

Chapter 1

The Nature and Conceptual Basis of Chemistry

- 1.2 “Absolute” means pure, so absolute alcohol is a substance; milk is a mixture; copper wire is a substance. Rust is a mixture (the reason for this answer is discussed on text page 7 with respect to salt / sodium chloride). Barium bromide is a substance. Concrete, baking soda, and baking powder are all mixtures. Absolute alcohol and barium bromide are compounds; copper wire is an element. All of the mixtures are heterogeneous.
- 1.4 Proving that a material is *not* an element requires finding a method, any one method, that successfully breaks it down into simpler substances. Proving that a material *is* an element requires the proof of a negative: that there is no way to break it down. Mistaken reports of new elements arise when a compound or mixture resists breakdown by all of the methods tried but subsequently proves decomposable by new methods.
- 1.6 The ratio of the mass of tellurium to the mass of hafnium in this compound is

$$\frac{m_{\text{Te}}}{m_{\text{Hf}}} = \frac{31.5 \text{ g Te}}{25.0 \text{ g Hf}} = \frac{1.26 \text{ g Te}}{\text{g Hf}}$$

Because the compound from the rock is identical, it contains Te and Hf in the same ratio.

$$m_{\text{Te}} = 0.125 \text{ g Hf} \times \left(1.26 \frac{\text{g Te}}{\text{g Hf}} \right) = 0.158 \text{ g Te}$$

The compound may of course contain other elements.

- 1.8 a) The mass of fluorine that combines with 1.0000 g of iodine in these compounds is the mass percentage of fluorine divided by the mass percentage of iodine. This is well shown by considering samples of the compounds that have masses of 100.000 g. The masses contributed by each element in the compounds are then very easily computed. The ratios in the last column of the following table, which are formed by the indicated divisions, are the answers.

Compound 1	13.021 g F / 86.979 g I	0.14970 g F / g I
Compound 2	30.993 g F / 69.007 g I	0.44913 g F / g I
Compound 3	42.809 g F / 57.191 g I	0.74853 g F / g I
Compound 4	51.171 g F / 48.829 g I	1.04796 g F / g I

b) The law of multiple proportions involves the ratio of these ratios. Divide all four of the answers in part a) by the smallest of the answers. The results are: 1.0000 for compound 1; 3.0002 for compound 2; 5.0002 for compound 3; 7.0004 for compound 4. These equal the small whole numbers 1, 3, 5, and 7 within the precision of the data.

1.10 As in problem 1.8, calculate the masses of chlorine per gram of tungsten in the four compounds:

Compound 1	27.83 g Cl / 72.17 g W	0.3856 g Cl / g W
Compound 2	43.55 g Cl / 56.45 g W	0.7715 g Cl / g W
Compound 3	49.09 g Cl / 50.91 g W	0.9643 g Cl / g W
Compound 4	53.64 g Cl / 46.36 g W	1.1570 g Cl / g W

The ratios of each mass of chlorine to the smallest mass of chlorine are

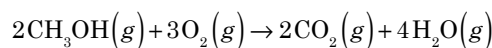
$$0.3856/0.3856 = 1.0000 = 2 : 2 \quad 0.7715/0.3856 = 2.0008 = 4 : 2$$

$$0.9643/0.3856 = 2.5008 = 5 : 2 \quad 1.1570/0.3856 = 3.0005 = 6 : 2$$

The formulas are WCl_2 , WCl_4 , WCl_5 , and WCl_6 .

1.12 The *only* products are gaseous N_2 and gaseous H_2 . From the formula of the starting compound there are twice as many molecules of H_2 as of N_2 in the products. The law of combining volumes (or, in this case, the law of “uncombining” volumes) then assures that the volume of hydrogen is twice the volume of nitrogen as long as the temperature and pressure remain unchanged. The answer is 27.4 mL.

1.14 The balanced chemical equation for this reaction is



2.0 L of CO_2 and 4.0 L of H_2O are produced from 2.0 L of CH_2OH , according to the law of combining volumes (and under the assumption that the reaction goes to completion as written).

1.16 To solve for the y -component of the velocity of the electron, start with Equation 1.4:

$$\frac{1}{2} a_y t^2 = \frac{1}{2} \left(\frac{e}{m_e} \right) \left(\frac{l}{|v_x|} \right)^2 E$$

Now substitute $a_y = \Delta v_y / \Delta t$:

$$\frac{1}{2} \left(\frac{\Delta v_y}{\Delta t} \right) t^2 = \frac{1}{2} \left(\frac{e}{m_e} \right) \left(\frac{l}{|v_x|} \right)^2 E$$

Define the time at which the electron just enters the left side of the deflection plate as t_0 and arbitrarily set this time equal to zero. At the entry point, the electron's velocity solely lies along the x -axis, therefore the initial y -component of the velocity, $v_{y,0}$, is also equal to zero. When the electron exits the plate region at time t , its velocity has a non-zero y -component, v_y . Taking this into consideration, we can write the y -component of the acceleration as:

$$a_y = \frac{\Delta v_y}{\Delta t} = \frac{v_y - v_{y,0}}{t - t_0} = \frac{v_y - 0}{t - 0} = \frac{v_y}{t}$$

Substituting, we get:

$$\frac{1}{2} \left(\frac{v_y}{t} \right) t^2 = \frac{1}{2} \left(\frac{e}{m_e} \right) \left(\frac{l}{|v_x|} \right)^2 E$$

$$v_y t = \left(\frac{e}{m_e} \right) \left(\frac{l}{|v_x|} \right)^2 E$$

$$v_y = \left(\frac{e}{m_e} \right) \left(\frac{l}{|v_x|} \right)^2 \frac{E}{t}$$

If we approximate the time spent in the plate region as:

$$t = \frac{l}{|v_x|}$$

where we take $|v_x|$ as the initial electron velocity, one last substitution yields:

$$\begin{aligned} v_y &= \left(\frac{e}{m_e} \right) \left(\frac{l}{|v_x|} \right)^2 \frac{E}{(l/|v_x|)} \\ &= \left(\frac{e}{m_e} \right) \left(\frac{l}{|v_x|} \right) E \end{aligned}$$

Solve for v_y by substituting the appropriate values:

$$v_y = (1.602 \times 10^{-19} \text{ C} / 9.109 \times 10^{-31} \text{ kg}) \times (0.10 \text{ m} / |8.00 \times 10^6 \text{ m s}^{-1}|) \times 200 \text{ V m}^{-1} = 4.40 \times 10^5 \text{ m s}^{-1}$$

Because the deflection in the y direction is negative, the y -component of the velocity must also be negative, therefore $v_y = -4.40 \times 10^5 \text{ m s}^{-1}$.

Strictly speaking, this is an approximation. The time spent in the plate region is actually just a little longer because of the curved path the electron takes. To check the change in the x -component of the velocity, we can use the relationship:

$$\begin{aligned} v^2 &= v_x^2 + v_y^2 \\ v_x^2 &= v^2 - v_y^2 \\ v_x &= \pm \sqrt{v^2 - v_y^2} \end{aligned}$$

Letting $v = 8.00 \times 10^6 \text{ m s}^{-1}$ (the electron velocity before it enters the plate region) and $v_y = -4.40 \times 10^5 \text{ m s}^{-1}$, we get $v_x = 7.99 \times 10^6 \text{ m s}^{-1}$. This is less than a 1% error, so our assumptions above are not bad!

Now we address the ratio of S/L and its relationship to v_x and v_y if v_y is calculated at the right edge of the plates. Once the electron leaves the plate region, it is no longer subject to a force acting on it. As such, the electron moves in straight line motion with constant velocity components v_x and v_y . Taking t_f to be the time of flight between the right edge of the plate and the fluorescent screen, the electron will travel a distance of $v_x t_f$ in the x -direction and a distance of $v_y t_f$ in the y -direction. With respect to the distances shown in Figure 1.11, the amount of travel in the x -direction between the right edge of the plate and the screen is $L - l/2$. In the y -direction, the distance is $S - D$. We thus have the following relationships:

$$\begin{aligned} v_x t_f &= L - \frac{l}{2} \\ v_y t_f &= S - D \end{aligned}$$

Rearranging:

$$\begin{aligned} v_x t_f + \frac{l}{2} &= L \\ v_y t_f + D &= S \end{aligned}$$

Taking the ratio of S/L :

$$\frac{S}{L} = \frac{v_y t_f + D}{v_x t_f + l/2}$$

- 1.18** The atomic mass of naturally occurring neon is found by multiplying each isotope's fractional abundance by its mass and summing over all the isotopes

$$\begin{aligned} A &= A_1 p_1 + A_2 p_2 + \dots + A_n p_n \\ A_{\text{Ne}} &= (0.9000)(19.99212) + (0.0027)(20.99316) + (0.0973)(21.99132) = 20.19 \end{aligned}$$

- 1.20** This problem resembles problem **1.16**, except that the atomic mass of one of the five isotopes of Zr is not known and the weighted-average atomic mass of natural zirconium (91.224) is known. Obtain the natural abundance of the isotope of interest by subtraction

$$p(^{90}\text{Zr}) = 1 - 0.1127 - 0.1717 - 0.1733 - 0.0278 = 0.5145$$

Let the relative mass of this isotope be A_{90} . Then

$$91.224 = 0.5145A_{90} + 0.1127(90.9056) + 0.1717(91.9050) + 0.1733(93.9063) + 0.0278(95.9083)$$

$$A_{90} = 89.91$$

- 1.22 a)** Promethium has an atomic number of 61; the ratio of the number of neutrons to protons in ^{145}Pm is $(145 - 61)/61 = 1.377$.
b) A neutral atom of Pm has 61 electrons.
- 1.24** The $^{266}_{109}\text{Mt}$ atom has 109 protons, 109 electrons, and 157 neutrons.
- 1.26** Avogadro's number of ^{12}C atoms has a mass of exactly 12 g. By use of the ratio given in the problem, Avogadro's number of F atoms must have a mass of 18.998403 g. For 100 million atoms of fluorine

$$m_{\text{F}} = 10^8 \text{ atoms F} \times \left(\frac{18.998403 \text{ g F}}{6.0221420 \times 10^{23} \text{ atom F}} \right) = 3.1547584 \times 10^{-15} \text{ g F}$$

- 1.28** The problem is about handling the nesting of parentheses in chemical formulas when computing molecular masses, formula masses, and molar masses. The answers: **a)** 177.382; **b)** 598.156; **c)** 254.2; **d)** 98.079; **e)** 450.446. These are relative masses and so have no units.
- 1.30** There are Avogadro's number of gold atoms in a mole of gold, each with a diameter of $2.88 \times 10^{-10} \text{ m}$. The length of the line is $(6.022 \times 10^{23})(2.88 \times 10^{-10} \text{ m}) = 1.73 \times 10^{14} \text{ m}$.
- 1.32** Express the amounts of each sample in the same unit of mass. In the case of the SF_4 , convert from the given number of moles to grams using the molar mass. In the cases of the Cl_2O_7 and Ar, convert from the given number of particles to chemical amount and from there to mass. The amount of CH_4 is already in grams. The results are

$$\text{SF}_4(115 \text{ g}) < \text{CH}_4(117 \text{ g}) < \text{Cl}_2\text{O}_7(264 \text{ g}) < \text{Ar}(2770 \text{ g})$$

- 1.34**

$$10.0 \text{ cm}^3 \text{ Au} \times \left(\frac{19.32 \text{ g Au}}{1 \text{ cm}^3 \text{ Au}} \right) \times \left(\frac{1 \text{ troy ounce}}{31.1035 \text{ g Au}} \right) \times \left(\frac{\$400}{1 \text{ troy ounce}} \right) = \$2.4846 \times 10^3$$

The cost to three significant figures is \$2.480.

- 1.36**

$$N_{\text{Si}} = 415 \text{ cm}^3 \times \frac{0.00278 \text{ g}}{1 \text{ cm}^3} \times \frac{1 \text{ mol Si}_2\text{H}_6}{62.219 \text{ g Si}_2\text{H}_6} \times \frac{6.022 \times 10^{23} \text{ molecule Si}_2\text{H}_6}{1 \text{ mol Si}_2\text{H}_6}$$

$$\times \frac{2 \text{ atoms Si}}{1 \text{ molecule Si}} = 2.23 \times 10^{22} \text{ atom Si}$$

- 1.38 a) As suggested in the hint, look at *differences* in charge. List the droplets in order of increasing charge and compute the amount by which each differs in charge from its predecessor

Droplet No.	Charge/ 10^{-19} C	Difference/ 10^{-19} C	No. e^- on droplet
1	6.563	—	4
2	8.204	1.641	5
3	11.50	3.296	7
4	13.13	1.63	8
5	16.48	3.35	10
6	18.08	1.60	11
7	19.71	1.63	12
8	22.89	3.18	14
9	26.18	3.29	16

Moving down the list, the charges on the droplets increase by either 1 or 2 times 1.64×10^{-19} C. This suggests that a fundamental unit of charge exists and is approximately equal to 1.64×10^{-19} C. Dividing this quantity into the nine observed charges gives results that are all very close to whole numbers. Take these whole numbers to equal the number of the fundamental units of charge (electrons) on each droplet.

b) Divide the observed charge on each droplet by the apparent number of electrons on that droplet (that is, divide column 2 by column 4 in the preceding):

$$\begin{array}{lll}
 1. 1.6407 \times 10^{-19} \text{ C} & 4. 1.6413 \times 10^{-19} \text{ C} & 7. 1.6425 \times 10^{-19} \text{ C} \\
 2. 1.6408 \times 10^{-19} \text{ C} & 5. 1.6480 \times 10^{-19} \text{ C} & 8. 1.6350 \times 10^{-19} \text{ C} \\
 3. 1.6429 \times 10^{-19} \text{ C} & 6. 1.6436 \times 10^{-19} \text{ C} & 9. 1.6363 \times 10^{-19} \text{ C}
 \end{array}$$

The average of the nine values is 1.641×10^{-19} C.

c) In the preceding, the least difference among the charges on the nine droplets has been taken as the “quantum of electrical charge.” The actual quantum of charge however might be some fraction ($\frac{1}{2}$, $\frac{1}{3}$, $\frac{1}{4}$, etc.) of this value. One can confirm that 1.641×10^{-19} C is truly the charge on a single electron only by extensive search for droplets having lesser charge.

1.40

$$\text{Density of neutron star} = \frac{\text{mass}}{\text{volume}} = \frac{6.0 \times 10^{56} \times 1.675 \times 10^{-24} \text{ g}}{\left(\frac{4}{3}\right) \pi (20 \times 10^5 \text{ cm})^3} = 3.0 \times 10^{13} \text{ g cm}^{-3}$$

$$\text{Mass of } ^{232}\text{Th nucleus} = 142(1.675 \times 10^{-24} \text{ kg}) + 90(1.673 \times 10^{-24} \text{ g}) = 3.884 \times 10^{-22} \text{ g}$$

$$\text{Density of } ^{232}\text{Th nucleus} = \frac{3.884 \times 10^{-22} \text{ g}}{\left(\frac{4}{3}\right) \pi (9.1 \times 10^{-13} \text{ cm})^3} = 1.2 \times 10^{14} \text{ g cm}^{-3}$$

This is four times larger than the density of a neutron star.

- 1.42 Let A_1 be the *fractional* abundance of ^{85}Rb and let A_2 be the fractional abundance of ^{87}Rb .

Then

$$A_1(84.9117) + A_2(86.9092) = 85.4678 \text{ and } A_1 + A_2 = 1$$

Solving gives $A_1 = 0.7216$. The percentage of ^{85}Rb is 72.16%; ^{87}Rb is 27.84%.