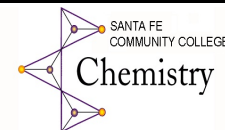




CHM 2045 FIRST ANSWER KEY



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MATH REVIEW and SIGNIFICANT FIGURE QUESTIONS

1. a. $a^{(m+n)}$ b. $a^{(1-m)}$ c. 1; for all "a" except $a = 0$
d. $1/a^2$ e. $\sqrt[n]{a}$
2. a. counted number b. counted number c. counted number
d. counted number e. one f. five
g. three h. one i. three
3. e. 1×10^{-1} cm f. 1.0010×10^2 cm g. 1.01 in
h. 5×10^{-3} g i. 5.00×10^{-3} g
4. a. 0.068 cm b. 0.0012 cm^2 c. 0.000 cm
d. 1.0 e. 0.031 cm
5. a. 10.08 in b. 0.94 sec c. 1.77×10^{16} A
d. $3.1 \times 10^{-3} \text{ m}^2$ e. $1 \times 10^1 \text{ g}^{2/3}$
6. a. 9.71×10^{-4} kg b. 8.2×10^4 ms c. $1.23 \times 10^3 \text{ mm}^2$
d. 213 cm^3 e. 0.0650 cm^{-1} f. $7.61 \times 10^3 \text{ mg/mL}$
7. a. $\text{money lost} = \frac{\$1000}{\text{oz}} \times \frac{1.00 \text{ oz}}{28.4 \text{ g}} \times \frac{3 \text{ g (exactly)}}{1000 \text{ stones}} \times 50 \text{ stones} = \5.28
b. The stones are worth: $\frac{\$1000}{28.4 \text{ g}} = \frac{\$35.21}{1.00 \text{ g}}$

Thus with a digital balance (as used in lab) the stones are weighed to the nearest 0.001 g and this value is multiplied by \$35.21/g. This will give the value to within \$0.035 or 3.5 cents.

c. Assuming each stone weighs the same:

$$\text{the value of each stone} = \frac{\$1000}{\text{oz}} \times \frac{1.00 \text{ oz}}{28.4 \text{ g}} \times \frac{3 \text{ g (exactly)}}{1000 \text{ stones}} = \$0.1056/\text{stone}$$

So count the stones and multiply by \$0.1056/stone and round off to the nearest penny.

$$8. \text{ Small pizza costs} = \frac{\$5.00}{\pi (5.0 \text{ inch})^2} = \frac{\$0.20_0}{\pi \text{ inch}^2} = \frac{\$0.064}{\text{inch}^2}$$

$$\text{Large pizza costs} = \frac{\$10.00}{\pi (7.0 \text{ inch})^2} = \frac{\$0.20_4}{\pi \text{ inch}^2} = \frac{\$0.065}{\text{inch}^2}$$

Thus the small pizza cost less per square inch and is therefore the better buy.

$$9. \text{ Medium grapefruit costs} = \frac{\$0.10}{\frac{4}{3} \pi (1.0 \text{ inch})^3} = \frac{\$0.10_0}{\frac{4}{3} \pi \text{ inch}^3} = \frac{\$0.024}{\text{inch}^3}$$

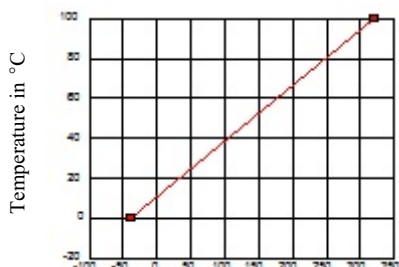
Temperature in °H

$$\text{Large grapefruit costs} = \frac{\$0.20}{\frac{4}{3} \pi (1.5 \text{ inch})^3} = \frac{\$0.059_3}{\frac{4}{3} \pi \text{ inch}^3} = \frac{\$0.014}{\text{inch}^3}$$

Thus the larger grapefruit is the better buy.

QUESTIONS ON MATTER and ENERGY

10. Metals tend to be solids at room temperature and are malleable and ductile. They are good conductors of heat and electricity, tend to have high densities and high MP and tend to be converted into cations during chemical reactions. The metals are located to the left side of the “stair-step”
11. Nonmetals tend to be gas or low melting solids at room temperature. In their solid form they are brittle. They are poor conductors of heat and electricity, tend to have low densities and low BP and tend to be converted into anions during chemical reactions. The metals are located to the right side of the “stair-step”
12. a. physical b. physical c. physical d. physical e. chemical
f. chemical g. physical h. physical i. chemical
13. The easiest method to find the equation to convert °H to °C is to make a graph of °H (on x-axis) vs °C (on y-axis).



Now find the equation for this line. The slope of the line (m) by definition is Δy over Δx or

$$m = \frac{\Delta y}{\Delta x} = \frac{(100^\circ\text{C}) - (0^\circ\text{C})}{(320^\circ\text{H}) - (-40^\circ\text{H})} = \frac{100^\circ\text{C}}{360^\circ\text{H}} = \frac{1^\circ\text{C}}{3.6^\circ\text{H}}$$

Also by definition the intercept, b is y minus m•x or

$$b = y - m \cdot x = (100^{\circ}\text{C}) - (320^{\circ}\text{H}) \times \frac{1^{\circ}\text{C}}{3.6^{\circ}\text{H}} = \frac{360^{\circ}\text{C}}{3.6} - \frac{(320^{\circ}\text{C})}{3.6} = \frac{(40^{\circ}\text{C})}{3.6}$$

$$\text{Thus, } y = m \cdot x + b \text{ becomes } ^{\circ}\text{C} = \frac{1^{\circ}\text{C}}{3.6^{\circ}\text{H}} \times ^{\circ}\text{H} + \frac{40^{\circ}\text{C}}{3.6} \approx \frac{1^{\circ}\text{C}}{3.6^{\circ}\text{H}} \times ^{\circ}\text{H} + 11.111^{\circ}\text{C}$$

Note, an easier to use equation can be created by combining terms in the above equation.

$$^{\circ}\text{C} = \frac{1^{\circ}\text{C}}{3.6^{\circ}\text{H}} \times ^{\circ}\text{H} + \frac{40^{\circ}\text{C}}{3.6} = \frac{1^{\circ}\text{C}}{3.6^{\circ}\text{H}} \times (^{\circ}\text{H} + 40^{\circ}\text{H})$$

$$\text{So to convert } 100^{\circ}\text{H to } ^{\circ}\text{C, } ^{\circ}\text{C} = \frac{1^{\circ}\text{C}}{3.6^{\circ}\text{H}} \times (100^{\circ}\text{H} + 40^{\circ}\text{H}) = \frac{140^{\circ}\text{C}}{3.6} = 38.9^{\circ}\text{C}$$

From a significant figure standpoint a reading on the Hokie scale more precisely defines the temperature since a degree Hokie is smaller than a degree on the Celsius scale.

14. a. endothermic b. endothermic c. exothermic d. endothermic e. exothermic
15. As the dissolving process of solid Na_2CO_3 liberates heat and makes the solution hotter, the dissolution process is exothermic.

QUESTIONS ON DENSITY

$$16. \quad D = \frac{M}{V} = \frac{10.0 \text{ oz}}{(1.00 \text{ inch})^3} \times \frac{28.4 \text{ g}}{1.00 \text{ oz}} \times \left(\frac{1 \text{ inch}}{2.54 \text{ cm}}\right)^3 = 17.3 \text{ g/cm}^3$$

$$\frac{17.3 \text{ g}}{\text{cm}^3} = \frac{17.3 \text{ g}}{\text{mL}} = \frac{17.3 \text{ kg}}{\text{L}}$$

$$17. \quad D = \frac{M}{V} = \frac{2.72 \text{ g Os}}{0.121 \text{ mL Os}} = 22.5 \text{ g/mL Os}$$

$$18. \quad \text{Since } D = \frac{M}{V} \text{ then } M = V \times D \quad 125 \text{ mL Cl}_2 \times \frac{10^{-3} \text{ L Cl}_2}{\text{mL Cl}_2} \times \frac{3.16 \text{ g Cl}_2}{\text{L Cl}_2} = 0.395 \text{ g Cl}_2$$

$$19. \quad \text{Since } D = \frac{M}{V} \text{ then } V = \frac{M}{D} \text{ or } V = M \times \frac{1}{D} \quad 11.3 \text{ g C} \times \frac{\text{cm}^3 \text{ C}}{2.25 \text{ g C}} = 5.02 \text{ cm}^3 \text{ C} \quad \text{or}$$

$$20. \quad \text{Volume metal} = \text{Vol}(\text{metal} + \text{H}_2\text{O}) - \text{Vol}(\text{H}_2\text{O})$$

$$\text{Density of metal} = \frac{\text{Mass metal}}{\text{Vol metal}} = \frac{20.12 \text{ g}}{21.6 \text{ mL} - 15.5 \text{ mL}} = 3.3 \text{ g/mL SigFigs!}$$

$$21. \quad \text{Mass Toluene} = \text{Mass (cyl. \& Toluene)} - \text{Mass(cyl.)}$$

$$V = M \times \frac{1}{D} \quad \text{Therefore } (87.127 \text{ g} - 57.832 \text{ g}) \text{Toluene} \times \frac{\text{mL Toluene}}{0.866 \text{ g Toluene}} = 33.8 \text{ mL Toluene}$$

QUESTIONS ON FUNDAMENTAL LAWS OF CHEMISTRY

22. Based on the Law of Conservation of Mass, if 16.0 g of oxygen react completely with 2.0 g hydrogen then 18.0 g of water are produced. Based on the Law of Definite Composition, if 16.0 g of oxygen react with 2.0 g of hydrogen then 4.0 g of oxygen will react with 0.5 g of hydrogen. (Both cases have an oxygen to hydrogen mass ratio of 8:1.) Therefore based on the Law of Conservation of Mass, there will be 1.5 g of hydrogen left and will produce 4.5 g of water.

23. i. We can use the Law of Multiple Proportions.

ii. For simplicity take 1.00 g G to be 1.00 part of G and 3.00 g M to be 1.00 part of M.

Note: Two different elements cannot both have the masses equal to one.

Therefore, in compound I there is one part G and one part M or a formula of GM

Likewise, in compound II there is one part G and two parts M or a formula of GM₂

Finally, in compound III there is one part G and three parts M or a formula of GM₃.

iii. Now 1.00 g G is proportional to 1 units of G and 3.00 g M is proportional to 2 units of M.

Therefore, compound I is GM₂, compound II is GM₄, and compound III is GM₆.

iv. Now 1.00 g G is proportional to 2 units of G and 3.00 g M is proportional to 5 units of M.

Therefore, compound I is G₂M₅, compound II is G₂M₁₀ or GM₅, and compound III is G₂M₁₅.

v. Now 1.00 g G is proportional to 1 unit of G and 6.00 g M is proportional to 1 unit of M.

Therefore, compound II is GM, compound I is GM_{0.5} or G₂M, and compound III is GM_{1.5} or G₂M₃.

QUESTIONS ON FUNDAMENTAL SUBATOMIC PARTICLE

24. His experiments showed that regardless of the material used for the cathode the particles produced all had the same properties (e/m) and therefore were in fact the same particles. Since all materials produced the same particles they must in fact be present in all materials and hence are fundamental to all matter. The same could not be said for the canal rays produced because they had different properties (e/m) which varied depending on the gas left in the tube.

25. Neutrons could not be isolated and characterized by the same methods as the proton and electron because the neutron has no charge which is required of a particle which is to be affected by a magnetic or electric field.

26. a. The droplets carry different charges because there may be 1, 2, 3 or more excess electrons on each droplet. The electron charge then is likely to be the greatest common factor in all the observed charges. Assuming this to be so, we calculate the apparent electronic charge from each droplet as follows:

$$A: -9.6132 \times 10^{-19} \text{ C} / 2 \text{ e}^- = -4.8066 \times 10^{-19} \text{ C/e}^-$$

$$B: -14.4198 \times 10^{-19} \text{ C} / 3 \text{ e}^- = -4.8066 \times 10^{-19} \text{ C/e}^-$$

$$C: -4.8066 \times 10^{-19} \text{ C} / 1 \text{ e}^- = -4.8066 \times 10^{-19} \text{ C/e}^-$$

$$D: -19.2264 \times 10^{-19} \text{ C} / 4 \text{ e}^- = -4.8066 \times 10^{-19} \text{ C/e}^-$$

The value $-4.8066 \times 10^{-19} \text{ C}$ could be taken as the unit charge on a single electron as this value may be multiplied by integers (whole numbers) to yield the other charges observed.

b. YES! The charge data are all multiples of the value $-2.4033 \times 10^{-19} \text{ C}$ also, so this value **could** be the correct value *based on these 4 pieces of data* **but**, please note that this value could not actually occur in a real oil drop experiment because it is not a multiple of the real electronic charge of $-1.6022 \times 10^{-19} \text{ C}$!

$$27. \text{ Mass of } \text{e}^- = \frac{\text{e}^-}{\text{e}^-/\text{m}_{\text{e}}^-} = \frac{-1.60 \times 10^{-19} \text{ C}}{-1.76 \times 10^8 \text{ C/g}} = 9.09 \times 10^{-28} \text{ g}$$

$$\text{Mass of } \text{H}^+ = \frac{\text{e}^+}{\text{e}^+/\text{m}_{\text{H}}^+} = \frac{+1.60 \times 10^{-19} \text{ C}}{+9.58 \times 10^4 \text{ C/g}} = 1.67 \times 10^{-24} \text{ g}$$

Therefore, the e^- mass as a % of H atom mass is :

$$\frac{\text{Mass of } \text{e}^-}{\text{mass of proton} + \text{mass of } \text{e}^-} \times 100\% = \frac{9.09 \times 10^{-28} \text{ g}}{1.67 \times 10^{-24} \text{ g} + 9.09 \times 10^{-28} \text{ g}} \times 100\% = 0.0544\%$$

Note that this very small percentage (negligible) would be even smaller for the other isotopes of hydrogen and for all other atoms as well because all would have atomic masses larger than hydrogen.

$$28. \text{ a. } -5.5 \times 10^{-15} \text{ C} \div (-1.60 \times 10^{-19} \text{ C/e}^-) = 3.4 \times 10^4 \text{ e}^-$$

$$\text{ b. } -6.4 \times 10^{-12} \text{ C} \div (-1.60 \times 10^{-19} \text{ C/e}^-) = 4.0 \times 10^7 \text{ e}^-$$

29. a. No net charge

b. Each F^- carries one excess e^- and therefore the excess charge carried by 1×10^{12} F^- ions is:

$$1.00 \times 10^{12} F^- \text{ ions} \times (-1.60 \times 10^{-19} \text{ C}/F^- \text{ ion}) = -1.60 \times 10^{-7} \text{ C.}$$

c. Each ${}^{22}_{10}\text{Ne}^{+2}$ ion has lost 2 e^- and therefore carries a positive charge which is twice that of the electron or $2 \times (1.60 \times 10^{-19} \text{ C})$. Thus the charge carried by 1.00×10^{12} ${}^{22}_{10}\text{Ne}^{+2}$ ions is:

$$1.00 \times 10^{12} \text{ Ne}^{+2} \text{ ions} \times (3.20 \times 10^{-19} \text{ C} / \text{Ne}^{+2} \text{ ion}) = 3.20 \times 10^{-7} \text{ C}$$

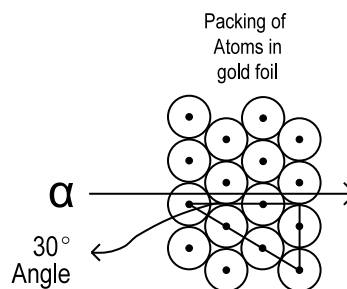
30. Remember that the purpose of Rutherford's experiment was to elucidate the structure of a single atom. It was not possible for him to use a single atom or a sheet of atoms one atom thick. So, Rutherford did the best he could to produce a sheet as thin as possible to simulate a sheet of atoms one atom thick. Note how his results would have drastically changed with a thick sheet; namely, a high percentage of the alpha particles would have bounced back. This would have suggested that the atom's mass is distributed throughout its structure, and would have provided little useful information as to the actual subatomic structure.

31. Recall $r = \frac{d}{2}$ and Volume of sphere = $\frac{4}{3}\pi r^3$

$$\text{Density} = \frac{\text{mass}}{\text{volume}} = \frac{1.67 \times 10^{-24} \text{ g}}{\frac{4}{3}\pi \left(\frac{1.5 \times 10^{-13} \text{ cm}}{2} \right)^3} = 9.5 \times 10^{14} \text{ g/cm}^3$$

As noted from the above calculation, the density of a proton is extremely large relative to the density of osmium (see problem 17). It can be reasonably assumed that almost all the atomic mass is located within the extremely small volume of the protons and neutrons defining the nucleus. The rest of the atomic volume is essentially "empty", a huge volume relative to the nuclear volume and occupied by very low mass electrons.

32. The illustration suggests how Au atoms are arranged with respect to one another in the Au foil. Note the layered structure of the atoms and realize that the alpha particle can strike only one atom per layer. Thus regardless of the angle at which the alpha particle travels through the foil it must pass through the same number of atoms. The packing has been redrawn with an inscribed triangle.



Now, if the foil is $4 \times 10^{-4} \text{ cm}$ thick we can calculate the length of the hypotenuse of our triangle from the relationship:

$$\cosine 30^\circ = \frac{4.0 \times 10^{-4} \text{ cm}}{\text{hypotenuse}}, \therefore \text{hypotenuse} = \frac{4.0 \times 10^{-4} \text{ cm}}{\cosine 30^\circ} = 4.6_2 \times 10^{-4} \text{ cm}$$

Reexamine our triangle and observe that along the hypotenuse Au atoms lie in straight line contact. We can calculate the number of Au atoms which lie along the hypotenuse by dividing the length of the hypotenuse by the diameter of the Au atom.

$$\frac{4.6_2 \times 10^{-4} \text{ cm}}{2.8 \times 10^{-8} \text{ cm/atom}} = 1.6 \times 10^4 \text{ atoms!}$$

There are 1.6×10^4 atoms along the hypotenuse and therefore there must be 1.6×10^4 layers in the foil. So, the alpha particle must travel through 1.6×10^4 Au atoms in the foil regardless of the angle of passage. If 99.9% of all alpha particles passed through the 1.6×10^4 atoms without impedance, it follows that the great majority of the volume of the atom is empty space. Is this not in good agreement with the conclusion reached by Rutherford as to the structure and composition of the atom?

33. The completed table is:

Elemental Symbol	Number of Protons	Number of Neutrons	Number of Electrons	Charge on Species	Name
$^{190}_{78}\text{Pt}$	78	112	78	0	Platinum one ninety
$^{41}_{20}\text{Ca}^{+2}$	20	21	18	+2	Calcium forty-one ion
$^{223}_{87}\text{Fr}$	87	136	87	0	Francium two-twenty-three
$^{139}_{53}\text{I}^{-1}$	53	86	54	-1	Iodide one-thirty-nine ion
^3_2He	2	1	2	0	Helium three
$^{13}_6\text{C}$	6	7	6	0	Carbon thirteen
$^{29}_{14}\text{Si}$	14	15	14	0	Silicon twenty-nine
$^{34}_{16}\text{S}^{-2}$	16	18	18	-2	
$^{56}_{26}\text{Fe}^{+3}$	26	30	23	+3	
$^{197}_{79}\text{Au}^{+3}$	79	118	76	+3	

34. The symbol Cl represents a chlorine atom. By definition, all atoms of chlorine have an atomic number of 17, i.e., 17 protons in the nucleus. Whether or not "17" appears to the lower left of the element symbol, there is no doubt that "Cl" possesses 17 protons. ${}^{35}_{17}\text{Cl}$ and ${}^{35}\text{Cl}$ both represent the specific isotope of chlorine with a mass number of 35 (18 neutrons). ${}_{17}\text{Cl}$ differs from ${}^{35}_{17}\text{Cl}$ in that ${}_{17}\text{Cl}$ does not indicate a specific isotope. It may be assumed that ${}_{17}\text{Cl}$ represents a mixture of the two isotopes of chlorine ${}^{35}_{17}\text{Cl}$ and ${}^{37}_{17}\text{Cl}$ in the relative proportions found in nature.
35. ${}^{60}\text{X}$ and ${}^{60}\text{Y}$ are not necessarily the same element. The mass number (here 60) is the sum of the protons and neutrons, of which numerous combinations of protons and neutrons are possible for 60.
36. Protium, ${}^1_1\text{H}$ (the most abundant), has 1 proton and 1 electron.
Deuterium, ${}^2_1\text{H}$ or D, has 1 proton, 1 neutron, and 1 electron.
Tritium, ${}^3_1\text{H}$ or T, has 1 proton, 2 neutrons, and 1 electron.
NOTE: The isotopes of hydrogen are occasionally given their own symbols, H, D, and T.
37. ${}^{16}_8\text{O}$ and ${}^{18}_8\text{O}$ possess the same number of protons in the nucleus, 8, and the same number of electrons, 8. The charged subatomic particles (protons and electrons) are essentially responsible for the chemical properties of the atom (particularly the number of electrons). ${}^{16}_8\text{O}$ and ${}^{18}_8\text{O}$ differ only in the number of neutrons in their nuclei, not a chemically important difference.
38. Neither protons nor neutrons have exactly integral masses in amu; their masses are 1.0073 and 1.0087 amu, respectively. Furthermore, there is a loss of mass (equivalent to a nonintegral number of amu) whenever protons and neutrons are fused into a nucleus. No nuclide is likely to have an integral mass when expressed in atomic mass units. ${}^{12}\text{C}$ is integral only because it has been arbitrarily set or defined at exactly 12 amu.
39. a.
$$\text{avg. atomic mass} = \frac{(38.9637 \text{ amu} \times 93.12\%) + (40.974 \text{ amu} \times 6.880\%)}{(93.12\% + 6.880\%)} = 39.10 \text{ amu}$$
- b.
$$\text{avg. atomic mass} = \frac{(19.99244 \text{ amu} \times 90.92\%) + (20.99395 \text{ amu} \times 0.2570\%) + (21.99138 \text{ amu} \times 8.820\%)}{(90.92\% + 0.2570\% + 8.820\%)} = 20.17 \text{ amu}$$
- c. No! When more than one natural isotope exists for any given element, the average atomic mass is a statistically weighted average of the masses of each isotope. Any given isotope would have its own mass, i.e., the constituent atoms of the element could have only the mass of one of the natural isotopes. Atoms of elements with only one isotope, of course, would have a mass exactly equal to the atomic mass of that element as listed on the periodic table. (e.g., F, P, Au)

40. We can write the percentage of ^{107}Ag as X and the percentage of ^{109}Ag as 100 - X. Then:

$$\frac{X\%(106.905 \text{ amu}) + (100\% - X\%)(108.905 \text{ amu})}{(100\%)} = 107.870 \text{ amu}$$

solving for X gives: $X = 51.75\%$ and $100 - X = 48.25\%$

QUESTIONS ON BONDING, IONS AND MOLECULES

41. An atom is the smallest uncharged particle of an element that retains the identity of that element. A molecule is the smallest (uncharged) particle of a substance that retains the composition and properties of that substance AND is capable of independent existence.
42. An atom is the smallest uncharged particle of an element that retains the identity of that element. A simple cation is created when a single atom loses one or more electrons (e.g., Na^+ or Mg^{+2}). A simple anion is created when a single atom gains one or more electrons (e.g., Cl^- or O^{-2}).
43. A molecule is the smallest (uncharged) particle of a substance that retains the composition and properties of that substance AND is capable of independent existence. A polyatomic ion is a group of atoms that have gained (to form a polyatomic anion) or lost electrons (to form a polyatomic cation).
44. A covalent bond is formed when two atoms share (usually two) electrons. Ionic bond formation is initiated when the atoms of one element each lose one or more electrons (to form cations) and the atoms of a different element each gain one or more electrons (to form anions). The mutual attraction between the collection of anions and cations to form a solid is called ionic bonding.
45. a) Ionic (Na is a metal element and Cl is a nonmetal element).
 b) Covalent (C and H are both nonmetal elements).
 c) Covalent (B and Cl are both nonmetal elements).
 d) Ionic (Fe is a metal element and O is a nonmetal element).
46. a) The correct formula for carbon dioxide is CO_2 (NOT CO_2).
 b) The molecule of H_2O actually contains two hydrogen atoms and one oxygen atom (NOT one hydrogen atom and two oxygen atoms).
 c) Sodium chloride is an ionic substance and therefore DOES NOT contain molecules. The formula unit of sodium chloride has a formula of NaCl .
 d) Mg^{+2} is a cation (NOT an anion).
 e) NH_3 is a molecule (NOT an ion; NH_3 has no charge).

47. a. Fe, 55.845 g/mol b. N₂O₄, 92.0110 g/mol
c. (NH₄)₃AsO₄, 193.0341 g/mol d. CO₃⁻², 60.009 g/mol
48. a. Fe, i) 55.84 amu ii) 55.845 amu x 1.66054 x 10⁻²⁴ g/amu = 9.2733 x 10⁻²³ g
or 55.845 g/mol × $\frac{1 \text{ mol}}{6.02214 \times 10^{23}}$ = 9.2733 × 10⁻²³ g
- b. N₂O₄, i) 92.0110 amu ii) 92.0110 amu x 1.66054 x 10⁻²⁴ g/amu = 1.5279 x 10⁻²² g
or 92.0110 g/mol × $\frac{1 \text{ mol}}{6.02214 \times 10^{23}}$ = 1.5279 × 10⁻²² g
- c. (NH₄)₃AsO₄, i) 193.03 amu ii) 193.0341 amu x 1.66054 x 10⁻²⁴ g/amu = 3.20541 x 10⁻²² g
or 193.0341 g/mol × $\frac{1 \text{ mol}}{6.02214 \times 10^{23}}$ = 3.20541 × 10⁻²² g
- d. CO₃⁻², i) 60.01 amu ii) 60.009 amu x 1.66054 x 10⁻²⁴ g/amu = 9.9648 x 10⁻²³ g
or 60.009 g/mol × $\frac{1 \text{ mol}}{6.02214 \times 10^{23}}$ = 9.9648 × 10⁻²³ g
49. a. 37.5 g H₂O × $\frac{1 \text{ mol}}{18.0152 \text{ g}}$ = 2.08 mol H₂O
- b. 3.25 × 10⁻² mol F⁻ × $\frac{18.998403 \text{ g}}{1 \text{ mol}}$ = 0.617 g F⁻
- c. 4.2 g I₂ × $\frac{1 \text{ mol}}{253.80894 \text{ g}}$ × $\frac{6.022 \times 10^{23} \text{ molecules}}{1 \text{ mol}}$ = 1.0 × 10²² molecules I₂
- d. 39.6 g (NH₄)₂SO₄ × $\frac{1 \text{ mol}}{132.14 \text{ g}}$ × $\frac{6.022 \times 10^{23} \text{ For. Units}}{1 \text{ mol}}$ = 1.80 × 10²³ For. Units of (NH₄)₂SO₄
- e. 4.5 × 10²⁵ molecules C₆H₁₂O₆ × $\frac{1 \text{ mol}}{6.022 \times 10^{23} \text{ molecules}}$ × $\frac{180.157 \text{ g}}{1 \text{ mol}}$ = 1.3 × 10⁴ g of C₆H₁₂O₆
- f. 0.25 mol CaCl₂ × $\frac{6.022 \times 10^{23} \text{ For. Units}}{1 \text{ mol}}$ = 1.5 × 10²³ For. Units of CaCl₂

$$g. \quad 6.26 \times 10^{-3} \text{ mol Mg}^{+2} \times \frac{6.022 \times 10^{23} \text{ ions}}{1 \text{ mol}} = 3.77 \times 10^{21} \text{ Mg}^{+2} \text{ ions}$$

$$h. \quad 4.5 \times 10^{25} \text{ molecules S}_8 \times \frac{1 \text{ mol}}{6.022 \times 10^{23} \text{ molecules}} = 75 \text{ mol S}_8$$

$$50. \text{ a. } K_2Cr_2O_7 \quad \%K = 26.58\% \quad \%Cr = 35.35\% \quad \%O = 38.07\%$$

$$b. \text{ C}_{12}\text{H}_{22}\text{O}_{11} \quad \%C = 42.11\% \quad \%H = 6.478\% \quad \%O = 51.42\%$$

$$51. \text{ a. } ZnSO_4 \cdot 7H_2O \quad \% H_2O = \frac{7 \times 18.0152 \text{ g}}{287.56_4 \text{ g}} \times 100\% = 43.853\%$$

$$b. \text{ NH}_2\text{CH}_2\text{CO}_2\text{H} \quad \text{g N} = 30.0 \text{ g NH}_2\text{CH}_2\text{CO}_2\text{H} \times \frac{14.0067 \text{ g N}}{75.0670 \text{ g NH}_2\text{CH}_2\text{CO}_2\text{H}} = 5.60 \text{ g N}$$

52. a. Using a 100 g sample of xenon fluoride:

$$63.3 \text{ g Xe} \times \frac{1 \text{ mol}}{131.29 \text{ g}} = 0.482 \text{ mol Xe} \quad 36.7 \text{ g F} \times \frac{1 \text{ mol}}{18.998403 \text{ g}} = 1.93 \text{ mol F}$$

$$\text{Therefore, the formula is Xe}_{0.482}\text{F}_{1.93} \text{ or } \text{Xe}_{\frac{0.482}{0.482}}\text{F}_{\frac{1.93}{0.482}} \text{ or } \text{Xe}_{1.00}\text{F}_{4.00} \text{ or } \text{XeF}_4$$

b. Using a 100 g sample of the compound:

$$60.59 \text{ g C} \times \frac{1 \text{ mol}}{12.011 \text{ g}} = 5.045 \text{ mol C} \quad 7.12 \text{ g H} \times \frac{1 \text{ mol}}{1.0079 \text{ g}} = 7.06 \text{ mol H and}$$

$$32.29 \text{ g O} \times \frac{1 \text{ mol}}{15.9994 \text{ g}} = 2.018 \text{ mol O}$$

$$\text{Therefore, the formula is C}_{5.045}\text{H}_{7.06}\text{O}_{2.018} \text{ or } \text{C}_{\frac{5.045}{2.018}}\text{H}_{\frac{7.06}{2.018}}\text{O}_{\frac{2.018}{2.018}} \text{ or } \text{C}_{2.500}\text{H}_{3.50}\text{O}_{1.000} \text{ or } \text{C}_5\text{H}_7\text{O}_2$$

c. Using a 100 g sample of compound 1:

$$59.9 \text{ g Ti} \times \frac{1 \text{ mol}}{47.867 \text{ g}} = 1.25 \text{ mol Ti} \quad 40.1 \text{ g O} \times \frac{1 \text{ mol}}{15.9994 \text{ g}} = 2.51 \text{ mol O}$$

$$\text{Therefore, the formula is Ti}_{1.25}\text{O}_{2.51} \text{ or } \text{Ti}_{\frac{1.25}{1.25}}\text{O}_{\frac{2.51}{1.25}} \text{ or } \text{TiO}_2$$

Using a 100 g sample of compound 2:

$$66.6 \text{ g Ti} \times \frac{1 \text{ mol}}{47.867 \text{ g}} = 1.39 \text{ mol Ti} \quad 33.4 \text{ g O} \times \frac{1 \text{ mol}}{15.9994 \text{ g}} = 2.09 \text{ mol O}$$

$$\text{Therefore, the formula is Ti}_{1.39}\text{O}_{2.09} \text{ or } \text{Ti}_{\frac{1.39}{1.39}}\text{O}_{\frac{2.09}{1.39}} \text{ or } \text{Ti}_2\text{O}_3$$

53. Recall, the molecular formula is a whole number multiple of the empirical formula.
Therefore, the molecular formula mass is a whole number multiple of the empirical formula mass.
The multiple is the ratio of the molecular mass over the empirical mass,

$$\frac{\text{molecular mass}}{\text{empirical formula mass}} = n, \text{ where } n = 1, 2, 3, \dots$$

CH₂, empirical formula

$$\frac{\text{molecular mass}}{\text{empirical formula mass}} = \frac{71 \text{ amu/molecule}}{14.0 \text{ amu/FU}} \approx$$

CH₂O, empirical formula

$$\frac{\text{molecular mass}}{\text{empirical formula mass}} = \frac{88 \text{ amu/molecule}}{30.0 \text{ amu/FU}} \approx$$

AlCl₃, empirical formula

$$\frac{\text{molecular mass}}{\text{empirical formula mass}} = \frac{267 \text{ amu/molecule}}{133.3 \text{ amu/FU}} \approx$$

54. a. $85.69 \text{ g C} \times \frac{1 \text{ mol}}{12.011 \text{ g}} = 7.134 \text{ mol C}$; $14.31 \text{ g H} \times \frac{1 \text{ mol}}{1.0079 \text{ g}} = 14.20 \text{ mol H}$

$$\text{C}_{\frac{7.134}{7.134}}\text{H}_{\frac{14.20}{7.134}} = \text{C}_{1.000}\text{H}_{1.990} = \text{CH}_2 \text{ as the empirical formula}$$

$$\frac{\text{Mol. mass}}{\text{Emp. mass}} = \frac{56 \text{ amu/molecule}}{14.0 \text{ amu/FU}} \approx \frac{4 \text{ FU}}{\text{molecule}}, 4[\text{CH}_2] = \text{C}_4\text{H}_8$$

$$\therefore \text{MM} = 56.107 \text{ amu}$$

b. $38.7 \text{ g C} \times \frac{1 \text{ mol}}{12.011 \text{ g}} = 3.22 \text{ mol C}$; $9.7 \text{ g H} \times \frac{1 \text{ mol}}{1.0079 \text{ g}} = 9.6 \text{ mol H}$

$$51.6 \text{ g O} \times \frac{1 \text{ mol}}{15.9994 \text{ g}} = 3.22 \text{ mol}$$

$$\text{C}_{\frac{3.22}{3.22}}\text{H}_{\frac{9.6}{3.22}}\text{O}_{\frac{3.22}{3.22}} = \text{C}_{1.00}\text{H}_{3.0}\text{O}_{1.00} = \text{CH}_3\text{O as the empirical formula}$$

$$\frac{\text{Mol. mass}}{\text{Emp. mass}} = \frac{60 \text{ amu/molecule}}{31 \text{ amu/FU}} \approx \frac{2 \text{ FU}}{\text{molecule}}, 2[\text{CH}_3\text{O}] = \text{C}_2\text{H}_6\text{O}_2$$

$$\therefore \text{MM} = 62.068 \text{ amu}$$

$$\text{c. } 59.0 \text{ g C} \times \frac{1 \text{ mol}}{12.011 \text{ g}} = 4.91 \text{ mol C} \quad ; \quad 7.1 \text{ g H} \times \frac{1 \text{ mol}}{1.0079 \text{ g}} = 7.0 \text{ mol H}$$

$$26.2 \text{ g O} \times \frac{1 \text{ mol}}{15.9994 \text{ g}} = 1.64 \text{ mol O} \quad ; \quad 7.7 \text{ g N} \times \frac{1 \text{ mol}}{14.0067 \text{ g}} = 0.55 \text{ mol N}$$

$$\text{C}_{\frac{4.91}{0.55}}\text{H}_{\frac{7.0}{0.55}}\text{O}_{\frac{1.64}{0.55}}\text{N}_{\frac{0.55}{0.55}} = \text{C}_{8.9}\text{H}_{13}\text{O}_{3.0}\text{N}_{1.0} = \text{C}_9\text{H}_{13}\text{O}_3\text{N} \text{ as the empirical formula}$$

$$\frac{\text{Mol. mass}}{\text{Emp. mass}} = \frac{182 \text{ amu/molecule}}{183.2 \text{ amu/FU}} \approx \frac{1 \text{ FU}}{\text{molecule}}, \therefore \text{C}_9\text{H}_{13}\text{O}_3\text{N} \text{ is also the molecular formula}$$

$$\therefore \text{MM} = 183.207 \text{ amu}$$

$$\text{d. } 49.5 \text{ g C} \times \frac{1 \text{ mol}}{12.011 \text{ g}} = 4.12 \text{ mol C} \quad ; \quad 5.15 \text{ g H} \times \frac{1 \text{ mol}}{1.0079 \text{ g}} = 5.11 \text{ mol H}$$

$$28.9 \text{ g N} \times \frac{1 \text{ mol}}{14.0067 \text{ g}} = 2.06 \text{ mol N} \quad ; \quad 16.5 \text{ g O} \times \frac{1 \text{ mol}}{15.9994 \text{ g}} = 1.03 \text{ mol O}$$

$$\text{C}_{\frac{4.12}{1.03}}\text{H}_{\frac{5.11}{1.03}}\text{N}_{\frac{2.06}{1.03}}\text{O}_{\frac{1.03}{1.03}} = \text{C}_{4.00}\text{H}_{4.96}\text{N}_{2.00}\text{O}_{1.00} = \text{C}_4\text{H}_5\text{N}_2\text{O} \text{ as the empirical formula}$$

$$\frac{\text{Mol. mass}}{\text{Emp. mass}} = \frac{195 \text{ amu/molecule}}{97.10 \text{ amu/FU}} \approx \frac{2 \text{ FU}}{\text{molecule}}, 2[\text{C}_4\text{H}_5\text{N}_2\text{O}] = \text{C}_8\text{H}_{10}\text{N}_4\text{O}_2$$

$$\therefore \text{MM} = 194.193 \text{ amu}$$

$$\text{e. } 1.640 \text{ g C} \times \frac{1 \text{ mol}}{12.011 \text{ g}} = 0.1365 \text{ mol C} \quad ; \quad 0.1032 \text{ g H} \times \frac{1 \text{ mol}}{1.0079 \text{ g}} = 0.1024 \text{ mol H}$$

$$0.4780 \text{ g N} \times \frac{1 \text{ mol}}{14.0067 \text{ g}} = 0.03413 \text{ mol N} \quad ; \quad 1.365 \text{ g O} \times \frac{1 \text{ mol}}{15.9994 \text{ g}} = 0.08532 \text{ mol O}$$

$$\text{C}_{\frac{0.1365}{0.03413}}\text{H}_{\frac{0.1024}{0.03413}}\text{N}_{\frac{0.03413}{0.03413}}\text{O}_{\frac{0.08532}{0.03413}} = 2[\text{C}_{3.999}\text{H}_{3.000}\text{N}_{1.000}\text{O}_{2.500}] = \text{C}_8\text{H}_6\text{N}_2\text{O}_5 \text{ as the emp. form.}$$

$$\frac{\text{Mol. mass}}{\text{Emp. mass}} = \frac{420 \text{ amu/molecule}}{210.1 \text{ amu/FU}} \approx \frac{2 \text{ FU}}{\text{molecule}}, 2[\text{C}_8\text{H}_6\text{N}_2\text{O}_5] = \text{C}_{16}\text{H}_{12}\text{N}_4\text{O}_{10}$$

$$\therefore \text{MM} = 420.292 \text{ amu}$$

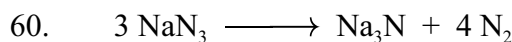
QUESTIONS ON WRITING EQUATIONS AND STOICHIOMETRY

55. a. $3 \text{ Mg (s)} + \text{N}_2 \text{ (g)} \longrightarrow \text{Mg}_3\text{N}_2 \text{ (s)}$
 b. $2 \text{ Bi}^{+3} \text{ (aq)} + 3 \text{ H}_2\text{S (g)} + 6 \text{ H}_2\text{O (l)} \longrightarrow \text{Bi}_2\text{S}_3 \text{ (s)} + 6 \text{ H}_3\text{O}^+ \text{ (aq)}$
 c. $2 \text{ Al (s)} + 6 \text{ H}_3\text{O}^+ \text{ (aq)} \longrightarrow 2 \text{ Al}^{+3} \text{ (aq)} + 3 \text{ H}_2 \text{ (g)} + 6 \text{ H}_2\text{O (l)}$
 d. $2 \text{ C}_8\text{H}_{18} \text{ (l)} + 25 \text{ O}_2 \text{ (g)} \longrightarrow 16 \text{ CO}_2 \text{ (g)} + 18 \text{ H}_2\text{O (l)}$
 e. $2 \text{ CO}_3^{-2} \text{ (aq)} + 4 \text{ NO (g)} + \text{O}_2 \text{ (g)} \longrightarrow 4 \text{ NO}_2^- \text{ (aq)} + 2 \text{ CO}_2 \text{ (g)}$
 f. $2 \text{ HCO}_3^- \text{ (aq)} + \text{Cu}^{+2} \text{ (aq)} \longrightarrow \text{CuCO}_3 \text{ (s)} + \text{CO}_2 \text{ (g)} + \text{H}_2\text{O (l)}$
 g. $\text{P}_4\text{O}_{10} + 6 \text{ H}_2\text{O} \longrightarrow 4 \text{ H}_3\text{PO}_4$
56. a. If magnesium metal reacts with nitrogen gas to form magnesium nitride then three magnesium atoms will react with one molecule of nitrogen to form one formula unit of magnesium nitride.
 b. If bismuth (III) ions react with hydrogen sulfide gas and water to form bismuth (III) sulfide and hydronium ions then two bismuth (III) ions will react with three molecules of hydrogen sulfide and six molecules of water to form one formula unit of bismuth (III) sulfide and six hydronium ions.
 c. If aluminum reacts with hydronium ions to form aluminum (III) ions, hydrogen gas and water then two atoms of aluminum will react with six hydronium ion to form two aluminum ions, three molecules of hydrogen, and six molecules of water.
57. a. $2 \text{ Na (s)} + \text{Cl}_2 \text{ (g)} \longrightarrow 2 \text{ NaCl (s)}$
 b. $2 \text{ C (s)} + \text{O}_2 \text{ (g)} \longrightarrow 2 \text{ CO (g)}$
 c. $\text{C (s)} + \text{O}_2 \text{ (g)} \longrightarrow \text{CO}_2 \text{ (g)}$
 d. $2 \text{ K (s)} + 2 \text{ H}_2\text{O (l)} \longrightarrow 2 \text{ K}^+ \text{ (aq)} + 2 \text{ OH}^- \text{ (aq)} + \text{H}_2 \text{ (g)}$
 e. $3 \text{ H}_2 \text{ (g)} + \text{N}_2 \text{ (g)} \longrightarrow 2 \text{ NH}_3 \text{ (g)}$
 f. $\text{Cl}_2\text{O}_7 \text{ (l)} + 3 \text{ H}_2\text{O (l)} \longrightarrow 2 \text{ H}_3\text{O}^+ \text{ (aq)} + 2 \text{ ClO}_4^- \text{ (aq)}$
 g. $\text{Fe}_3\text{O}_4 \text{ (s)} + 4 \text{ H}_2 \text{ (g)} \longrightarrow 3 \text{ Fe (s)} + 4 \text{ H}_2\text{O (l)}$
 h. $4 \text{ FeS}_2 \text{ (s)} + 11 \text{ O}_2 \text{ (g)} \longrightarrow 2 \text{ Fe}_2\text{O}_3 \text{ (s)} + 8 \text{ SO}_2 \text{ (g)}$
58. a. $4 \text{ Fe (s)} + 3 \text{ O}_2 \text{ (g)} \longrightarrow 2 \text{ Fe}_2\text{O}_3 \text{ (s)}$
 b. $\text{S}_8 \text{ (s)} + 8 \text{ O}_2 \text{ (g)} \longrightarrow 8 \text{ SO}_2 \text{ (g)}$
 c. $\text{Na}^+ \text{ (aq)} + \text{Cl}^- \text{ (aq)} \longrightarrow \text{NaCl (s)}$
 d. $\text{C}_2\text{H}_5\text{OH (l)} + 3 \text{ O}_2 \text{ (g)} \longrightarrow 2 \text{ CO}_2 \text{ (g)} + 3 \text{ H}_2\text{O (l)}$
 e. $2 \text{ H}_2\text{O (l)} \longrightarrow 2 \text{ H}_2 \text{ (g)} + \text{O}_2 \text{ (g)}$
 f. $2 \text{ H}_2 \text{ (g)} + \text{O}_2 \text{ (g)} \longrightarrow 2 \text{ H}_2\text{O (l)}$



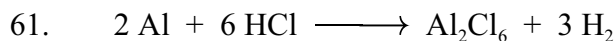
a. $0.50 \text{ mol S}_8 \times \frac{4 \text{ mol P}_4\text{S}_{10}}{5 \text{ mol S}_8} = 0.40 \text{ mol P}_4\text{S}_{10}$

b. $16.0 \text{ g S}_8 \times \frac{1 \text{ mol S}_8}{256.56 \text{ g S}_8} \times \frac{4 \text{ mol P}_4}{5 \text{ mol S}_8} = 4.99 \times 10^{-2} \text{ mol P}_4$



a. $0.219 \text{ mol NaN}_3 \times \frac{4 \text{ mol N}_2}{3 \text{ mol NaN}_3} = 0.292 \text{ mol N}_2$

b. $25.0 \text{ g N}_2 \times \frac{1 \text{ mol N}_2}{28.0134 \text{ g N}_2} \times \frac{3 \text{ mol NaN}_3}{4 \text{ mol N}_2} = 0.669 \text{ mol NaN}_3$



a. $25.0 \text{ g Al} \times \frac{1 \text{ mol Al}}{26.981538 \text{ g Al}} \times \frac{3 \text{ mol H}_2}{2 \text{ mol Al}} \times \frac{2.0158 \text{ g H}_2}{1 \text{ mol H}_2} = 2.80 \text{ g H}_2$

b. $1.00 \times 10^{24} \text{ molecules H}_2 \times \frac{1 \text{ mol H}_2}{6.022 \times 10^{23} \text{ molecules H}_2} \times \frac{2 \text{ mol Al}}{3 \text{ mol H}_2} \times \frac{26.981538 \text{ g Al}}{1 \text{ mol Al}} = 29.9 \text{ g Al}$



b. $210. \text{ g Fe} \times \frac{1 \text{ mol Fe}}{55.845 \text{ g Fe}} \times \frac{3 \text{ mol Br}_2}{2 \text{ mol Fe}} \times \frac{159.808 \text{ g Br}_2}{1 \text{ mol Br}_2} = 901 \text{ g Br}_2$

c. $210 \text{ g Fe} \times \frac{1 \text{ mol Fe}}{55.845 \text{ g Fe}} \times \frac{2 \text{ mol FeBr}_3}{2 \text{ mol Fe}} \times \frac{295.557 \text{ g FeBr}_3}{1 \text{ mol FeBr}_3} = 1.11 \times 10^3 \text{ g FeBr}_3$

d. $\% \text{theo. yield} = \frac{\text{mass FeBr}_3 \text{ recovered}}{\text{theo. yield FeBr}_3} \times 100\% = \frac{974 \text{ g}}{1.11 \times 10^3 \text{ g}} \times 100\% = 87.7\%$

63. a. Calculate the limiting reagent by using either of the following equations.

$$1.00 \text{ g Mg} \times \frac{1 \text{ mol Mg}}{24.305 \text{ g Mg}} \times \frac{1 \text{ mol N}_2}{3 \text{ mol Mg}} \times \frac{28.0134 \text{ g N}_2}{1 \text{ mol N}_2} = 0.384 \text{ g N}_2$$

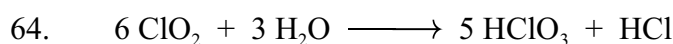
Therefore, 0.384 g of nitrogen gas is required for the complete reaction of 1.00 g of magnesium metal. Since 1.00 g N_2 is present, N_2 is in excess making the Mg the limiting reagent.

$$\underline{\text{OR}} \quad 1.00 \text{ g N}_2 \times \frac{1 \text{ mol N}_2}{28.0134 \text{ g N}_2} \times \frac{3 \text{ mol Mg}}{1 \text{ mol N}_2} \times \frac{24.305 \text{ g Mg}}{1 \text{ mol Mg}} = 2.60 \text{ g Mg}$$

Therefore, 2.60 g of magnesium metal are required for the complete reaction of 1.00 g of nitrogen gas. Since only 1.00 g of Mg is present, Mg is the limiting reagent.

$$\text{b. } 1.00 \text{ g Mg} \times \frac{1 \text{ mol Mg}}{24.305 \text{ g Mg}} \times \frac{1 \text{ mol Mg}_3\text{N}_2}{3 \text{ mol Mg}} \times \frac{100.928 \text{ g Mg}_3\text{N}_2}{1 \text{ mol Mg}_3\text{N}_2} = 1.38 \text{ g Mg}_3\text{N}_2$$

c. From part (a), 1.00 g Mg consumes 0.384 g N₂, thus, excess N₂ = 1.00 g – 0.384 g = 0.62 g N₂.



$$\text{a. } 14.3 \text{ g ClO}_2 \times \frac{1 \text{ mol ClO}_2}{67.452 \text{ g ClO}_2} \times \frac{5 \text{ mol HClO}_3}{6 \text{ mol ClO}_2} = 0.177 \text{ mol HClO}_3$$

$$\text{b. } 5.74 \text{ g HCl} \times \frac{1 \text{ mol HCl}}{36.461 \text{ g HCl}} \times \frac{3 \text{ mol H}_2\text{O}}{1 \text{ mol HCl}} \times \frac{18.0152 \text{ g H}_2\text{O}}{1 \text{ mol H}_2\text{O}} = 8.51 \text{ g H}_2\text{O}$$

c. Calculate the limiting reagent by using either of the following equations.

$$4.25 \text{ g ClO}_2 \times \frac{1 \text{ mol ClO}_2}{67.452 \text{ g ClO}_2} \times \frac{3 \text{ mol H}_2\text{O}}{6 \text{ mol ClO}_2} \times \frac{18.0152 \text{ g H}_2\text{O}}{1 \text{ mol H}_2\text{O}} = 0.568 \text{ g H}_2\text{O}$$

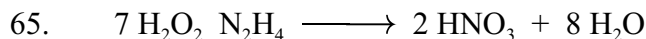
Therefore, 0.568 g of water is required for the complete reaction of 4.25 g of ClO₂. Since 0.853 g H₂O is present, H₂O is in excess making the ClO₂ the limiting reagent.

$$\underline{\text{OR}} \quad 0.853 \text{ g H}_2\text{O} \times \frac{1 \text{ mol H}_2\text{O}}{18.0152 \text{ g H}_2\text{O}} \times \frac{6 \text{ mol ClO}_2}{3 \text{ mol H}_2\text{O}} \times \frac{67.452 \text{ g ClO}_2}{1 \text{ mol ClO}_2} = 6.39 \text{ g ClO}_2$$

Therefore, 6.39 g of ClO₂ are required for the complete reaction of 0.853 g of water. Since only 4.25 g of ClO₂ are present, ClO₂ is the limiting reagent.

Thus, the yield of HClO₃ is based on the amount of ClO₂ present and not on the amount of water present.

$$4.25 \text{ g ClO}_2 \times \frac{1 \text{ mol ClO}_2}{67.452 \text{ g ClO}_2} \times \frac{5 \text{ mol HClO}_3}{6 \text{ mol ClO}_2} \times \frac{84.459 \text{ g HClO}_3}{1 \text{ mol HClO}_3} = 4.43 \text{ g HClO}_3$$

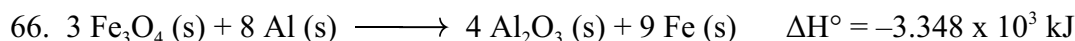


a. $0.0250 \text{ mol N}_2\text{H}_4 \times \frac{2 \text{ mol HNO}_3}{1 \text{ mol N}_2\text{H}_4} = 0.0500 \text{ mol HNO}_3$

b. $22.0 \text{ g N}_2\text{H}_4 \times \frac{1 \text{ mol N}_2\text{H}_4}{32.0450 \text{ g N}_2\text{H}_4} \times \frac{7 \text{ mol H}_2\text{O}_2}{1 \text{ mol N}_2\text{H}_4} = 4.80 \text{ mol H}_2\text{O}_2$

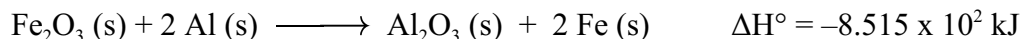
c. $1.87 \text{ mol HNO}_3 \times \frac{8 \text{ mol H}_2\text{O}}{2 \text{ mol HNO}_3} \times \frac{18.0153 \text{ g H}_2\text{O}}{1 \text{ mol H}_2\text{O}} = 135 \text{ g H}_2\text{O}$

d. $45.8 \text{ g HNO}_3 \times \frac{1 \text{ mol HNO}_3}{63.0128 \text{ g HNO}_3} \times \frac{7 \text{ mol H}_2\text{O}_2}{2 \text{ mol HNO}_3} \times \frac{34.0146 \text{ g H}_2\text{O}_2}{1 \text{ mol H}_2\text{O}_2} = 86.5 \text{ g H}_2\text{O}_2$



Since ΔH° is negative, the heat per mole of Fe liberated in this reaction is;

$$\frac{-\Delta H^\circ}{\# \text{ mol Fe}} = \frac{3348 \text{ kJ}}{9 \text{ mol Fe}} = 372.0 \text{ kJ/mol Fe}$$



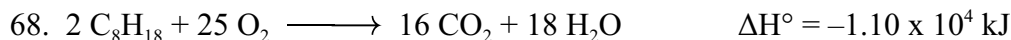
Since ΔH° is negative, the heat per mole of Fe liberated in this reaction is;

$$\frac{-\Delta H^\circ}{\# \text{ mol Fe}} = \frac{851.4 \text{ kJ}}{2 \text{ mol Fe}} = 425.7 \text{ kJ/mol Fe}$$



Since ΔH° is negative, heat will be liberated in this reaction.

$$10.0 \text{ g C}_2\text{H}_5\text{OH} \times \frac{1 \text{ mol C}_2\text{H}_5\text{OH}}{46.069 \text{ g C}_2\text{H}_5\text{OH}} \times \frac{1367 \text{ kJ}}{1 \text{ mol C}_2\text{H}_5\text{OH}} = 297 \text{ kJ}$$



Since ΔH° is negative, heat will be liberated in this reaction.

$$6.00 \text{ lb C}_8\text{H}_{18} \times \frac{453.6 \text{ g}}{1 \text{ lb}} \times \frac{1 \text{ mol C}_8\text{H}_{18}}{114.230 \text{ g C}_8\text{H}_{18}} \times \frac{1.10 \times 10^4 \text{ kJ}}{2 \text{ mol C}_8\text{H}_{18}} = 1.31 \times 10^5 \text{ kJ}$$

or $1.31 \times 10^5 \text{ kJ RELEASED}$



Since ΔH° is positive, heat will be absorbed in this reaction.

$$562.0 \text{ g Hg} \times \frac{1 \text{ mol Hg}}{200.59 \text{ g Hg}} \times \frac{181.7 \text{ kJ}}{2 \text{ mol Hg}} = 254.5 \text{ kJ} \quad \text{or } 254.5 \text{ kJ ABSORBED}$$

QUESTIONS INVOLVING SOLUTIONS

70. The liquid state is usually the easiest state in which to carry out reactions.

<u>Physical State</u>	<u>Advantages</u>	<u>Disadvantages</u>
Gas	Particles in rapid motion. Therefore, particle mix and react rapidly.	Gases occupy large volumes. Special container needed to contain gases.
Solid	Solids occupy small volumes. No special container needed.	Particle movement nearly absent. Therefore, reaction very slow.
Liquid	Particles in motion. Therefore, particles mix and react reasonably fast. Volumes occupied by liquids are almost as small as solids. No special equipment needed.	????????

71. A solution is defined as a **homogeneous mixture**. The definition does not specify the physical state. Thus, a solution may be a solid, liquid or a gas mixture (as long as it is homogeneous).
72. The two components of a solution are the solvent and the solute. The distinction between them is arbitrary. The distinction is often based on the relative amounts of the two components with the solvent being present in a larger amount. Sometimes, the difference is based on the final physical state of the mixture. For example, if one of the components is a solid and the other a liquid then the distinction is made based on the state of the mixture. If the mixture is a liquid then the solvent is considered to be the liquid. If the mix is a solid then the solid is the solvent.
73. Reactions are generally carried out in the liquid state for the advantages listed in problem 1. If one or more of the reactants are gases or solids, they are converted into a **liquid solution** by dissolving them into a liquid solvent.
74. Since chemicals combine by number and not by mass it follows that one would wish to determine the moles of the various reactants present in the reaction. Furthermore, since the most convenient property to measure for a liquid is volume (see reasons for using liquid solutions above), it follows that one would need a conversion factor to convert between the volume of liquid used and the moles of solute dissolved in the solution. Therefore, molarity (M) is the most convenient concentration unit for chemists.

75. $\text{Molarity (M)} = \frac{\text{moles of solute}}{\text{liters of solution}}$

76.
$$M = \frac{53.5 \text{ g C}_{12}\text{H}_{22}\text{O}_{11}}{746 \text{ mL soln}} \times \frac{1 \text{ mole C}_{12}\text{H}_{22}\text{O}_{11}}{342.299 \text{ g C}_{12}\text{H}_{22}\text{O}_{11}} \times \frac{1 \text{ mL soln}}{10^{-3} \text{ L soln}} = 0.210 \text{ M C}_{12}\text{H}_{22}\text{O}_{11}$$

77.
$$M = \frac{1.45 \text{ g KCl}}{50.0 \text{ mL soln}} \times \frac{1 \text{ mole KCl}}{74.551 \text{ g KCl}} \times \frac{1 \text{ mL soln}}{10^{-3} \text{ L soln}} = 0.389 \text{ M KCl}$$

78.
$$\text{g} = \frac{84.9947 \text{ g NaNO}_3}{1 \text{ mole NaNO}_3} \times \frac{1.00 \text{ mole NaNO}_3}{\text{L soln}} \times \frac{10^{-3} \text{ L soln}}{1 \text{ mL soln}} \times 75.0 \text{ mL soln} = 6.37 \text{ g NaNO}_3$$