_2O}{0.00684 \text{ mol } MgSO_4} = \frac{7.00 \text{ mol } H_2O}{1 \text{ mol } MgSO_4}$$

There are 7 water molecules per formula unit of $MgSO_4$

2.158 4.74 g hydrated compound – 2.16 g H_2O = 2.58 g $KAl(SO_4)_2$

$$2.16 \text{ g } H_2O \cdot \frac{1 \text{ mol } H_2O}{18.02 \text{ g } H_2O} = 0.120 \text{ mol } H_2O$$

$$2.58 \text{ g } KAl(SO_4)_2 \cdot \frac{1 \text{ mol } KAl(SO_4)_2}{258.2 \text{ g } KAl(SO_4)_2} = 0.00999 \text{ mol } KAl(SO_4)_2$$

$$\frac{0.120 \text{ mol } H_2O}{0.00999 \text{ mol KAl}(SO_4)_2} = \frac{12.0 \text{ mol } H_2O}{1 \text{ mol KAl}(SO_4)_2}$$

There are 12 water molecules per formula unit of $KAl(SO_4)_2$; $x = 12$

2.159 1.056 g Sn total – 0.601 g Sn remaining = 0.455 g Sn consumed

$$0.455 \text{ g Sn} \cdot \frac{1 \text{ mol Sn}}{118.710 \text{ g}} = 0.00383 \text{ mol Sn}$$

$$1.947 \text{ g I consumed} \cdot \frac{1 \text{ mol I}}{126.9045 \text{ g I}} = 0.01534 \text{ mol I}$$

0.01534 mol I/0.00383 mol Sn = 4.01 mol I/mol Sn

Formula is SnI_4.

2.160 Assume 100.0 g of sample.

$$54.0 \text{ g C} \cdot \frac{1 \text{ mol C}}{12.01 \text{ g C}} = 4.50 \text{ mol C} \qquad 6.00 \text{ g H} \cdot \frac{1 \text{ mol H}}{1.008 \text{ g H}} = 5.95 \text{ mol H}$$

$$40.0 \text{ g O} \cdot \frac{1 \text{ mol O}}{16.00 \text{ g O}} = 2.50 \text{ mol O}$$

$$\frac{4.50 \text{ mol C}}{2.50 \text{ mol O}} = \frac{1.8 \text{ mol C}}{1 \text{ mol O}} = \frac{9 \text{ mol C}}{5 \text{ mol O}} \qquad \frac{5.95 \text{ mol H}}{2.50 \text{ mol O}} = \frac{2.38 \text{ mol H}}{1 \text{ mol O}} = \frac{12 \text{ mol H}}{5 \text{ mol O}}$$

Answer (d) $C_9H_{12}O_5$ is correct. The other students apparently did not correctly calculate the number of moles of material in 100.0 g or they improperly calculated the ratio of those moles in determining their empirical formula.

2.161 0.832 g hydrated sample – 0.739 g heated sample = 0.093 g H_2O

$$0.093 \text{ g } H_2O \cdot \frac{1 \text{ mol } H_2O}{18.02 \text{ g } H_2O} = 0.0052 \text{ mol } H_2O$$

$$0.739 \text{ g } CaCl_2 \cdot \frac{1 \text{ mol } CaCl_2}{111.0 \text{ g } CaCl_2} = 0.00666 \text{ mol } CaCl_2$$

$$\frac{0.0052 \text{ mol } H_2O}{0.00666 \text{ mol } CaCl_2} = \frac{0.78 \text{ mol } H_2O}{1 \text{ mol } CaCl_2}$$

The students should (c) heat the crucible again and then reweigh it.

2.162 14.710 g crucible & Sn – 13.457 g crucible = 1.253 g Sn

$$1.253 \text{ g Sn} \cdot \frac{1 \text{ mol Sn}}{118.710 \text{ g Sn}} = 0.01056 \text{ mol Sn}$$

15.048 g crucible & Sn & O – 14.710 g crucicble & Sn = 0.338 g O

$$0.338 \text{ g O} \cdot \frac{1 \text{ mol}}{15.9994 \text{ g O}} = 0.0211 \text{ mol O}$$

0.0211 mol O/0.01056 mol Sn = 2 mol O/1 mol Sn

Formula is SnO_2.

2.163 (b) the molar mass of iron, (c) Avogadro's number, and (d) the density of iron are needed

$$1.00 \text{ cm}^3 \cdot \frac{7.87 \text{ g Fe}}{1 \text{ cm}^3} \cdot \frac{1 \text{ mol Fe}}{55.85 \text{ g Fe}} \cdot \frac{6.022 \times 10^{23} \text{ atoms Fe}}{1 \text{ mol Fe}} = 8.49 \times 10^{22} \text{ atoms Fe}$$

2.164 Element abundance generally decreases with increasing atomic number (with exceptions at Li–B and Sc–Fe). Elements with an even atomic number appear to be slightly more abundant than those with an odd atomic number.

2.165 (a) Barium would be even more reactive than calcium, so a more vigorous evolution of hydrogen would occur (it might even ignite).

(b) Mg, Ca, and Ba are in periods 3, 4, and 6, respectively. Reactivity increases on going down a group in the periodic table.

2.166 One possible method involves the following steps: (1) weigh a representative sample of jelly beans (about 10) in order to determine the average mass of a jelly bean; (2) weight the jelly beans in the jar (subtract the mass of the empty jar from the mass of the jar filled with jelly beans; (3) use the average mass per jelly bean and the total mass of the jelly beans in the jar to determine the approximate number of jelly beans in the jar.

SOLUTIONS TO APPLYING CHEMICAL PRINCIPLES: ARGON – AN AMAZING DISCOVERY

1. $0.20389 \text{ g} \cdot (1 \text{ L}/1.25718 \text{ g}) = 0.16218 \text{ L} = 162.18 \text{ mL} = 162.18 \text{ cm}^3$

2. (0.2096)(1.42952 g/L) + (0.7811)(1.25092 g/L) + (0.00930)X = 1.000(1.29327 g/L)

   X = 1.78 g/L

3. Argon M = 39.948 u

   100 % – 0.337 % – 0.063 % = 99.600 %

   (0.00337)(35.967545 u) + (0.00063)(37.96732 u) +(0.99600)X = 39.948 u

   X = 39.963 u

4. $4.0 \text{ m} \cdot 5.0 \text{ m} \cdot 2.4 \text{ m} \cdot (1 \text{ L}/1.00 \times 10^{-3} \text{ m}^3) = 4.8 \times 10^4 \text{ L}$

   $4.8 \times 10^4 \text{ L} \cdot 1.78 \text{ g/L} \cdot 1 \text{ mol}/39.948 \text{ g} \cdot 6.022 \times 10^{23} \text{ atoms/mol} = 1.3 \times 10^{27} \text{ atoms}$