

CHAPTER 2

ATOMS, MOLECULES, AND IONS

2.7 First, convert 1 cm to picometers.

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

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

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

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

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

$$A = 26 + 28 = 54$$

2.14 **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:

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

$$\text{number of neutrons} = \text{mass number} - \text{number of protons} = 239 - 94 = 145$$

2.15	Isotope	${}^3_2\text{He}$	${}^4_2\text{He}$	${}^{24}_{12}\text{Mg}$	${}^{25}_{12}\text{Mg}$	${}^{48}_{22}\text{Ti}$	${}^{79}_{35}\text{Br}$	${}^{195}_{78}\text{Pt}$
	No. Protons	2	2	12	12	22	35	78
	No. Neutrons	1	2	12	13	26	44	117

2.16	Isotope	${}^{15}_7\text{N}$	${}^{33}_{16}\text{S}$	${}^{63}_{29}\text{Cu}$	${}^{84}_{38}\text{Sr}$	${}^{130}_{56}\text{Ba}$	${}^{186}_{74}\text{W}$	${}^{202}_{80}\text{Hg}$
	No. Protons	7	16	29	38	56	74	80
	No. Neutrons	8	17	34	46	74	112	122
	No. Electrons	7	16	29	38	56	74	80

2.17 (a) ${}^{23}_{11}\text{Na}$ (b) ${}^{64}_{28}\text{Ni}$

2.18 The accepted way to denote the atomic number and mass number of an element X is as follows:



where,

A = mass number

Z = atomic number



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

2.24 (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).

2.25 The following data were measured at 20°C.

(a) Li (0.53 g/cm³) K (0.86 g/cm³) H₂O (0.98 g/cm³)

(b) Au (19.3 g/cm³) Pt (21.4 g/cm³) Hg (13.6 g/cm³)

(c) Os (22.6 g/cm³)

(d) Te (6.24 g/cm³)

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

2.31 (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.

2.32 (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.

2.33 **Elements:** N₂, S₈, H₂

Compounds: NH₃, NO, CO, CO₂, SO₂

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

(a) H₂ and F₂ (b) HCl and CO (c) S₈ and P₄

(d) H₂O and C₁₂H₂₂O₁₁ (sucrose)

2.35	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

2.36 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.

$$\text{number of electrons (ion)} = \text{number of protons} - \text{charge on the ion}$$

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

- 2.43 (a) Sodium ion has a +1 charge and oxide has a -2 charge. The correct formula is 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 $Co_2(SO_4)_3$.
 (d) Barium ion has a +2 charge and fluoride has a -1 charge. The correct formula is BaF_2 .
- 2.44 (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 Mn_2O_3 .
 (c) We have the Hg_2^{2+} ion and iodide (I^-). The correct formula is Hg_2I_2 .
 (d) Magnesium ion has a +2 charge and phosphate has a -3 charge. The correct formula is $Mg_3(PO_4)_2$.
- 2.45 (a) CN (b) CH (c) C_9H_{20} (d) P_2O_5 (e) BH_3
- 2.46 **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 some 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 Al_2Br_6 is **$AlBr_3$** .
 (b) Dividing all subscripts by 2, the simplest whole number ratio of the atoms in $Na_2S_2O_4$ is **$NaSO_2$** .
 (c) The molecular formula as written, **N_2O_5** , contains the simplest whole number ratio of the atoms present. In this case, the molecular formula and the empirical formula are the same.
 (d) The molecular formula as written, **$K_2Cr_2O_7$** , contains the simplest whole number ratio of the atoms present. In this case, the molecular formula and the empirical formula are the same.
- 2.47 The molecular formula of glycine is **$C_2H_5NO_2$** .
- 2.48 The molecular formula of ethanol is **C_2H_6O** .
- 2.49 Compounds of metals with nonmetals are usually ionic. Nonmetal-nonmetal compounds are usually molecular.
- Ionic:** $LiF, BaCl_2, KCl$
Molecular: $SiCl_4, B_2H_6, C_2H_4$
- 2.50 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

- 2.57
- | | |
|---|------------------------------|
| (a) potassium dihydrogen phosphate | (h) iodic acid |
| (b) potassium hydrogen phosphate | (i) phosphorus pentafluoride |
| (c) hydrogen bromide (molecular compound) | (j) tetraphosphorus hexoxide |
| (d) hydrobromic acid | (k) cadmium iodide |
| (e) lithium carbonate | (l) strontium sulfate |
| (f) potassium dichromate | (m) aluminum hydroxide |
| (g) ammonium nitrite | |

- 2.58 **Strategy:** When naming ionic compounds, our reference for the names of cations and anions is Table 2.3 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 hypochlorite**. Hypochlorite is a polyatomic ion with one less O atom than the chlorite ion, ClO_2^- .
- (b) **silver carbonate**
- (c) This is an oxoacid that contains the nitrite ion, NO_2^- . The “-ite” suffix is changed to “-ous”. The correct name is **nitrous acid**.
- (d) **potassium permanganate** (e) **cesium chlorate** (f) **potassium ammonium sulfate**
- (g) This is an ionic compound in which the metal can form more than one cation. Use a Roman numeral to specify the charge of the Fe ion. Since the oxide ion has a -2 charge, the Fe ion has a $+2$ charge. The correct name is **iron(II) oxide**.
- (h) **iron(III) oxide**
- (i) This is an ionic compound in which the metal can form more than one cation. Use a Roman numeral to specify the charge of the Ti ion. Since each of the four chloride ions has a -1 charge (total of -4), the Ti ion has a $+4$ charge. The correct name is **titanium(IV) chloride**.
- (j) **sodium hydride** (k) **lithium nitride** (l) **sodium oxide**
- (m) This is an ionic compound in which the metal cation (Na^+) has only one charge. The O_2^{2-} ion is called the peroxide ion. Each oxygen has a -1 charge. You can determine that each oxygen only has a -1 charge, because each of the two Na ions has a $+1$ charge. Compare this to sodium oxide in part (l). The correct name is **sodium peroxide**.
- 2.59
- | | | | | |
|------------------------------|--------------------------|----------------------------------|----------------------------------|----------------------|
| (a) RbNO_2 | (b) K_2S | (c) NaHS | (d) $\text{Mg}_3(\text{PO}_4)_2$ | (e) CaHPO_4 |
| (f) KH_2PO_4 | (g) IF_7 | (h) $(\text{NH}_4)_2\text{SO}_4$ | (i) AgClO_4 | (j) BCl_3 |

- 2.60 **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 Table 2.3 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 2.3 of the text).

Solution:

- (a) The Roman numeral I tells you that the Cu cation has a +1 charge. Cyanide has a -1 charge. Since, the charges are numerically equal, no subscripts are necessary in the formula. The correct formula is **CuCN**.
- (b) Strontium is an alkaline earth metal. It only forms a +2 cation. The polyatomic ion chlorite, ClO_2^- , has a -1 charge. Since 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 **Sr(ClO₂)₂**.
- (c) Perbromic tells you that the anion of this oxoacid is perbromate, BrO_4^- . The correct formula is **HBrO₄(aq)**. Remember that (aq) means that the substance is dissolved in water.
- (d) Hydroiodic tells you that the anion of this binary acid is iodide, I^- . The correct formula is **HI(aq)**.
- (e) Na is an alkali metal. It only forms a +1 cation. The polyatomic ion ammonium, NH_4^+ , has a +1 charge and the polyatomic ion phosphate, PO_4^{3-} , has a -3 charge. To balance the charge, you need 2 Na^+ cations. The correct formula is **Na₂(NH₄)PO₄**.
- (f) The Roman numeral II tells you that the Pb cation has a +2 charge. The polyatomic ion carbonate, CO_3^{2-} , has a -2 charge. Since, the charges are numerically equal, no subscripts are necessary in the formula. The correct formula is **PbCO₃**.
- (g) The Roman numeral II tells you that the Sn cation has a +2 charge. Fluoride has a -1 charge. Since 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 **SnF₂**.
- (h) This is a molecular compound. The Greek prefixes tell you the number of each type of atom in the molecule. The correct formula is **P₄S₁₀**.
- (i) The Roman numeral II tells you that the Hg cation has a +2 charge. Oxide has a -2 charge. Since, the charges are numerically equal, no subscripts are necessary in the formula. The correct formula is **HgO**.
- (j) The Roman numeral I tells you that the Hg cation has a +1 charge. However, this cation exists as Hg_2^{2+} . Iodide has a -1 charge. You need two iodide ion to balance the +2 charge of Hg_2^{2+} . The correct formula is **Hg₂I₂**.
- (k) This is a molecular compound. The Greek prefixes tell you the number of each type of atom in the molecule. The correct formula is **SeF₆**.

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

2.62 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.

2.63 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 **Zn²⁺**.

2.64 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^- .

2.65 (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:** ${}_{5}^{10}\text{B}$ **B:** ${}_{7}^{14}\text{N}^{3-}$ **C:** ${}_{19}^{39}\text{K}^+$ **D:** ${}_{30}^{66}\text{Zn}^{2+}$ **E:** ${}_{35}^{81}\text{Br}^-$ **F:** ${}_{5}^{11}\text{B}$ **G:** ${}_{9}^{19}\text{F}$

2.66 NaCl is an ionic compound; it doesn't form molecules.

2.67 **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.

2.68 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

(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

2.69 (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.

2.70 (a) Ammonium is NH_4^+ , not NH_3^+ . The formula should be **$(\text{NH}_4)_2\text{CO}_3$** .

(b) Calcium has a $+2$ charge and hydroxide has a -1 charge. The formula should be **$\text{Ca}(\text{OH})_2$** .

(c) Sulfide is S^{2-} , not SO_3^{2-} . The correct formula is **CdS** .

(d) Dichromate is $\text{Cr}_2\text{O}_7^{2-}$, not $\text{Cr}_2\text{O}_4^{2-}$. The correct formula is **ZnCr_2O_7** .

2.71	Symbol	${}_{5}^{11}\text{B}$	${}_{26}^{54}\text{Fe}^{2+}$	${}_{15}^{31}\text{P}^{3-}$	${}_{79}^{196}\text{Au}$	${}_{86}^{222}\text{Rn}$
	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

2.72 (a) Ionic compounds are typically formed between metallic and nonmetallic elements.

(b) In general the transition metals, the actinides and lanthanides have variable charges.

2.73 (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.

2.74 The symbol ^{23}Na provides more information than $_{11}\text{Na}$. 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?

2.75 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.

2.76 Mercury (Hg) and bromine (Br_2)

2.77	(a)	Isotope	^4_2He	$^{20}_{10}\text{Ne}$	$^{40}_{18}\text{Ar}$	$^{84}_{36}\text{Kr}$	$^{132}_{54}\text{Xe}$
		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.

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

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

2.80 They do not have a strong tendency to form compounds. Helium, neon, and argon are chemically inert.

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

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

2.83 **(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).

(c) Arsenic, Cesium, Chlorine, Chromium, Iodine.

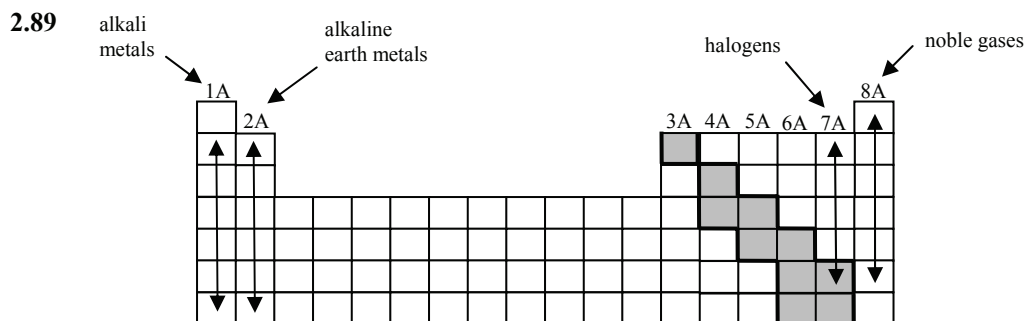
2.84 Argentina is named after silver (argentum, Ag).

2.85 The mass of fluorine reacting with hydrogen and deuterium would be the same. The ratio of F atom to hydrogen (or deuterium) 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.

2.86 (a) NaH, sodium hydride (b) B₂O₃, diboron trioxide (c) Na₂S, sodium sulfide
(d) AlF₃, aluminum fluoride (e) OF₂, oxygen difluoride (f) SrCl₂, strontium chloride

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

2.88 All of these are molecular compounds. We use prefixes to express the number of each atom in the molecule. The names are nitrogen trifluoride (NF₃), phosphorus pentabromide (PBr₅), and sulfur dichloride (SCl₂).



The metalloids are shown in gray.

2.90

Cation	Anion	Formula	Name
Mg ²⁺	HCO ₃ ⁻	Mg(HCO ₃) ₂	Magnesium bicarbonate
Sr ²⁺	Cl ⁻	SrCl ₂	Strontium chloride
Fe ³⁺	NO ₂ ⁻	Fe(NO ₂) ₃	Iron(III) nitrite
Mn ²⁺	ClO ₃ ⁻	Mn(ClO ₃) ₂	Manganese(II) chlorate
Sn ⁴⁺	Br ⁻	SnBr ₄	Tin(IV) bromide
Co ²⁺	PO ₄ ³⁻	Co ₃ (PO ₄) ₂	Cobalt(II) phosphate
Hg ₂ ²⁺	I ⁻	Hg ₂ I ₂	Mercury(I) iodide
Cu ⁺	CO ₃ ²⁻	Cu ₂ CO ₃	Copper(I) carbonate
Li ⁺	N ³⁻	Li ₃ N	Lithium nitride
Al ³⁺	S ²⁻	Al ₂ S ₃	Aluminum sulfide

2.91 (a) CO₂(s), solid carbon dioxide (f) Ca(OH)₂, calcium hydroxide
(b) NaCl, sodium chloride (g) NaHCO₃, sodium bicarbonate
(c) N₂O, nitrous oxide (h) Na₂CO₃·10H₂O, sodium carbonate decahydrate
(d) CaCO₃, calcium carbonate (i) CaSO₄·2H₂O, calcium sulfate dihydrate
(e) CaO, calcium oxide (j) Mg(OH)₂, magnesium hydroxide

2.92 The change in energy is equal to the energy released. We call this ΔE . Similarly, Δm is the change in mass.

Because $m = \frac{E}{c^2}$, we have

$$\Delta m = \frac{\Delta E}{c^2} = \frac{(1.715 \times 10^3 \text{ kJ}) \times \frac{1000 \text{ J}}{1 \text{ kJ}}}{(3.00 \times 10^8 \text{ m/s})^2} = 1.91 \times 10^{-11} \text{ kg} = \mathbf{1.91 \times 10^{-8} \text{ g}}$$

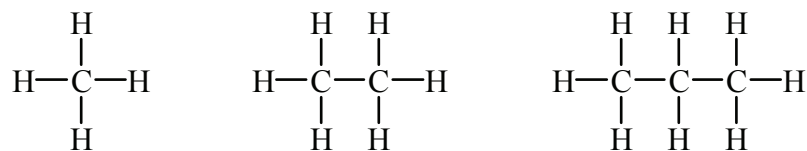
Note that we need to convert kJ to J so that we end up with units of kg for the mass. $\left(1 \text{ J} = \frac{1 \text{ kg} \cdot \text{m}^2}{\text{s}^2}\right)$

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

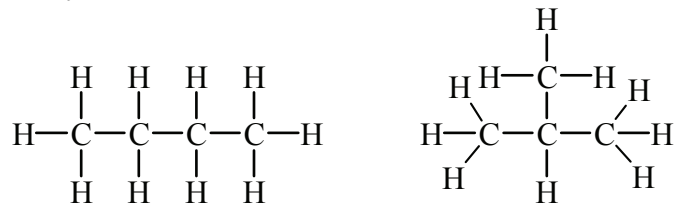
$$12.096 \text{ g} + 96.000 = 108.096 \text{ g}$$

The predicted change (loss) in mass is only $1.91 \times 10^{-8} \text{ g}$ 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.

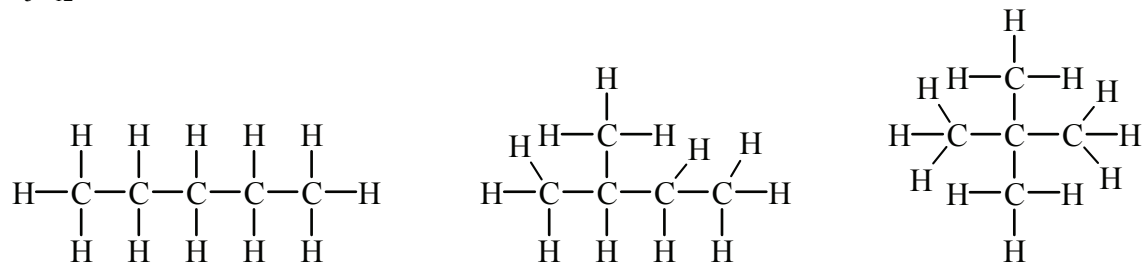
2.93 CH_4 , C_2H_6 , and C_3H_8 each only have one structural formula.



C_4H_{10} has two structural formulas.



C_5H_{12} has three structural formulas.



2.94 (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.

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

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:

$$11 \text{ electrons} \times \frac{9.1095 \times 10^{-28} \text{ g}}{1 \text{ electron}} = 1.00205 \times 10^{-26} \text{ g}$$

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:

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

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

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

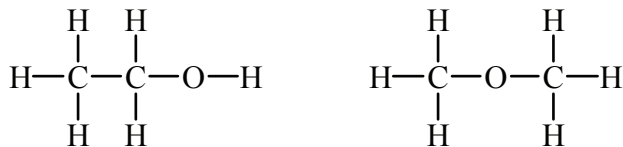
As you can see, the volume occupied by the nucleus is insignificant compared to the space occupied by the electrons.

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

$$d = \frac{m}{V} = \frac{1.00205 \times 10^{-26} \text{ g}}{2.695 \times 10^{-23} \text{ cm}^3} = 3.72 \times 10^{-4} \text{ g/cm}^3$$

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.

2.95 Two different structural formulas for the molecular formula $\text{C}_2\text{H}_6\text{O}$ are:



In the second hypothesis of Dalton's Atomic Theory, he states that in any compound, the ratio of the number of atoms of any two of the elements present is either an integer or simple fraction. In the above two compounds, the ratio of atoms is the same. This does not necessarily contradict Dalton's hypothesis, but Dalton was not aware of chemical bond formation and structural formulas.

2.96	(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 ₂ H ₆	C ₂ H ₂

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

cm³ → grams → atoms

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

- (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:

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

2.98 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**.

2.99

S	N
B	I

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