CHM 1025
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. 3.1×10^{-3} m^2 e. 1×10^{1} $g^{2/3}$

6. a. 9.71×10^{-4} kg b. 8.2×10^{4} ms c. 1.23×10^{3} mm^2

   d. 213 cm^3 e. 0.0650 cm^{-1} f. 7.61×10^{3} mg/mL

7. a. $$\text{money lost} = \frac{\$1000}{\text{oz}} \times \frac{1.000\ \text{oz}}{28.35\ \text{g}} \times \frac{3\,\text{g (exactly)}}{1000\ \text{stones}} \times 50\ \text{stones} = \$5.29$$

   b. $$\text{The stones are worth: } \frac{\$1000}{28.35\ \text{g}} = \frac{\$35.27}{\text{g}}$$

   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:

   $$\text{the value of each stone} = \frac{\$1000}{\text{oz}} \times \frac{1.000\ \text{oz}}{28.35\ \text{g}} \times \frac{3\,\text{g (exactly)}}{1000\ \text{stones}} = \$0.1058/\text{stone}$$

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

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

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

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

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

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

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 gases 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 nonmetals 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 j. chemical

13. a. Extrinsic physical properties: "small crystals" and "powder"

Intrinsic physical properties: "colorless solid" and "density = 1.6 g/mL"

Intrinsic chemical properties: "chars or blackens with heat" and
"ignites and burns with a yellow flame"
(All chemical properties are intrinsic.)

b. Extrinsic physical properties: none

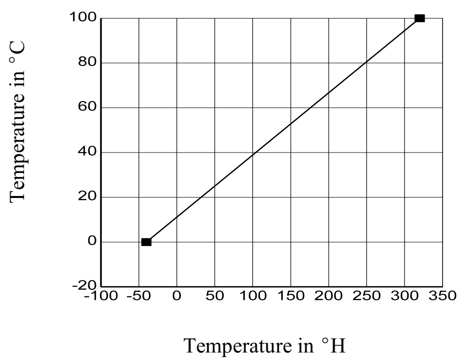
Intrinsic physical properties: "silver-white and soft" , "good conductor of electricity",
"BP = 883 °C" and "vapor is violet"

Intrinsic chemical properties: "prepared by electrolysis" , tarnishes in air" , and
"burns in air or in an atmosphere of bromine vapor"

14. a. 44 °F b. −28 °C c. 628 K d. −123 °C

e. 322 K f. −100 °F

15. 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

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

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

$$b = y - m \bullet x = (100°C) - (320°H) \times \frac{1°C}{3.6°H} = \frac{360°C}{3.6} - \frac{(320°C)}{3.6} = \frac{(40°C)}{3.6}$$

Thus, $y = m \bullet x = b$ becomes $°C = \frac{1°C}{3.6°H} \times °H + \frac{40\ °C}{3.6} \approx \frac{1°C}{3.6°H} \times °H + 11.111\ °C$

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

$$°C = \frac{1°C}{3.6°H} \times °H + \frac{40\ °C}{3.6} = \frac{1°C}{3.6°H} \times (°H + 40°H)$$

So to convert 100 °H to °C,

$$°C = \frac{1°C}{3.6°H} \times (100\ °H + 40°H) = \frac{140°C}{3.6} = 38.9\ °C$$

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.

16. a. endothermic b. endothermic c. exothermic
d. endothermic e. exothermic

17. As the dissolving process of solid Na_2CO_3 liberates heat and makes the solution hotter, the dissolution process is exothermic.

18. As the dissolving process of solid KNO_3 absorbs heat and makes the solution cooler, the dissolution process is endothermic.

QUESTIONS ON DENSITY

19. $$D = \frac{M}{V} = \frac{10.0 \text{ oz}}{(1.00 \text{ inch})^3} \times \frac{28.35 \text{ g}}{1 \text{ oz}} \times \left(\frac{1 \text{ inch}}{2.54 \text{ cm}}\right)^3 = 17.3 \text{ g/cm}^3$$

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

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

21. Since $D = \frac{M}{V}$ then $M = V \times D$

a. $6.00 \text{ cm}^3 \times 13.5939 \text{ g/cm}^3 = 81.6$ g Hg.

b. $4.00 \text{ cm}^3 \times 0.97 \text{ g/cm}^3 = 3.9$ g Na.

c. $125 \text{ mL} \times (1 \times 10^{-3} \text{ L/mL}) \times (3.16 \text{ g/L}) = 3.95 \times 10^{-1} \text{ g } Cl_2$

22. Since $D = \frac{M}{V}$ then $V = \frac{M}{D}$

a. $25 \text{ g} \div 4.93 \text{ g/mL} = 5.1 \text{ mL } I_2$

b. $3.28 \text{ g} \div 0.089 \text{ g/L} = 37 \text{ L } H_2$

c. $11.3 \text{ g} \div 2.25 \text{ g/cm}^3 = 5.02 \text{ cm}^3$ graphite

23. Volume metal = Vol(metal + H_2O) − Vol(H_2O) = 21.5 mL − 15.5 mL = 6.0 mL

$$\text{Density of metal} = \frac{\text{Mass metal}}{\text{Vol metal}} = \frac{20.12 \text{ g}}{6.0 \text{ mL}} = 3.4 \text{ g/mL}$$

24. Mass Toluene = Mass (cyl. & Toluene) − Mass(cyl.)

= 87.127 g − 57.832 g = 29.295 g

Therefore, Vol. Toluene = $29.295 \text{ g} \div 0.866 \text{ g/cm}^3 = 33.8 \text{ cm}^3$

25. Since the drop was lost in transferring the liquid from the buret to the flask the measured mass would be less than the actual mass and therefore the measured density (D = M/V) would also be less than the true density.

QUESTIONS ON FUNDAMENTAL LAWS OF CHEMISTRY

26. 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.

27. 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 GM_2
Finally, in compound III there is one part G and three parts M or a formula of GM_3.

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 GM_2 , compound II is GM_4 , and compound III is GM_6.

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 G_2M_5 , compound II is G_2M_{10} or GM_5 , and compound III is G_2M_{15}.

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 G_2M, and compound III is $GM_{1.5}$ or G_2M_3.

QUESTIONS ON FUNDAMENTAL SUBATOMIC PARTICLE

28. 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.

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

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

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

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

Note that this very small percentage 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.

30. a. The droplets carry different charges because there may be 1, 2, 3 or more extra 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: -9.6132×10^{-19} C / 2 e^- = -4.8066×10^{-19} C/e^- B: -14.4198×10^{-19} C / 3 e^- = -4.8066×10^{-19} C/e^-

C: -4.8066×10^{-19} C / 1 e^- = -4.8066×10^{-19} C/e^- D: -19.2264×10^{-19} C / 4 e^- = -4.8066×10^{-19} C/e^-

The value -4.8066×10^{-19} 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 other charge data are all multiples of the value 2.4033×10^{-19} C, 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 -1.6022×10^{-19} C!

31. a) -5.5×10^{-15} C ÷ (-1.60×10^{-19} C/e^-) = 3.4×10^4 e^-

b) -6.4×10^{-12} C ÷ (-1.60×10^{-19} C/e^-) = 4.0×10^7 e^-

32. a. No net charge

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

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

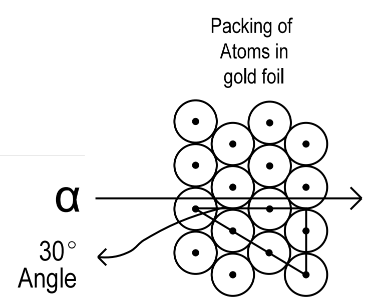
c. Each ${}^{22}_{10}Ne^{+2}$ ion has lost 2 e^- and therefore carries a positive charge which is twice that of the electron or 2 x (1.60×10^{-19} C). Thus the charge carried by 1.00×10^{12} ${}^{22}_{10}Ne^{+2}$ ions is:

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

33. 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.

34. 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.

35. 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 4×10^{-4} cm thick we can calculate the length of the hypotenuse of our triangle from the relationship:

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

Re-examine 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 x 10^4 atoms along the hypotenuse and therefore there must be 1.6 x 10^4 layers in the foil. So, the alpha particle must travel through 1.6 x 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 x 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?

36. $$r = \frac{d}{2} = \frac{1.5 \times 10^{-13}\ \text{cm}}{2} = 7.5 \times 10^{-14}\ \text{cm}$$

$$\text{Volume} = \frac{4}{3}\pi r^3 = \frac{4}{3}(3.1416)(7.5 \times 10^{-14}\ \text{cm})^3 = 1.7_7 \times 10^{-39}\ \text{cm}^3$$

$$\text{Density} = \frac{\text{mass}}{\text{volume}} = \frac{1.67 \times 10^{-24}\ \text{g}}{1.7_7 \times 10^{-39}\ \text{cm}^3} = 9.5 \times 10^{14}\ \text{g/cm}^3$$

As noted from the above calculation, the density of a proton is extremely large relative to the density of osmium (see problem 20). 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.

37. The completed table is:

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

38. The symbol Cl represents a chlorine atom. By definition, all atoms of chlorine have an atomic number of 17, ie., 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. ${}^{35}_{17}Cl$ and ${}^{35}Cl$ both represent the specific isotope of chlorine with a mass number of 35 (18 neutrons). ${}_{17}Cl$ differs from ${}^{35}_{17}Cl$ in that ${}_{17}Cl$ does not indicate a specific isotope. It may be assumed that ${}_{17}Cl$ represents a mixture of the two isotopes of chlorine ${}^{35}_{17}Cl$ and ${}^{37}_{17}Cl$) in the relative proportions found in nature.

39. ${}^{60}X$ and ${}^{60}Y$ 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.

40. Protium, ${}^{1}_{1}H$(the most abundant), has 1 proton and 1 electron.
Deuterium, ${}^{2}_{1}H$ or D, has 1 proton, 1 neutron, and 1 electron.
Tritium, ${}^{3}_{1}H$ 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.

41. ${}^{16}_{8}O$ and ${}^{18}_{8}O$ 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). ${}^{16}_{8}O$ and ${}^{18}_{8}O$ differ only in the number of neutrons in their nuclei, not a chemically important difference.

42. 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. ${}^{12}C$ is integral only because it has been arbitrarily set or defined at exactly 12 amu.

43. 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. 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)

44. 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

45. 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.

46. 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}).

47. 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).

48. 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.

49. 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).

50. a) The correct formula for carbon dioxide is CO_2 (NOT CO2).

    b) Mg^{+2} is a cation (NOT an anion).

    c) The molecule of H_2O actually contains two hydrogen atoms and one oxygen atom (NOT one hydrogen atom and two oxygen atoms).

    d) Sodium chloride is an ionic substance and therefore DOES NOT contain molecules. The formula unit of sodium chloride has a formula of NaCl.

    e) NH_3 is a molecule (NOT an ion; NH_3 has no charge).

QUESTIONS ON MOLES, FORMULAS AND PERCENT COMPOSITION

51. a. Fe, 55.845 g/mol b. N_2O_4 , 92.0110 g/mol

c. $(NH_4)_3AsO_4$, 193.0341 g/mol d. CO_3^{-2}, 60.009 g/mol

52. a. Fe, i) 55.845 amu ii) 55.845 amu x 1.66054 x 10^{-24} g/amu = 9.2733 x 10^{-23} g

$$\text{or} \quad 55.845 \text{ g/mol} \times \frac{1 \text{ mol}}{6.02214 \times 10^{23}} = 9.2733 \times 10^{-23} \text{ g}$$

b. N_2O_4, i) 92.0110 amu ii) 92.0110 amu x 1.66054 x 10^{-24} g/amu = 1.52788 x 10^{-22} g

$$\text{or} \quad 92.0110 \text{ g/mol} \times \frac{1 \text{ mol}}{6.02214 \times 10^{23}} = 1.52788 \times 10^{-22} \text{ g}$$

c. $(NH_4)_3AsO_4$, i) 193.0341 amu ii) 193.0341 amu x 1.66054 x 10^{-24} g/amu = 3.20541 x 10^{-22} g

$$\text{or} \quad 193.0341 \text{ g/mol} \times \frac{1 \text{ mol}}{6.02214 \times 10^{23}} = 3.20541 \times 10^{-22} \text{ g}$$

d. CO_3^{-2}, i) 60.009 amu ii) 60.009 amu x 1.66054 x 10^{-24} g/amu = 9.9647 x 10^{-23} g

$$\text{or} \quad 60.009 \text{ g/mol} \times \frac{1 \text{ mol}}{6.02214 \times 10^{23}} = 9.9647 \times 10^{-23} \text{ g}$$

53. a. $$37.5 \text{ g } H_2O \times \frac{1 \text{ mol}}{18.0152 \text{ g}} = 2.08 \text{ mol } H_2O$$

b. $$3.25 \times 10^{-2} \text{ mol } F^- \times \frac{18.998403 \text{ g}}{1 \text{ mol}} = 0.617 \text{ g } F^-$$

c. $$4.2 \text{ g } I_2 \times \frac{1 \text{ mol}}{253.80894 \text{ g}} \times \frac{6.022 \times 10^{23} \text{ molecules}}{1 \text{ mol}} = 1.0 \times 10^{22} \text{ molecules } I_2$$

d $$39.6 \text{ g } (NH_4)_2SO_4 \times \frac{1 \text{ mol}}{132.14 \text{ g}} \times \frac{6.022 \times 10^{23} \text{ For. Units}}{1 \text{ mol}} = 1.80 \times 10^{23} \text{ For. Units of } (NH_4)_2SO_4$$

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

f . $$4.5 \times 10^{25} \text{ molecules } S_8 \times \frac{1 \text{ mol}}{6.022 \times 10^{23} \text{ molecules}} = 75 \text{ mol } S_8$$

$$4.5 \times 10^{25} \text{ molecules } C_6H_{12}O_6 \times \frac{1 \text{ mol}}{6.022 \times 10^{23} \text{ molecules}} \times \frac{180.157 \text{ g}}{1 \text{ mol}} = 1.3 \times 10^{4} \text{ g of } C_6H_{12}O_6$$

h. $$0.25 \text{ mol } CaCl_2 \times \frac{6.022 \times 10^{23} \text{ For. Units}}{1 \text{ mol}} = 1.5 \times 10^{23} \text{ For. Units of } CaCl_2$$

54. a. $K_2Cr_2O_7$ %K = 26.58% %Cr = 35.35% %O = 38.07%

b. $C_{12}H_{22}O_{11}$ %C = 42.11% %H = 6.478% %O = 51.42%

55. a. $ZnSO_4{\cdot}7H_2O$ $\% \; H_2O = \dfrac{7 \times 18.0152 \text{ g}}{287.56_4 \text{ g}} \times 100\% = 43.853\%$

b. $NH_2CH_2CO_2H$ $\text{g N} = 30.0 \text{ g } NH_2CH_2CO_2H \times \dfrac{14.0067 \text{ g N}}{75.0670 \text{ g } NH_2CH_2CO_2H} = 5.60 \text{ g N}$

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

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

Therefore, the formula is $Xe_{0.482}F_{1.93}$ or $Xe_{\frac{0.482}{0.482}}F_{\frac{1.93}{0.482}}$ or $Xe_{1.00}F_{4.00}$ or XeF_4

b. Using a 100 g sample of the compound:

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

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

Therefore, the formula is $C_{5.045}H_{7.06}O_{2.018}$ or $C_{\frac{5.045}{2.018}}H_{\frac{7.06}{2.018}}O_{\frac{2.018}{2.018}}$ or $C_{2.500}H_{3.50}O_{1.000}$ or $C_5H_7O_2$

c. Using a 100 g sample of compound 1:

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

Therefore, the formula is $Ti_{1.25}O_{2.51}$ or $Ti_{\frac{1.25}{1.25}}O_{\frac{2.51}{1.25}}$ or TiO_2

Using a 100 g sample of compound 2:

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

Therefore, the formula is $Ti_{1.39}O_{2.09}$ or $Ti_{\frac{1.39}{1.39}}O_{\frac{2.09}{1.39}}$ or Ti_2O_3

57. 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,

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

CH_2 , empirical formula mass = 14.0 amu/FU

$$\frac{\text{molecular mass}}{\text{empirical formula mass}} = \frac{70 \text{ amu/molecule}}{14.0 \text{ amu/FU}} \approx 5 \text{ FU/molecule and } 5 \times (CH_2) = C_5H_{10}$$

CH_2O , empirical formula mass = 30.0 amu/FU

$$\frac{\text{molecular mass}}{\text{empirical formula mass}} = \frac{88 \text{ amu/molecule}}{30.0 \text{ amu/FU}} \approx 3 \text{ FU/molecule and } 3 \times (CH_2O) = C_3H_6O_3$$

$AlCl_3$, empirical formula mass = 133.3 amu/FU

$$\frac{\text{molecular mass}}{\text{empirical formula mass}} = \frac{267 \text{ amu/molecule}}{133.3 \text{ amu/FU}} \approx 2 \text{ FU/molecule and } 2 \times (AlCl_3) = Al_2Cl_6$$

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

$$C_{\frac{7.134}{7.134}}H_{\frac{14.20}{7.134}} = C_{1.000}H_{1.990} = CH_2 \text{ as the empirical formula}$$

$$\frac{\text{Mol. mass}}{\text{Emp. mass}} = \frac{56 \text{ amu/molecule}}{14.0 \text{ amu/FU}} \approx \frac{4 \text{ FU}}{\text{molecule}},\ 4[CH_2] = C_4H_8$$

$\therefore$ MM = 56.107 amu

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

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

$$C_{\frac{3.22}{3.22}}H_{\frac{9.6}{3.22}}O_{\frac{3.22}{3.22}} = C_{1.00}H_{3.0}O_{1.00} = CH_3O \text{ as the empirical formula}$$

$$\frac{\text{Mol. mass}}{\text{Emp. mass}} = \frac{60 \text{ amu/molecule}}{31 \text{ amu/FU}} \approx \frac{2 \text{ FU}}{\text{molecule}},\ 2[CH_3O] = C_2H_6O_2$$

$\therefore$ MM = 62.068 amu

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

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

$C_{\frac{4.91}{0.55}}H_{\frac{7.0}{0.55}}O_{\frac{1.64}{0.55}}N_{\frac{0.55}{0.55}} = C_{8.9}H_{13}O_{3.0}N_{1.0} = C_9H_{13}O_3N$ as the empirical formula

$\dfrac{\text{Mol. mass}}{\text{Emp. mass}} = \dfrac{182 \text{ amu/molecule}}{183.2 \text{ amu/FU}} \approx \dfrac{1 \text{ FU}}{\text{molecule}}$, $\therefore$ $C_9H_{13}O_3N$ is also the molecular formula

$\therefore$ MM = 183.207 amu

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

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

$C_{\frac{4.12}{1.03}}H_{\frac{5.11}{1.03}}N_{\frac{2.06}{1.03}}O_{\frac{1.03}{1.03}} = C_{4.00}H_{4.96}N_{2.00}O_{1.00} = C_4H_5N_2O$ as the empirical formula

$\dfrac{\text{Mol. mass}}{\text{Emp. mass}} = \dfrac{195 \text{ amu/molecule}}{97.10 \text{ amu/FU}} \approx \dfrac{2 \text{ FU}}{\text{molecule}}$, $2[C_4H_5N_2O] = C_8H_{10}N_4O_2$

$\therefore$ MM = 194.193 amu

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

$0.4780 \text{ g N} \times \dfrac{1 \text{ mol}}{14.0067 \text{ g}} = 0.03413 \text{ mol N}$; $1.365 \text{ g O} \times \dfrac{1 \text{ mol}}{15.9994 \text{ g}} = 0.8532 \text{ mol O}$

$C_{\frac{0.1365}{0.03413}}H_{\frac{0.1024}{0.03413}}N_{\frac{0.03413}{0.03413}}O_{\frac{0.08532}{0.03413}} = 2[C_{3.999}H_{3.000}N_{1.000}O_{2.500}] = C_8H_6N_2O_5$ as the emp. form.

$\dfrac{\text{Mol. mass}}{\text{Emp. mass}} = \dfrac{420 \text{ amu/molecule}}{210.1 \text{ amu/FU}} \approx \dfrac{2 \text{ FU}}{\text{molecule}}$, $2[C_8H_6N_2O_5] = C_{16}H_{12}N_4O_{10}$

$\therefore$ MM = 420.292 amu