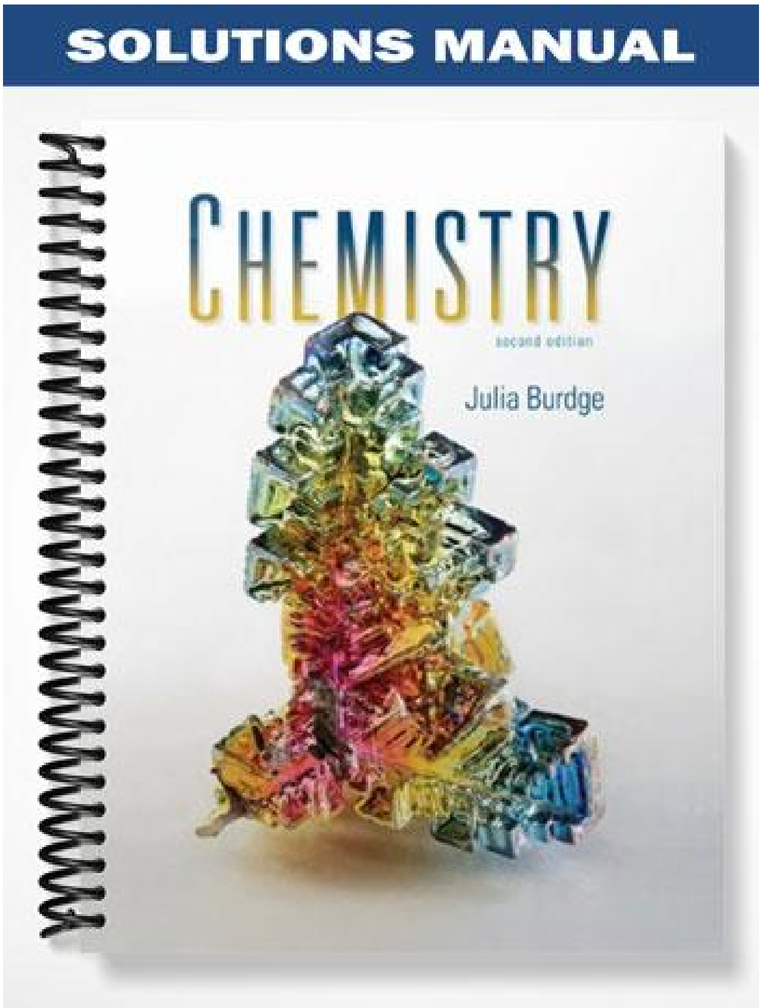
SOLUTIONS MANUAL
CHEMISTRY
second edition
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CHAPTER 2
ATOMS, MOLECULES, AND IONS

2.3 $$\frac{\text{ratio of N to O in compound 1}}{\text{ratio of N to O in compound 2}} = \frac{0.8756}{0.4378} \approx 2:1$$

2.4 $$\frac{\text{ratio of P to Cl in compound 1}}{\text{ratio of P to Cl in compound 2}} = \frac{0.2912}{0.1747} \approx 1.667 \approx 5:3$$

2.5 $$\frac{\text{ratio of F to S in } S_2F_{10}}{\text{ratio of F to S in } SF_4} = \frac{2.962}{2.370} \approx 1.250$$

$$\frac{\text{ratio of F to S in } SF_6}{\text{ratio of F to S in } SF_4} = \frac{3.555}{2.370} \approx 1.5$$

$$\frac{\text{ratio of F to S in } SF_4}{\text{ratio of F to S in } SF_4} = 1$$

ratio in SF_6 : ratio in S_2F_{10} : ratio in $SF_4 = 1.5:1.25:1$

Multiply through to get all whole numbers. $4\cdot(1.5:1.25:1) = 6:5:4$

2.6 $$\frac{\text{ratio of O to Fe in FeO}}{\text{ratio of O to Fe in } Fe_2O_3} = \frac{0.2865}{0.4297} \approx 0.667 \approx 2:3$$

2.7 $$\frac{\text{g blue: 1.00 g red (right)}}{\text{g blue: 1.00 g red (left)}} = \frac{2/3}{1/1} \approx 0.667 \approx 2:3$$

2.8 $$\frac{\text{g green: 1.00 g orange (right)}}{\text{g green: 1.00 g orange (left)}} = \frac{4/2}{3/1} \approx 0.667 \approx 2:3$$

2.14 First, convert 1 cm to picometers.

$$1\text{ cm} \times \frac{0.01\text{ m}}{1\text{ cm}} \times \frac{1\text{ pm}}{1\times10^{-12}\text{ m}} = 1\times10^{10}\text{ pm}$$

$$(1\times10^{10}\text{ pm}) \times \frac{1\text{ He atom}}{1\times10^{2}\text{ pm}} = \mathbf{1\times10^{8}\text{ He atoms}}$$

2.15 Note that you are given information to set up the conversion factor relating meters and miles.

$$\boldsymbol{r}_{\textbf{atom}} = 10^4 r_{\text{nucleus}} = 10^4 \times 2.0\text{ cm} \times \frac{1\text{ m}}{100\text{ cm}} \times \frac{1\text{ mi}}{1609\text{ m}} = \mathbf{0.12\text{ mi}}$$

2.20 For iron, the atomic number Z is 26. Therefore the mass number A is:

$$\boldsymbol{A} = 26 + 28 = \mathbf{54}$$

2.21 Strategy: The 239 in Pu-239 is the mass number. The **mass number (*A*)** is the total number of neutrons and protons present in the nucleus of an atom of an element. You can look up the atomic number (number of protons) on the periodic table.

Solution:

mass number = number of protons + number of neutrons

number of neutrons = mass number – number of protons = 239 – 94 = **145**

2.22

Isotope	$^{3}_{2}He$	$^{4}_{2}He$	$^{24}_{12}Mg$	$^{25}_{12}Mg$	$^{48}_{22}Ti$	$^{79}_{35}Br$	$^{195}_{78}Pt$
No. Protons	2	2	12	12	22	35	78
No. Neutrons	1	2	12	13	26	44	117

2.23

Isotope	$^{15}_{7}N$	$^{33}_{16}S$	$^{63}_{29}Cu$	$^{84}_{38}Sr$	$^{130}_{56}Ba$	$^{186}_{74}W$	$^{202}_{80}Hg$
No. Protons	7	16	29	38	56	74	80
No. Electrons	7	16	29	38	56	74	80
No. Neutrons	8	17	34	46	74	112	122

2.24 **(a)** $^{23}_{11}Na$ **(b)** $^{64}_{28}Ni$ **(c)** $^{115}_{50}Sn$ **(d)** $^{42}_{20}Ca$

2.25 The accepted way to denote the atomic number and mass number of an element X is $^{A}_{Z}X$
where ***A*** = mass number and ***Z*** = atomic number.

(a) $^{186}_{74}W$ **(b)** $^{201}_{80}Hg$ **(c)** $^{76}_{34}Se$ **(d)** $^{239}_{94}Pu$

2.26 **(a)** 10 **(b)** 26 **(c)** 81 **(d)** 196

2.27 **(a)** 19 **(b)** 34 **(c)** 75 **(d)** 192

2.28 ^{198}Au: 119 neutrons, ^{47}Ca: 27 neutrons, ^{60}Co: 33 neutrons, ^{18}F: 9 neutrons, ^{125}I: 72 neutrons, ^{131}I: 78 neutrons, ^{42}K: 23 neutrons, ^{43}K: 24 neutrons, ^{24}Na: 13 neutrons, ^{32}P: 17 neutrons, ^{85}Sr: 47 neutrons, ^{99}Tc: 56 neutrons.

2.34 Helium and Selenium are nonmetals whose name ends with *ium*. (Tellurium is a metalloid whose name ends in *ium*.)

2.35 **(a)** Metallic character increases as you progress down a group of the periodic table. For example, moving down Group 4A, the nonmetal carbon is at the top and the metal lead is at the bottom of the group.

(b) Metallic character decreases from the left side of the table (where the metals are located) to the right side of the table (where the nonmetals are located).

2.36 The following data were measured at 20°C.

(a) Li (0.53 g/cm^3) K (0.86 g/cm^3) H_2O (0.98 g/cm^3)

(b) Au (19.3 g/cm^3) Pt (21.4 g/cm^3) Hg (13.6 g/cm^3)

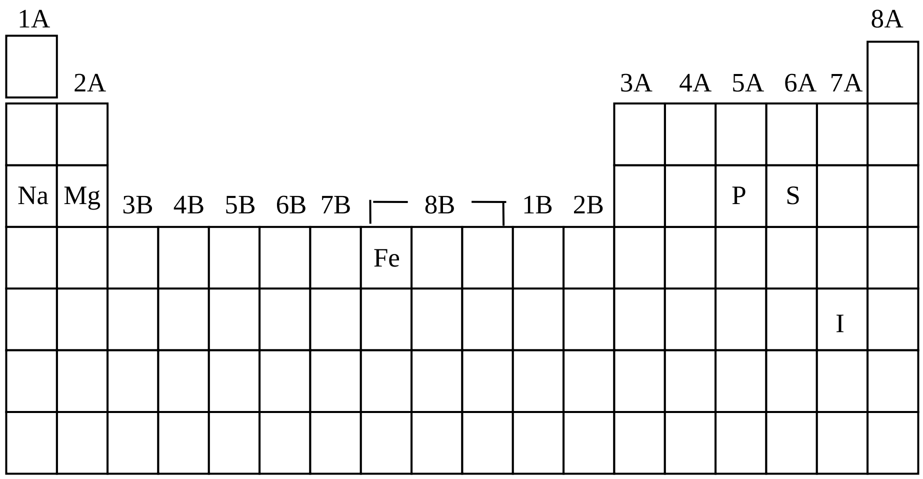
(c) Os (22.6 g/cm^3)

(d) Te (6.24 g/cm^3)

2.37 Na and K are both Group 1A elements; they should have similar chemical properties. N and P are both Group 5A elements; they should have similar chemical properties. F and Cl are Group 7A elements; they should have similar chemical properties.

2.38 I and Br (both in Group 7A), O and S (both in Group 6A), Ca and Ba (both in Group 2A)

2.39



Atomic number 26, iron, Fe, (present in hemoglobin for transporting oxygen)
Atomic number 53, iodine, I, (present in the thyroid gland)
Atomic number 11, sodium, Na, (present in intra- and extra-cellular fluids)
Atomic number 15, phosphorus, P, (present in bones and teeth)
Atomic number 16, sulfur, S, (present in proteins)
Atomic number 12, magnesium, Mg, (present in chlorophyll molecules)

2.44 (34.968 amu)(0.7553) + (36.956 amu)(0.2447) = **35.45 amu**

2.45 (203.973020 amu)(0.014) + (205.974440 amu)(0.241) +(206.975872 amu)(0.221) + (207.976627 amu)(0.524) = **207.2 amu**

2.46 The fractional abundances of the two isotopes of Tl must add to 1. Therefore, we can write

$$(202.972320 \text{ amu})(x) + (204.974401 \text{ amu})(1 - x) = 204.4 \text{ amu}$$

Solving for x gives 0.2869. Therefore, the natural abundances of ^{203}Tl and ^{205}Tl are **28.69%** and **71.31%**, respectively.

2.47 Strategy: Each isotope contributes to the average atomic mass based on its relative abundance. Multiplying the mass of an isotope by its fractional abundance (not percent) will give the contribution to the average atomic mass of that particular isotope.

It would seem that there are two unknowns in this problem, the fractional abundance of ^{6}Li and the fractional abundance of ^{7}Li. However, these two quantities are not independent of each other; they are related by the fact that they must sum to 1. Start by letting x be the fractional abundance of ^{6}Li. Since the sum of the two fractional abundances must be 1, we can write

$$(6.0151 \text{ amu})(x) + (7.0160 \text{ amu})(1 - x) = 6.941 \text{ amu}$$

Solution: Solving for x gives 0.075, which corresponds to the fractional abundance of ^{6}Li. The fractional abundance of ^{7}Li is $(1 - x) = 0.925$. Therefore, the natural abundances of ^{6}Li and ^{7}Li are **7.5%** and **92.5%**, respectively.

2.48 The conversion factor required is $\dfrac{6.022\times10^{23}\text{ amu}}{1\text{ g}}$

$$13.2\text{ amu} \times \frac{1\text{ g}}{6.022\times10^{23}\text{ amu}} = \mathbf{2.19 \times 10^{-23}\ g}$$

2.49 The conversion factor required is $\dfrac{6.022\times10^{23}\text{ amu}}{1\text{ g}}$

$$8.4\text{ g} \times \frac{6.022\times10^{23}\text{ amu}}{1\text{ g}} = \mathbf{5.1 \times 10^{24}\ amu}$$

2.59 **(a)** This is a polyatomic molecule that is an elemental form of the substance. It is not a compound.
(b) This is a polyatomic molecule that is a compound.
(c) This is a diatomic molecule that is a compound.

2.60 **(a)** This is a diatomic molecule that is a compound.
(b) This is a polyatomic molecule that is a compound.
(c) This is a polyatomic molecule that is the elemental form of the substance. It is not a compound.

2.61 **Elements:** N_2, S_8, H_2
Compounds: NH_3, NO, CO, CO_2, SO_2

2.62 There are more than two correct answers for each part of the problem.

(a) H_2 and F_2 **(b)** HCl and CO **(c)** S_8 and P_4
(d) H_2O and $C_{12}H_{22}O_{11}$ (sucrose)

2.63 Strategy: An *empirical formula* tells us which elements are present and the *simplest* whole-number ratio of their atoms. Can you divide the subscripts in the formula by a common factor to end up with smaller whole-number subscripts?

Solution:

(a) Dividing both subscripts by 2, the simplest whole number ratio of the atoms in C_2N_2 is **CN**.
(b) Dividing all subscripts by 6, the simplest whole number ratio of the atoms in C_6H_6 is **CH**.
(c) The molecular formula as written, $\mathbf{C_9H_{20}}$, contains the simplest whole number ratio of the atoms present. In this case, the molecular formula and the empirical formula are the same.
(d) Dividing all subscripts by 2, the simplest whole number ratio of the atoms in P_4O_{10} is $\mathbf{P_2O_5}$.
(e) Dividing all subscripts by 2, the simplest whole number ratio of the atoms in B_2H_6 is $\mathbf{BH_3}$.

2.64 **(a)** $AlBr_3$ **(b)** $NaSO_2$ **(c)** N_2O_5 **(d)** $K_2Cr_2O_7$ **(e)** HCO_2

2.65 $C_3H_7NO_2$

2.66 C_2H_6O (The formula for ethanol can also be written as C_2H_5OH or CH_3CH_2OH.)

2.67 **(a)** nitrogen trichloride **(b)** iodine heptafluoride **(c)** tetraphosphorus hexoxide
(d) disulfur dichloride

2.68 **(a)** PBr_3 **(b)** N_2F_4 **(c)** XeO_4 **(d)** SeO_3

2.69 All of these are molecular compounds. We use prefixes to express the number of each atom in the molecule. The molecular formulas and names are: **(a)** NF_3: nitrogen trifluoride **(b)** PBr_5: phosphorus pentabromide **(c)** SCl_2: sulfur dichloride

2.70 **(a)** OF_2: oxygen difluoride **(b)** Al_2Br_6: dialuminum hexabromide
(c) N_2F_4: dinitrogen tetrafluoride (also "perfluorohydrazine")

2.75 The **atomic number (*Z*)** is the number of protons in the nucleus of each atom of an element. You can find this on a periodic table. The number of **electrons** in an *ion* is equal to the number of protons minus the charge on the ion.

number of electrons (ion) = number of protons − charge on the ion

Ion	Na^+	Ca^{2+}	Al^{3+}	Fe^{2+}	I^-	F^-	S^{2-}	O^{2-}	N^{3-}
No. protons	11	20	13	26	53	9	16	8	7
No. electrons	10	18	10	24	54	10	18	10	10

2.76

Ion	K^+	Mg^{2+}	Fe^{3+}	Br^-	Mn^{2+}	C^{4-}	Cu^{2+}
No. protons	19	12	26	35	25	6	29
No. electrons	18	10	23	36	23	10	27

2.77 **(a)** Sodium ion has a +1 charge and oxide has a −2 charge. The correct formula is $\mathbf{Na_2O}$.
(b) The iron ion has a +2 charge and sulfide has a −2 charge. The correct formula is **FeS**.
(c) The correct formula is $\mathbf{Co_2(SO_4)_3}$.
(d) Barium ion has a +2 charge and fluoride has a −1 charge. The correct formula is $\mathbf{BaF_2}$.

2.78 **(a)** The copper ion has a +1 charge and bromide has a −1 charge. The correct formula is **CuBr**.
(b) The manganese ion has a +3 charge and oxide has a −2 charge. The correct formula is $\mathbf{Mn_2O_3}$.
(c) We have the Hg_2^{2+} ion and iodide (I^-). The correct formula is $\mathbf{Hg_2I_2}$.
(d) Magnesium ion has a +2 charge and phosphate has a −3 charge. The correct formula is $\mathbf{Mg_3(PO_4)_2}$.

2.79 Compounds of metals with nonmetals are usually ionic. Nonmetal-nonmetal compounds are usually molecular.

Ionic: LiF, $BaCl_2$, KCl

Molecular: $SiCl_4$, B_2H_6, C_2H_4

2.80 Compounds of metals with nonmetals are usually ionic. Nonmetal-nonmetal compounds are usually molecular.

Ionic: NaBr, BaF_2, CsCl.
Molecular: CH_4, CCl_4, ICl, NF_3

2.81 Strategy: When naming ionic compounds, our reference for the names of cations and anions are Tables 2.8 and 2.9 of the text. Keep in mind that if a metal can form cations of different charges, we need to use the Stock system. In the Stock system, Roman numerals are used to specify the charge of the cation. The metals that have only one charge in ionic compounds are the alkali metals (+1), the alkaline earth metals (+2), Ag^+, Zn^{2+}, Cd^{2+}, and Al^{3+}.

When naming acids, binary acids are named differently than oxoacids. For binary acids, the name is based on the nonmetal. For oxoacids, the name is based on the polyatomic anion. For more detail, see Section 2.7 of the text.

Solution:

(a) This is an ionic compound in which the metal cation (K^+) has only one charge. The correct name is **potassium dihydrogen phosphate**.

(b) This is an ionic compound in which the metal cation (K^+) has only one charge. The correct name is **potassium hydrogen phosphate**

(c) This is molecular compound. In the gas phase, the correct name is **hydrogen bromide**.

(d) The correct name of this compound in water is **hydrobromic acid**.

(e) This is an ionic compound in which the metal cation (Li^+) has only one charge. The correct name is **lithium carbonate**.

(f) This is an ionic compound in which the metal cation (K^+) has only one charge. The correct name is **potassium dichromate**.

(g) This is an ionic compound in which the cation is a polyatomic ion with a charge of +1. The anion is an oxoanion with one less O atom than the corresponding –ate ion (nitrate). The correct name is **ammonium nitrite**.

(h) The oxoanion in this acid is analogous to the chlorate ion. The correct name of this compound is **hydrogen iodate (in water, iodic acid)**

(i) This is a molecular compound. We use a prefix to denote how many F atoms it contains. The correct name is **phosphorus pentafluoride**.

(j) This is a molecular compound. We use prefixes to denote the numbers of both types of atom. The correct name is **tetraphosphorus hexoxide**.

(k) This is an ionic compound in which the metal cation (Cd^{2+}) has only one charge. The correct name is **cadmium iodide**.

(l) This is an ionic compound in which the metal cation (Sr^{2+}) has only one charge. The correct name is **strontium sulfate**.

(m) This is an ionic compound in which the metal cation (Al^{3+}) has only one charge. The correct name is **aluminum hydroxide**.

2.82

(a) potassium hypochlorite
(b) silver carbonate
(c) nitrous acid
(d) potassium permanganate
(e) cesium chlorate
(f) potassium ammonium sulfate
(g) iron(II) oxide
(h) iron(III) oxide
(i) titanium(IV) chloride
(j) sodium hydride
(k) lithium nitride
(l) sodium oxide
(m) sodium peroxide

2.83 Strategy: When writing formulas of molecular compounds, the prefixes specify the number of each type of atom in the compound.

When writing formulas of ionic compounds, the subscript of the cation is numerically equal to the charge of the anion, and the subscript of the anion is numerically equal to the charge on the cation. If the charges of the cation and anion are numerically equal, then no subscripts are necessary. Charges of common cations and anions are listed in Tables 2.8 and 2.9 of the text. Keep in mind that Roman numerals specify the charge of the cation, *not* the number of metal atoms. Remember that a Roman numeral is not needed for some metal cations, because the charge is known. These metals are the alkali metals (+1), the alkaline earth metals (+2), Ag^+, Zn^{2+}, Cd^{2+}, and Al^{3+}.

When writing formulas of oxoacids, you must know the names and formulas of polyatomic anions (see Table 2.9 of the text).

Solution:

(a) Rubidium is an alkali metal. It only forms a +1 cation. The polyatomic ion nitrite, NO_2^-, has a −1 charge. Because the charges on the cation and anion are numerically equal, the ions combine in a one-to-one ratio. The correct formula is **$RbNO_2$**.

(b) Potassium is an alkali metal. It only forms a +1 cation. The anion, sulfide, has a charge of −2. Because the charges on the cation and anion are numerically different, the subscript of the cation is numerically equal to the charge on the anion, and the subscript of the anion is numerically equal to the charge on the cation. The correct formula is **K_2S**.

(c) Sodium is an alkali metal. It only forms a +1 cation. The anion is the *hydrogen sulfide* ion (the sulfide ion plus one hydrogen), HS^-. Because the charges are numerically the same, the ions combine in a one-to-one ratio.The correct formula is **NaHS**.

(d) Magnesium is an alkaline earth metal. It only forms a +2 cation. The polyatomic phosphate anion has a charge of −3, PO_4^{3-}. Because the charges on the cation and anion are numerically different, the subscript of the cation is numerically equal to the charge on the anion, and the subscript of the anion is numerically equal to the charge on the cation. The correct formula is **$Mg_3(PO_4)_2$**. Note that for its subscript to be changed, a polyatomic ion must be enclosed in parentheses.

(e) Calcium is an alkaline earth metal. It only forms a +2 cation. The polyatomic ion hydrogen phosphate, HPO_4^{2-}, has a −2 charge. Because the charges are numerically the same, the ions combine in a one-to-one ratio. The correct formula is **$CaHPO_4$**.

(f) Lead (II), Pb^{2+}, is a cation with a charge +2. The polyatomic ion carbonate, CO_3^{2-}, has a −2 charge. Because the charges on the cation and anion are numerically equal, the ions combine in a one-to-one ratio. The correct formula is **$PbCO_3$.**

(g) Tin (II), Sn^{2+}, is a cation with a charge of +2. The anion, fluoride, has a change of −1. Because the charges on the cation and anion are numerically different, the subscript of the cation is numerically equal to the charge on the anion, and the subscript of the anion is numerically equal to the charge on the cation. The correct formula is **SnF_2**.

(h) The polyatomic ion ammonium, NH_4^+, has a +1 charge and the polyatomic ion sulfate, SO_4^{2-}, has a −2 charge. To balance the charge, we need 2 NH_4^+ cations. The correct formula is **$(NH_4)_2SO_4$**.

(i) Silver forms only a +1 ion. The perchlorate ion, ClO_4^-, has a charge of −1. Because the charges are numerically the same, the ions combine in a one-to-one ratio. The correct formula is **$AgClO_4$**.

(j) This is a molecular compound. The Greek prefixes tell you the number of each type of atom in the molecule: no prefix indicates 1 and tri- indicates 3. The correct formula is **BCl_3**.

2.84 **(a)** CuCN **(b)** $Sr(ClO_2)_2$ **(c)** $HBrO_4(aq)$ **(d)** HI(*aq*) **(e)** $Na_2(NH_4)PO_4$ **(f)** KH_2PO_4 **(g)** IF_7 **(h)** P_4S_{10} **(i)** HgO **(j)** Hg_2I_2 **(k)** SeF_6

2.85 **(a)** $Mg(NO_3)_2$ **(b)** Al_2O_3 **(c)** LiH **(d)** Na_2S

2.86 **(a)** one green sphere, one red sphere **(b)** one green sphere, two red spheres **(c)** three green spheres, two red spheres **(d)** two green spheres, one red sphere

2.87 acid: compound that produces H^+; base: compound that produces OH^-; oxoacids: acids that contain oxygen; oxoanions: the anions that remain when oxoacids lose H^+ ions; hydrates: ionic solids that have water molecules in their formulas.

2.88 Uranium is radioactive. It loses mass because it constantly emits alpha (α) particles.

2.89 **(c)** Changing the electrical charge of an atom usually has a major effect on its chemical properties. The two electrically neutral carbon isotopes should have nearly identical chemical properties.

2.90 The number of protons = 65 − 35 = 30. The element that contains 30 protons is zinc, Zn. There are two fewer electrons than protons, so the charge of the cation is +2. The symbol for this cation is **Zn^{2+}**.

2.91 Atomic number = 127 − 74 = 53. This anion has 53 protons, so it is an iodide ion. Since there is one more electron than protons, the ion has a −1 charge. The correct symbol is **I^-**.

2.92 **(a)** Species with the same number of protons and electrons will be neutral. **A, F, G**.
(b) Species with more electrons than protons will have a negative charge. **B, E**.
(c) Species with more protons than electrons will have a positive charge. **C, D**.
(d) **A**: ${}^{10}_{5}B$ **B**: ${}^{14}_{7}N^{3-}$ **C**: ${}^{39}_{19}K^+$ **D**: ${}^{66}_{30}Zn^{2+}$ **E**: ${}^{81}_{35}Br^-$ **F**: ${}^{11}_{5}B$ **G**: ${}^{19}_{9}F$

2.93 NaCl is an ionic compound; it doesn't consist of molecules.

2.94 **Yes**. The law of multiple proportions requires that the masses of sulfur combining with phosphorus must be in the ratios of small whole numbers. For the three compounds shown, four phosphorus atoms combine with three, seven, and ten sulfur atoms, respectively. If the atom ratios are in small whole number ratios, then the mass ratios must also be in small whole number ratios.

2.95 The species and their identification are as follows:

(a)	SO_2	molecule and compound	**(g)**	O_3	element and molecule
(b)	S_8	element and molecule	**(h)**	CH_4	molecule and compound
(c)	Cs	element	**(i)**	KBr	compound, not molecule
(d)	N_2O_5	molecule and compound	**(j)**	S	element
(e)	O	element	**(k)**	P_4	element and molecule

(f) O_2 element and molecule **(l)** LiF compound, not molecule

2.96 **(a)** This is an ionic compound. Prefixes are *not* used. The correct name is barium chloride.
(b) Iron has a +3 charge in this compound. The correct name is iron(III) oxide.
(c) NO_2^- is the nitrite ion. The correct name is cesium nitrite.
(d) Magnesium is an alkaline earth metal, which always has a +2 charge in ionic compounds. The roman numeral is not necessary. The correct name is magnesium bicarbonate.

2.97 All masses are relative, which means that the mass of every object is compared to the mass of a standard object (such as the piece of metal in Paris called the "standard kilogram"). The mass of the standard object is determined by an international committee, and that mass is an arbitrary number to which everyone in the scientific community agrees.

Atoms are so small it is hard to compare their masses to the standard kilogram. Instead, we compare atomic masses to the mass of one specific atom. In the 19th century the atom was ^{1}H, and for a good part of the 20th century it was ^{16}O. Now it is ^{12}C, which is given the arbitrary mass of 12 amu exactly. All other isotopic masses (and therefore average atomic masses) are measured relative to the assigned mass of ^{12}C.

2.98 **(a)** Ammonium is NH_4^+, not NH_3^+. The formula should be **$(NH_4)_2CO_3$**.
(b) Calcium has a +2 charge and hydroxide has a −1 charge. The formula should be **$Ca(OH)_2$**.
(c) Sulfide is S^{2-}, not SO_3^{2-}. The correct formula is **CdS**.
(d) Dichromate is $Cr_2O_7^{2-}$, not $Cr_2O_4^{2-}$. The correct formula is **$ZnCr_2O_7$**.

2.99

Symbol	$^{11}_{5}B$	$^{54}_{26}Fe^{2+}$	$^{31}_{15}P^{3-}$	$^{196}_{79}Au$	$^{222}_{86}Rn$
Protons	5	26	15	79	86
Neutrons	6	28	16	117	136
Electrons	5	24	18	79	86
Net Charge	0	+2	−3	0	0

2.100 **(a)** Ionic compounds are typically formed between metallic and nonmetallic elements.
(b) In general the transition metals, the actinides and lanthanides have variable charges.

2.101 **(a)** Li^+, alkali metals always have a +1 charge in ionic compounds
(b) S^{2-}
(c) I^-, halogens have a −1 charge in ionic compounds
(d) N^{3-}
(e) Al^{3+}, aluminum always has a +3 charge in ionic compounds
(f) Cs^+, alkali metals always have a +1 charge in ionic compounds
(g) Mg^{2+}, alkaline earth metals always have a +2 charge in ionic compounds.

2.102 The symbol ^{23}Na provides more information than $_{11}Na$. The mass number plus the chemical symbol identifies a specific isotope of Na (sodium) while combining the atomic number with the chemical symbol tells you nothing new. Can other isotopes of sodium have different atomic numbers?

2.103 The binary Group 7A element acids are: HF, hydrofluoric acid; HCl, hydrochloric acid; HBr, hydrobromic acid; HI, hydroiodic acid. Oxoacids containing Group 7A elements (using the specific examples for chlorine) are: $HClO_4$, perchloric acid; $HClO_3$, chloric acid; $HClO_2$, chlorous acid: HClO, hypochlorous acid.

Examples of oxoacids containing other Group A-block elements are: H_3BO_3, boric acid (Group 3A); H_2CO_3, carbonic acid (Group 4A); HNO_3, nitric acid and H_3PO_4, phosphoric acid (Group 5A); and H_2SO_4, sulfuric acid (Group 6A). Hydrosulfuric acid, H_2S, is an example of a binary Group 6A acid while HCN, hydrocyanic acid, contains both a Group 4A and 5A element.

2.104 **(a)** C_2H_2, CH. **(b)** C_6H_6, CH. **(c)** C_2H_6, CH_3. **(d)** C_3H_8, C_3H_8.

2.105 **(a)**

Isotope	$^{4}_{2}He$	$^{20}_{10}Ne$	$^{40}_{18}Ar$	$^{84}_{36}Kr$	$^{132}_{54}Xe$
No. Protons	2	10	18	36	54
No. Neutrons	2	10	22	48	78

(b)

neutron/proton ratio	1.00	1.00	1.22	1.33	1.44

The neutron/proton ratio increases with increasing atomic number.

2.106 H_2, N_2, O_2, F_2, Cl_2, He, Ne, Ar, Kr, Xe, Rn

2.107 Cu, Ag, and Au are fairly chemically unreactive. This makes them especially suitable for making coins and jewelry that you want to last a very long time.

2.108 They generally do not react with other elements. Helium, neon, and argon are chemically inert.

2.109 Magnesium and strontium are also alkaline earth metals. You should expect the charge of the metal to be the same (+2). **MgO** and **SrO**.

2.110 All isotopes of radium are radioactive. It is a radioactive decay product of uranium-238. Radium itself does *not* occur naturally on Earth.

2.111 **(a)** Berkelium (Berkeley, CA); Europium (Europe); Francium (France); Scandium (Scandinavia); Ytterbium (Ytterby, Sweden); Yttrium (Ytterby, Sweden).
(b) Einsteinium (Albert Einstein); Fermium (Enrico Fermi); Curium (Marie and Pierre Curie); Mendelevium (Dmitri Mendeleev); Lawrencium (Ernest Lawrence), Meitnerium (Lise Meitner).
(c) Arsenic, Cesium, Chlorine, Chromium, Iodine.

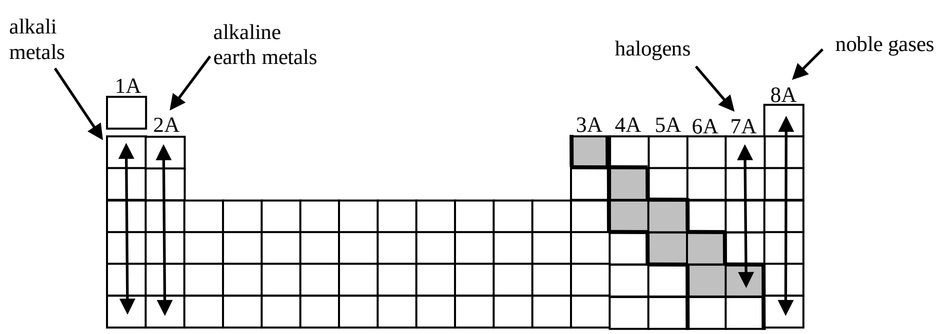
2.112 Argentina is named after silver (argentum, Ag).

2.113 The mass of fluorine reacting with hydrogen and deuterium would be the same. The ratio of F atoms to hydrogen (or deuterium) atoms is 1:1 in both compounds. This does not violate the law of definite proportions. When the law of definite proportions was formulated, scientists did not know of the existence of isotopes.

2.114 **(a)** NaH, sodium hydride **(b)** B_2O_3, diboron trioxide **(c)** Na_2S, sodium sulfide
(d) AlF_3, aluminum fluoride **(e)** OF_2, oxygen difluoride **(f)** $SrCl_2$, strontium chloride

2.115 **(a)** Br **(b)** Rn **(c)** Se **(d)** Rb **(e)** Pb

2.116



The metalloids are shown in gray.

2.117

Cation	Anion	Formula	Name
$\mathbf{Mg^{2+}}$	$\mathbf{HCO_3^-}$	$\mathbf{Mg(HCO_3)_2}$	Magnesium bicarbonate
$\mathbf{Sr^{2+}}$	$\mathbf{Cl^-}$	$SrCl_2$	**Strontium chloride**
Fe^{3+}	NO_2^-	$\mathbf{Fe(NO_2)_3}$	**Iron(III) nitrite**
$\mathbf{Mn^{2+}}$	$\mathbf{ClO_3^-}$	$\mathbf{Mn(ClO_3)_2}$	Manganese(II) chlorate
$\mathbf{Sn^{4+}}$	$\mathbf{Br^-}$	$SnBr_4$	**Tin(IV) bromide**
Co^{2+}	PO_4^{3-}	$\mathbf{Co_3(PO_4)_2}$	**Cobalt(II) phosphate**
Hg_2^{2+}	I^-	$\mathbf{Hg_2I_2}$	**Mercury(I) iodide**
$\mathbf{Cu^+}$	$\mathbf{CO_3^{2-}}$	Cu_2CO_3	**Copper(I) carbonate**
$\mathbf{Li^+}$	$\mathbf{N^{3-}}$	$\mathbf{Li_3N}$	Lithium nitride
Al^{3+}	S^{2-}	$\mathbf{Al_2S_3}$	**Aluminum sulfide**

2.118 **(a)** $CO_2(s)$
(b) NaCl
(c) N_2O
(d) $CaCO_3$
(e) $NaHCO_3$
(f) NH_3
(g) H_2O
(h) $Mg(OH)_2$
(i) $MgSO_4{\cdot}7H_2O$

2.119 The change in energy is equal to the energy released. We call this ΔE. Similarly, Δm is the change in mass. Because $m = \dfrac{E}{c^2}$, we have

$$\Delta m = \frac{\Delta E}{c^2} = \frac{(1.715\times10^3\ \text{kJ})\left(\dfrac{1000\ \text{J}}{1\ \text{kJ}}\right)}{(2.998\times10^8\ \text{m/s})^2} = 1.908\times10^{-11}\ \text{kg} = \mathbf{1.908\times10^{-8}\ g}$$

Note that we need to convert kJ to J so that we end up with units of kg for the mass. $\left(1\ \text{J} = \dfrac{1\ \text{kg}\cdot\text{m}^2}{\text{s}^2}\right)$

We can add together the masses of hydrogen and oxygen to calculate the mass of water that should be formed.

$$12.096\ \text{g} + 96.000 = 108.096\ \text{g}$$

The predicted change (loss) in mass is only 1.908×10^{-8} g which is too small a quantity to measure. Therefore, for all practical purposes, the law of conservation of mass is assumed to hold for ordinary chemical processes.

2.120 **(a)** Rutherford's experiment is described in detail in Section 2.2 of the text. From the average magnitude of scattering, Rutherford estimated the number of protons (based on electrostatic interactions) in the nucleus.

(b) Assuming that the nucleus is spherical, the volume of the nucleus is:

$$V = \frac{4}{3}\pi r^3 = \frac{4}{3}\pi(3.04 \times 10^{-13}\ \text{cm})^3 = 1.177 \times 10^{-37}\ \text{cm}^3$$

The density of the nucleus can now be calculated.

$$\boldsymbol{d} = \frac{m}{V} = \frac{3.82 \times 10^{-23}\ \text{g}}{1.177 \times 10^{-37}\ \text{cm}^3} = \mathbf{3.25 \times 10^{14}\ g / cm^3}$$

To calculate the density of the space occupied by the electrons, we need both the mass of 11 electrons, and the volume occupied by these electrons.

The mass of 11 electrons is:

$$11\ \text{electrons} \times \frac{9.1094 \times 10^{-28}\ \text{g}}{1\ \text{electron}} = 1.00203 \times 10^{-26}\ \text{g}$$

The volume occupied by the electrons will be the difference between the volume of the atom and the volume of the nucleus. The volume of the nucleus was calculated above. The volume of the atom is calculated as follows:

$$186\ \text{pm} \times \frac{1 \times 10^{-12}\ \text{m}}{1\ \text{pm}} \times \frac{1\ \text{cm}}{1 \times 10^{-2}\ \text{m}} = 1.86 \times 10^{-8}\ \text{cm}$$

$$V_{\text{atom}} = \frac{4}{3}\pi r^3 = \frac{4}{3}\pi(1.86 \times 10^{-8}\ \text{cm})^3 = 2.695 \times 10^{-23}\ \text{cm}^3$$

$$V_{\text{electrons}} = V_{\text{atom}} - V_{\text{nucleus}} = (2.695 \times 10^{-23}\ \text{cm}^3) - (1.177 \times 10^{-37}\ \text{cm}^3) = 2.695 \times 10^{-23}\ \text{cm}^3$$

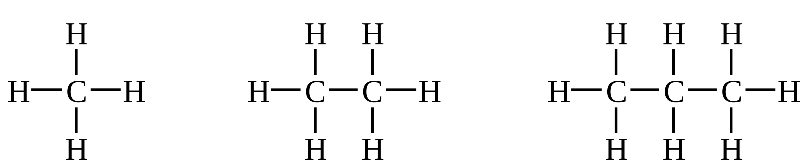
As you can see, the volume occupied by the nucleus is insignificant compared to the space occupied by the electrons.

The density of the space occupied by the electrons can now be calculated.

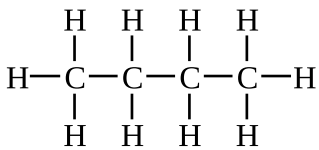
$$\boldsymbol{d} = \frac{m}{V} = \frac{1.00203 \times 10^{-26}\ \text{g}}{2.695 \times 10^{-23}\ \text{cm}^3} = \mathbf{3.72 \times 10^{-4}\ g / cm^3}$$

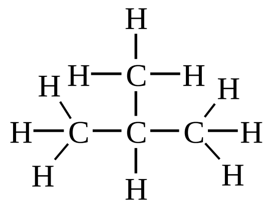
The above results do support Rutherford's model. Comparing the space occupied by the electrons to the volume of the nucleus, it is clear that most of the atom is empty space. Rutherford also proposed that the nucleus was a *dense* central core with most of the mass of the atom concentrated in it. Comparing the density of the nucleus with the density of the space occupied by the electrons also supports Rutherford's model.

2.121 CH_4, C_2H_6, and C_3H_8 each only have one structural formula.

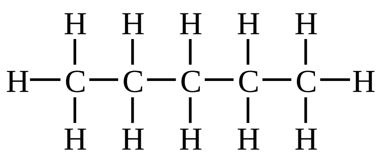


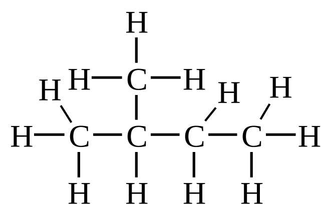
C_4H_{10} has two structural formulas.

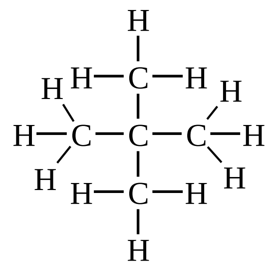




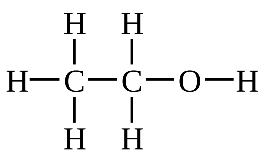
C_5H_{12} has three structural formulas.

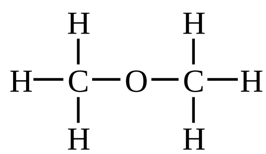






2.122 Two different structural formulas for the molecular formula C_2H_6O are:





The second hypothesis of Dalton's Atomic Theory states that compounds are composed of atoms of more than one element, and in any given compound, the same types of atoms are always present in the same relative numbers. Both of the above compounds are consistent with the second hypothesis.

2.123 **(a)**

Ethane	Acetylene
2.65 g C	4.56 g C
0.665 g H	0.383 g H

Let's compare the ratio of the hydrogen masses in the two compounds. To do this, we need to start with the same mass of carbon. If we were to start with 4.56 g of C in ethane, how much hydrogen would combine with 4.56 g of carbon?

$$0.665 \text{ g H} \times \frac{4.56 \text{ g C}}{2.65 \text{ g C}} = 1.14 \text{ g H}$$

We can calculate the ratio of H in the two compounds.

$$\frac{1.14 \text{ g}}{0.383 \text{ g}} \approx 3$$

This is consistent with the Law of Multiple Proportions which states that if two elements combine to form more than one compound, the masses of one element that combine with a fixed mass of the other element are in ratios of small whole numbers. In this case, the ratio of the masses of hydrogen in the two compounds is 3:1.

(b) For a given amount of carbon, there is 3 times the amount of hydrogen in ethane compared to acetylene. Reasonable formulas would be:

Ethane	Acetylene
CH_3	CH

C_2H_6 $\quad\quad$ C_2H_2

2.124 **(a)** The following strategy can be used to convert from the volume of the Pt cube to the number of Pt atoms.

$$\text{cm}^3 \rightarrow \text{grams} \rightarrow \text{atoms}$$

$$1.0\ \text{cm}^3 \times \frac{21.45\ \text{g Pt}}{1\ \text{cm}^3} \times \frac{1\ \text{atom Pt}}{3.240 \times 10^{-22}\ \text{g Pt}} = \mathbf{6.6 \times 10^{22}\ Pt\ atoms}$$

(b) Since 74 percent of the available space is taken up by Pt atoms, 6.6×10^{22} atoms occupy the following volume:

$$0.74 \times 1.0\ \text{cm}^3 = 0.74\ \text{cm}^3$$

We are trying to calculate the radius of a single Pt atom, so we need the volume occupied by a single Pt atom.

$$\text{volume Pt atom} = \frac{0.74\ \text{cm}^3}{6.6 \times 10^{22}\ \text{Pt atoms}} = 1.12 \times 10^{-23}\ \text{cm}^3/\text{Pt atom}$$

The volume of a sphere is $\frac{4}{3}\pi r^3$. Solving for the radius:

$$V = 1.12 \times 10^{-23}\ \text{cm}^3 = \frac{4}{3}\pi r^3$$

$$r^3 = 2.67 \times 10^{-24}\ \text{cm}^3$$

$$r = 1.4 \times 10^{-8}\ \text{cm}$$

Converting to picometers:

$$\textbf{radius Pt atom} = (1.4 \times 10^{-8}\ \text{cm}) \times \frac{0.01\ \text{m}}{1\ \text{cm}} \times \frac{1\ \text{pm}}{1 \times 10^{-12}\ \text{m}} = \mathbf{1.4 \times 10^2\ pm}$$

2.125 The mass number is the sum of the number of protons and neutrons in the nucleus.

$$\text{Mass number} = \text{number of protons} + \text{number of neutrons}$$

Let the atomic number (number of protons) equal A. The number of neutrons will be $1.2A$. Plug into the above equation and solve for A.

$$55 = A + 1.2A$$
$$A = 25$$

The element with atomic number 25 is **manganese**, **Mn**.

2.126

S	N
B	I

2.127 The acids, from left to right, are chloric acid, nitrous acid, hydrocyanic acid, and sulfuric acid.

2.128 **(a)** Assume that the nucleons (protons and neutrons) are hard objects of fixed size. Then the volume of the nucleus is well-approximated by the direct proportion $V = kA$, where A is the number of nucleons (mass number of the atom). For a spherical nucleus, then $V = kA = \frac{4}{3}\pi r^3$. Solving for r:

$$kA = \frac{4}{3}\pi r^3$$

$$\left(\frac{3}{4\pi}\right)kA = r^3$$

$$\left[\left(\frac{3}{4\pi}\right)kA\right]^{1/3} = r$$

$$\left[\left(\frac{3}{4\pi}\right)k\right]^{1/3}\left(A^{1/3}\right) = r$$

$$cA^{1/3} = r \quad (c \text{ is a constant})$$

(b) For the volume calculation, use lithium-7 (A = 7).

$$V = \frac{4}{3}\pi r^3 = \frac{4}{3}\pi\left(r_0 A^{1/3}\right)^3 = \left(\frac{4}{3}\pi r_0^3\right)(A) = \left[\frac{4}{3}\pi\left(1.2\times10^{-15}\text{ m}\right)^3\right](7) \approx 5.1\times10^{-44}\text{ m}^3$$

(c) Use r = 152 pm = 152 × 10^{-12} m for the atomic radius. Then, the atomic volume of lithium-7 is:

$$V = \frac{4}{3}\pi r^3 = \frac{4}{3}\pi\left(152\times10^{-12}\text{ m}\right)^3 \approx 1.5\times10^{-29}\text{ m}^3$$

The fraction of the atomic radius occupied by the nucleus is $\frac{5.1\times10^{-44}}{1.5\times10^{-29}} \approx 3.4\times10^{-15}$. This is consistent with Rutherford's discovery that the nucleus occupies a very small region within the atom.