Chapter 1

Early Experiments

1. Distinguish between a qualitative observation and a quantitative observation. Give two examples of each.

qualitative observation - An observation of an object, property, or phenomenon which not measured or quantified (involves no numbers). Examples: a) the rock is heavy; b) the water sample contains a small amount of benzene; c) upon burning magnesium in air, a solid white residue was formed.

quantitative observation - one in which an object, property, or phenomenon or object is measured or quantified. Examples: a) the rock weighs 79.3 kg; b) the concentration of benzene in the water sample is 2.3 x 10^{-7} mol/liter; c) upon burning 10.0 g of magnesium in air, 16.6 g of a solid white residue was formed.

3. Indicate whether each of the following represents a mixture of atoms, a mixture of molecules, or a mixture of atoms and molecules. Is each a mixture of elements, compounds, or elements and compounds?

a) Each unit contains only a single atom, so it is a mixture of atoms and elements.

b) Single spheres are atoms and elements, two bound spheres are molecules. Molecules of two blue spheres contain only one atom type, so they are elements. Molecules of blue and red spheres contain different atom types, so they are compounds.

c) The single spheres are atoms and elements. The units containing a green and a yellow sphere are molecules or compounds.

d) All units contain more than one sphere and are molecules. Some are composed of the same atom type (blue) and are elements, but others contain different atom types (yellow and green) and are compounds.

5. Classify each of the following as an element or compound:

a) P_4 - element **b) Fe -** element **c) C_3H_6O -** compound **d) SO_2 -** compound **e) O_3 -** element

7. Classify each of the following as an atom or a molecule:

a) P_4 - molecule **b) Fe -** atom **c) C_3H_6O -** molecule **d) SO_2 -** molecule **e) O_3 -** molecule

9. Classify each of the following as an atom, molecule, anion or cation:

a) NH_3 - molecule **b) NH_4^{1+} -** cation **c) N^{3-} -** anion **d) CH_3COO^{1-} -** anion **e) Si -** atom

11. Give the name of each of the following elements:

a) Na - sodium **b) Br -** bromine **c) Hg -** mercury **d) Fe -** iron **e) Ag -** silver

13. Write the symbol for each of the following elements:

a) copper - Cu **b) lead** - Pb **c) strontium** – Sr **d) silicon** - Si **e) tin** - Sn

15. Determine the number of moles of atoms that are present in each of the following samples:

a) 5.0 g K $5.0\text{ g K}\times\frac{1\text{ mol K}}{39.1\text{ g K}} = 0.13\text{ mol K}$

b) 17 g Mg $17\text{ g Mg}\times\frac{1\text{ mol Mg}}{24.3\text{ g Mg}} = 0.70\text{ mol Mg}$

c) 3.0 g C $3.0\text{ g C}\times\frac{1\text{ mol C}}{12.0\text{ g C}} = 0.25\text{ mol C}$

d) 2.2 kg Fe $2.2\text{ kg Fe}\times\frac{1000\text{ g Fe}}{1\text{ kg Fe}}\times\frac{1\text{ mol Fe}}{55.85\text{ g Fe}} = 39\text{ mol Fe}$

e) 14 mg Ag $14\text{ mg Ag}\times\frac{1\text{ g Ag}}{1000\text{ mg Ag}}\times\frac{1\text{ mol Ag}}{108\text{ Ag}} = 1.3\times10^{-4}\text{ mol}$

17. How many moles of molecules are in a 10.0-g sample of each of the following compounds? How many moles of atoms are in each sample?

a) SF_6 $10.0\text{ g}\times\frac{1\text{ mol }SF_6}{146\text{ g}} = 0.0685\text{ mol }SF_6;\quad 0.0685\text{ mol }SF_6\times\frac{7\text{ mol atoms}}{1\text{ mol }SF_6} = 0.480\text{ mol atoms}$

b) CCl_4 $10.0\text{ g}\times\frac{1\text{ mol }CCl_4}{154\text{ g}} = 0.0649\text{ mol }CCl_4;\quad 0.0649\text{ mol }CCl_4\times\frac{5\text{ mol atoms}}{1\text{ mol }CCl_4} = 0.325\text{ mol atoms}$

c) C_6H_{14} $10.0\text{ g}\times\frac{1\text{ mol }C_6H_{14}}{86.2\text{ g}} = 0.116\text{ mol }C_6H_{14};\quad 0.116\text{ mol }C_6H_{14}\times\frac{20\text{ mol atoms}}{1\text{ mol }C_6H_{14}} = 2.32\text{ mol atoms}$

d) SO_3 $\quad 10.0\text{ g} \times \frac{1\text{ mol } SO_3}{80.0\text{ g}} = 0.125\text{ mol } SO_3$; $\quad 0.125\text{ mol } SO_3 \times \frac{4\text{ mol atoms}}{1\text{ mol } SO_3} = 0.500\text{ mol atoms}$

e) BF_3 $\quad 10.0\text{ g} \times \frac{1\text{ mol } BF_3}{67.8\text{ g}} = 0.148\text{ mol } BF_3$; $\quad 0.148\text{ mol } BF_3 \times \frac{4\text{ mol atoms}}{1\text{ mol } BF_3} = 0.590\text{ mol atoms}$

19. Determine the mass of the following samples.

a) 2.5 mol $CaCl_2$ $\quad 2.5\text{ mol } CaCl_2 \times \frac{111\text{ g}}{1\text{ mol } CaCl_2} = 2.8 \times 10^2\text{ g} = 0.28\text{ kg}$

b) 0.75 mol C_6H_{12} $\quad 0.75\text{ mol } C_6H_{12} \times \frac{84\text{ g}}{1\text{ mol } C_6H_{12}} = 63\text{ g}$

c) 1.8 mol CO_2 $\quad 1.8\text{ mol } CO_2 \times \frac{44\text{ g}}{1\text{ mol } CO_2} = 79\text{ g}$

21. Consider a 5.00-g sample of Ca_2S_3.

a) How many moles of Ca_2S_3 does it contain?

M_m = (2 mol Cal)(40.0 g/mol) + (3 mol S)(32.0 g/mol) = 176 g/mol

$$n = 5.00\text{ g } Ca_2S_3 \times \frac{1\text{ mol } Ca_2S_3}{176\text{ g } Ca_2S_3} = 0.0284\text{ mol } Ca_2S_3$$

b) How many moles of sulfur does it contain? $\quad 0.0284\text{ mol } Ca_2S_3 \times \frac{3\text{ mol S}}{1\text{ mol } Ca_2S_3} = 0.0852\text{ mol S}$

c) How many grams of sulfur does it contain? $\quad 0.0852\text{ mol S} \times \frac{32.0\text{ g S}}{\text{mol S}} = 2.73\text{ g S}$

23. Balance the following equations using the smallest integer coefficients:

a) $N_2 + H_2 \rightarrow NH_3$ $\quad N_2 + 3H_2 \rightarrow 2NH_3$

b) $C_2H_6 + O_2 \rightarrow CO_2 + H_2O$ $\quad 2C_2H_6 + 7O_2 \rightarrow 4CO_2 + 6H_2O$

c) $Al + O_2 \rightarrow Al_2O_3$ $\quad 4Al + 3O_2 \rightarrow 2Al_2O_3$

d) $CO_2 + H_2O \rightarrow C_6H_{12}O_6 + O_2$ $\quad 6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$

e) $P_4O_{10} + H_2O \rightarrow H_3PO_4$ $\quad P_4O_{10} + 6H_2O \rightarrow 4H_3PO_4$

f) $Ca + O_2 \rightarrow CaO$ $\quad 2Ca + O_2 \rightarrow 2CaO$

25. Consider the reaction of 0.30 mol K with O_2, $4K + O_2 \rightarrow 2K_2O$

a) How many moles of molecular oxygen are required? $\quad 0.30\text{ mol K} \times \frac{1\text{ mol } O_2}{4\text{ mol K}} = 0.075\text{ mol } O_2$

b) How many moles of potassium oxide would form? $\quad 0.30\text{ mol K} \times \frac{2\text{ mol } K_2O}{4\text{ mol K}} = 0.15\text{ mol } K_2O$

c) What mass, in grams, of potassium oxide would form?

M_m = 2 mol K x 39.1 g/mol + 1 mol O x 16.0 g/mol = 94.2 g/mol

$$0.15\text{ mol } K_2O \times \frac{94.2\text{ g } K_2O}{\text{mol } K_2O} = 14\text{ g } K_2O$$

27. The green molecules (G_2) react with the blue molecules (B_2) to form molecules of G_3B in the container shown in the text. Each circle represents one mole of the atom, and the atomic masses of G and B are 10 and 30, respectively.

a) How many grams of G_2 and B_2 are in the container?

The molar mass of G_2 = 2(10) = 20 g/mol. There are 6 mol, so the mass of G_2 is (6 mol)(20 g/mol) = 120 g

The molar mass of B_2 = 2(30) = 60 g/mol. There are 3 mol, so the mass of B_2 is (3 mol)(60 g/mol) = 180 g

b) How many G_3B molecules can be produced?

There are 6 mol G_2 or 12 mol G atoms, which is enough to produce 4 mol G_3B molecules. There are 6 mol B atoms, which is enough to proude 6 mol of G_3B molecules. Thus G_2 is the limiting reactant and only 4 mol G_3B can be produced.

c) What is the balanced chemical equation for the reaction?

$3G_2 + B_2 \rightarrow 2G_3B$

d) How many grams of G_3B would be produced?

The molar mass of G_3B is 3(10) + 30 = 60 g/mol. In part b, we saw that 4 mol is produced, so the mass is (4 mol)(60 g/mol) = 240 g G_3B

e) What mass of G_2 or B_2 molecules would be left over?

G_2 is the limiting reactant, so no G_2 remains. Use the balanced equation to determine how many moles of B_2 would react with 6 mol G_2.

$6\,\text{mol}\,G_2 \times \frac{1\,\text{mol}\,B_2}{3\,\text{mol}\,G_2} = 2\,\text{mol}\,B_2$ react , so 3 – 2 = 1 mol remains or 60 g B_2 remains.

Note that conservation of mass is obeyed:

initial mass = 120 g G_2 + 180 g B_2 = 300 g; final mass = 240 g G_3B + 60 g B_2 = 300 g.

29. Consider the reaction of 6 mol Fe and 6 mol O_2 to produce Fe_3O_4.

a) Write the balanced chemical equation.

$3Fe + 2O_2 \rightarrow Fe_3O_4$

b) How many moles of Fe_3O_4 could be produced?

$6\,\text{mol}\,Fe \times \frac{1\,\text{mol}\,Fe_3O_4}{3\,\text{mol}\,Fe} = 2\,\text{mol}\,Fe_3O_4$; $6\,\text{mol}\,O_2 \times \frac{1\,\text{mol}\,Fe_3O_4}{2\,\text{mol}\,O_2} = 3\,\text{mol}\,Fe_3O_4$

Less can be made from Fe, so it is the limiting reactant and 2 mol Fe_3O_4 can be produced.

c) How many moles of excess reactant remain after the reaction is done?

Determine how much O_2 is needed to react with the Fe: $6\,\text{mol}\,Fe \times \frac{2\,\text{mol}\,O_2}{3\,\text{mol}\,Fe} = 4\,\text{mol}\,O_2$ react

There were 6 mol O_2 initially and 4 mol react, so 2 mol O_2 is left over.

31. Use Coulomb's law to explain why Na^{1+} ions and the Cl^{1-} ions exist as separated ions in liquid water (ε = 79) but pair together as uncharged NaCl units in liquid carbon tetrachloride (ε = 2).

The force of attraction between the opposite charges is given by Coulomb's law to be $F \propto \frac{(+1)(-1)}{\varepsilon r^2}$. The greater the force of attraction, the more likely it is that the charges will pair. The value of e in water is about 40 times greater than in carbon tetrachloride. This means that the ions are 40 times more likely to pair in carbon tetrachloride than in water, or that the distance between the ions in carbon tetrachloride must be $\sqrt{40}$ ~ 6 times greater than in water to experience the same force of attraction.

33. What is the charge in coulombs of a mole of electrons? (This amount of charge is called a Faraday.) The charge of an electron from Table 1.1 is -1.6×10^{-19} C

$$-\frac{1.6\times10^{-19}\ \text{C}}{\text{electron}} \times \frac{6.0\times10^{23}\ \text{electrons}}{\text{mol electrons}} = -9.6\times10^{4}\ \text{C/mol}$$

35. List the following systems of charged particles from most negative to most positive energies of interaction. Also list the forces from most attractive to most repulsive.

Use Equations 1.3 and 1.4, but we need only relative values. Therefore, k and ε can be ignored because they are constant. The charges are all multiples of the fundamental charge ($1.6\text{x}10^{-19}$ C) and can be used without conversion. Finallly, all r values have the same units, so they do not have to be converted to meters.

a) +2 and +2 charges separated by 10 nm $F_a \propto (+2)(+2)/10^2 = +0.0400$ $E_a \propto (+2)(+2)/10 = +0.40$

b) -2 and +3 charges separated by 11 nm $F_b \propto (-2)(+3)/11^2 = -0.0496$ $E_b \propto (-2)(+3)/11 = -0.545$

c) +2 and +1 charges separated by 6 nm $F_c \propto (+2)(+1)/6^2 = +0.0556$ $E_c \propto (+2)(+1)/6 = +0.33$

Energy: most negative = E_b, E_c, E_a = most positive. Force: most attractive = F_b, F_a, F_c = most repulsive

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37. Why did not the oil droplets in Millikan's experiment all have the same charge? What did the charges all have in common?

The number of electrons that adhered to the droplet varied, so the charge on the droplets also varied. The observed charges were all multiples of one number, the charge on the electron.

39. The deflection of an X^{1+} ion in an electric field is 14% of that of an α-particle. What is the identity of X? An α-particle is $^4He^{2+}$.

deflection of X^{1+} = 0.14 x deflection of $^4He^{2+}$, so

$$\left(\frac{q}{m}\right)_X = 0.14\times\left(\frac{q}{m}\right)_{He} = 0.14\times\frac{2}{4} = 0.0070$$

$$\frac{1}{m_X} = 0.070 \Rightarrow m_X = \frac{1}{0.070} = 14,$$

so X has an atomic mass of 14. Therefore, X is a nitrogen atom.

41. Use Figure 1.7 and the periodic law to determine the formulas of the oxides of the following elements:

- **a) phosphorus** 2.5 O atoms for each P atom, so the formula is P_2O_5.
- **b) arsenic** As is in the same group as P, so the formula is predicted to be As_2O_5 by analogy.
- **c) selenium** Se is in the same group as S, so there are two O atoms for each Se or SeO_2.
- **d) carbon** Two oxygens per carbon yield a formula of CO_2.
- **e) cesium** Cs is in the same family as Na and K, which combine with O in a 1:2 ratio, so the formula is Cs_2O.

43. Predict the following formulas based on periodic behavior.

a) the compound formed between Pb and Cl, given the formulas TlCl and $BiCl_3$

Pb falls between Tl and Bi on the periodic table so the number of chlorine atoms per lead atom is predicted to be between the 1:1 and 3:1 ratios of the given compounds. Consequently, the formula is $PbCl_2$

b) the compound formed between Sc and Br, given the formulas KBr and $CaBr_2$

Sc is after Ca so the Sc:Br ratio should be the one following the trend of 1:1 and 1:2. The formula should be $ScBr_3$.

45. Determine the number of protons, neutrons and electrons in each of the following:

	protons	neutrons	electrons
a) $^{16}O^{2-}$	8	16 - 8 = 8	8 + 2 = 10
b) $^{27}Al^{3+}$	13	27 - 13 = 14	13 - 3 = 10
c) ^{25}Mg	12	25 -12 = 13	12 + 0 = 12
d) ^{19}F	9	19 - 9 = 10	9 + 0 = 9
e) $^{48}Ti^{4+}$	22	48 - 22 = 26	22 - 4 = 18
e) $^{207}Pb^{2+}$	82	207 - 82 = 125	82 - 2 = 80

47. Write the symbol for the species with the number of protons (p) and electrons (e) shown below.

a) 34 p + 36 e = Se^{2-} **b) 26 p + 23 e** = Fe^{3+} **c) 47 p + 47 e** = Ag

49. Distinguish between a group and a period. How are the properties of the elements in each related?

group (or family) - one of the vertical columns in the Periodic Table. Elements within a group exhibit similar chemical properties

period - one of the horizontal rows in the Periodic Table. As one progresses across the elements in a period, properties change gradually from one extreme to another.

51. Identify each of the following elements:

- **a) metalloid in the same family as gallium** B
- **b) nonmetal in the same family as germanium** C
- **c) gas in the fifth period** Xe
- **d) halogen in the same period as lead** At
- **e) only metal in the same group as sulfur** Po

53. Group the following elements in pairs that are likely to have similar chemical properties: Ca, S, Sr, He, O, Ar.

Elements in a family are similar: Ca & Sr (2A) S & O (6A) He & Ar (8A)