Chapter 1
Let's Review

PRACTICING SKILLS

Temperature Scales

1. Express 25 ˚C in kelvins:

   K = (25 °C+ 273) or 298 K

3. Make the following temperature conversions:

˚C	K
(a) 16	16 + 273.15 = 289
(b) 370 - 273 or 97	370
(c) 40	40 + 273.15 = 310

Note no decimal point after 40

Length, Volume, Mass, and Density

5. The distance of a marathon (42.195 km) in meters; in miles:

$$\frac{42.195\text{ km}}{1} \bullet \frac{1000\text{ m}}{1\text{ km}} = 42195\text{ m}$$

$$\frac{42.195\text{ km}}{1} \bullet \frac{0.62137\text{ miles}}{1\text{ km}} = 26.219\text{ miles}$$

The factor (0.62137 mi/km) is found inside the back cover of the text.

7. Express the area of a 2.5 cm x 2.1 cm stamp in cm^2 ; in m^2 :

$$2.5\text{ cm} \bullet 2.1\text{ cm} = 5.3\text{ cm}^2$$

$$5.3\text{ cm}^2 \bullet \left(\frac{1\text{ m}}{100\text{ cm}}\right)^2 = 5.3 \times 10^{-4}\text{ m}^2$$

9. Express volume of 250. mL beaker in cm^3; in liters (L); in m^3 ; in dm^3:

$$\frac{250.\text{ cm}^3}{1\text{ beaker}} \bullet \frac{1\text{cm}^3}{1\text{mL}} = \frac{250.\text{ cm}^3}{1\text{ beaker}}$$

$$\frac{250.\text{ cm}^3}{1\text{ beaker}} \bullet \frac{1\text{L}}{1000\text{cm}^3} = \frac{0.250\text{ L}}{1\text{ beaker}}$$

$$\frac{250.\ cm^3}{1\ beaker} \bullet \frac{1 m^3}{1 x 10^6 cm^3} = \frac{2.50\ x\ 10^{-4}\ m^3}{1\ beaker}$$

$$\frac{250.\ cm^3}{1\ beaker} \bullet \frac{1L}{1000 cm^3} \bullet \frac{1\ dm^3}{1\ L} = \frac{0.250\ dm^3}{1\ beaker}$$

11. Convert book's mass of 2.52 kg into grams:

$$\frac{2.52\ kg}{1\ book} \bullet \frac{1\ x\ 10^3 g}{1\ kg} = \frac{2.52\ x\ 10^3\ g}{book}$$

13. What mass of ethylene glycol (in grams) possesses a volume of 500. mL of the liquid?

$$\frac{500.\ mL}{1} \bullet \frac{1\ cm^3}{1\ mL} \bullet \frac{1.11\ g}{cm^3} = 555\ g$$

15. To determine the density, given the data, one must first convert each length to units of cm:

$$\left[\frac{1.05\ mm}{1} \bullet \frac{1\ cm}{10\ mm}\right] \bullet \frac{2.35\ cm}{1} \bullet \frac{1.34\ cm}{1} = 0.3306\ cm^3\ (\ 0.331\ to\ 3sf)$$

The density is calculated Mass/Volume or $\frac{2.361\ g}{0.3306\ cm^3} = 7.14 \frac{g}{cm^3}$. Given the selection of metals, the identity of the metal is **zinc**.

Accuracy, Precision, Error, and Standard Deviation

17. Using the data provided, the averages and their deviations are as follows:

Data point	Method A	deviation	Method B	deviation
1	2.2	0.2	2.703	0.777
2	2.3	0.1	2.701	0.779
3	2.7	0.3	2.705	0.775
4	2.4	0.0	5.811	2.331
Averages:	2.4	0.2	3.480	1.166

Note that the deviations for both methods are calculated by first determining the average of the four data points, and then subtracting the individual data points from the average (without regard to sign)

(a) The average density for method A is 2.4 ± 0.2 grams while the average density for method B is 3.480 ± 1.166 grams—if one includes all the data points. *Data point 4* in *Method B* has a large deviation, and *should probably be excluded* from the calculation. If one omits data point 4, Method B gives a density of 2.703 ± 0.001 g

(b) The percent error for each method:

Error = experimental value - accepted value

From Method A error = (2.4 - 2.702) = 0.3

From Method B error = (2.703 - 2.702) = 0.001 (omitting data point 4)

error = (3.480 - 2.702) = 0.778 (including all data points)

and the percent error is then:

$$(\text{Method A}) = \frac{0.3}{2.702} \bullet \frac{100}{1} = \text{ about 10\% to 1 s.f.}$$

$$(\text{Method B}) = \frac{0.001}{2.702} \bullet \frac{100}{1} = \text{ about 0.04\% to 1 s.f.)}$$

(c) The standard deviation for each method:

$$\text{Method A: } \sqrt{\frac{(0.2)^2 + (0.1)^2 + (0.3)^2 + (0.0)^2}{3}} = \sqrt{\frac{0.14}{3}} = 0.216 \text{ or } 0.2 \text{ (to 1 s.f.)}$$

$$\text{and for Method B: } \sqrt{\frac{(0.777)^2 + (0.779)^2 + (0.775)^2 + (2.331)^2}{3}} =$$

$$\sqrt{\frac{7.244}{3}} = 1.554 \text{ or } 1.55 \text{ (to 3 s.f.)}$$

(d) If one counts all data points, the deviations **for all data points** of Method A are less than those for **the data points of** Method B, Method A offers *better precision*. On the other hand, omitting data point 4, Method B offers both *better accuracy* (average closer to the accepted value) and *better precision* (since the value is known to a greater number of significant figures).

Exponential Notation and Significant Figures

19. Express the following numbers in exponential (or scientific) notation:

(a) 0.054 = 5.4×10^{-2} To locate the decimal behind the first non-zero digit, we move the decimal place to the right by 2 spaces (-2); 2 significant figures

(b) 5462 = 5.462×10^{3} To locate the decimal behind the first non-zero digit, we move the decimal place to the left by 3 spaces (+3); 4 significant figures

(c) 0.000792 = 7.92×10^{-4} To locate the decimal behind the first non-zero digit, we move the decimal place to the right by 4 spaces (-4); 3 significant figures

(d) 1600 mL = 1.6×10^{3} To locate the decimal behind the first non-zero digit, we move the decimal place to the left by 3 spaces (+3); 2 significant figures

21. Perform operations and report answers to proper number of s.f.:

(a) $(1.52)(6.21 \times 10^{-3}) = 9.44 \times 10^{-3}$ (3 sf since each term in the product has 3)

(b) $\left(6.217 \text{ x } 10^3\right) - \left(5.23 \text{ x } 10^2\right) = 5.694 \text{ x} 10^3$ [Convert 5.23 x 10^2 to 0.523 x 10^3 and subtract, leaving 5.694 x 10^3. With 3 decimal places to the right of the decimal place in both numbers, we can express the difference with 3 decimal places.

(c) $\left(6.217 \text{ x } 10^3\right) \div \left(5.23 \text{ x } 10^2\right) = 11.887$ or 11.9 (3 s.f.)

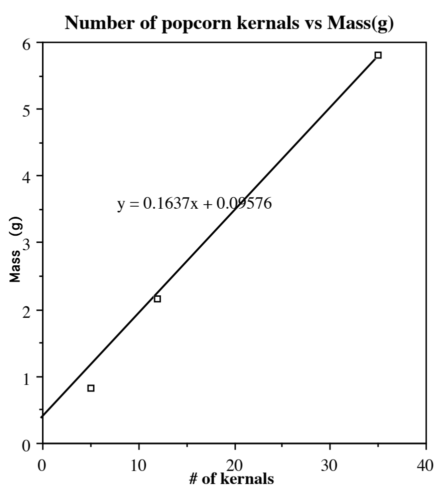
Recall that in multiplication and division, the result should have the same number of significant figures as the **term** with the fewest significant figures (3 in this case).

(d) $(0.0546)(16.0000)\left[\frac{7.779}{55.85}\right]$=0.121678 or 0.122 (3 s.f.)

the same rule applies, as in part (c) above: The first term has 3 s.f., the second term 6 s.f.—yes the zeroes count, and the third term 4 s.f. Dividing the two terms in the last quotient gives an answer with 4 s.f. So with 3,6, and 4 s.f. in the terms, the answer should have **no more than** 3 s.f.

Graphing

23. Plot the data for Number of kernals of popcorn versus mass (in grams):



The best straight line has the equation, y = 0.1637x + 0.09576, with a slope of 0.1637. This slope indicates that the mass increases by a factor of 0.1637grams with each kernal of popcorn. The mass of 20 kernals would be: mass = (0.1637)(20) + 0.09576 or 3.3698 grams. To determine the number of kernals (x) with a mass of 20.88 grams, substitute 20.88 for mass (i.e. y) and solve for the number of kernals.

20.88 g = 0.1637(x) + 0.09576; (20.88 – 0.09576) = 0.1637x and dividing by the slope:

$\frac{[20.88 - 0.09576]}{0.1637}$ = x or 126.96 kernals—approximately 127 kernals.

25. Using the graph shown, determine the values of the equation of the line:

(a) Using the first and last data points, we can calculate the slope (rise/run):

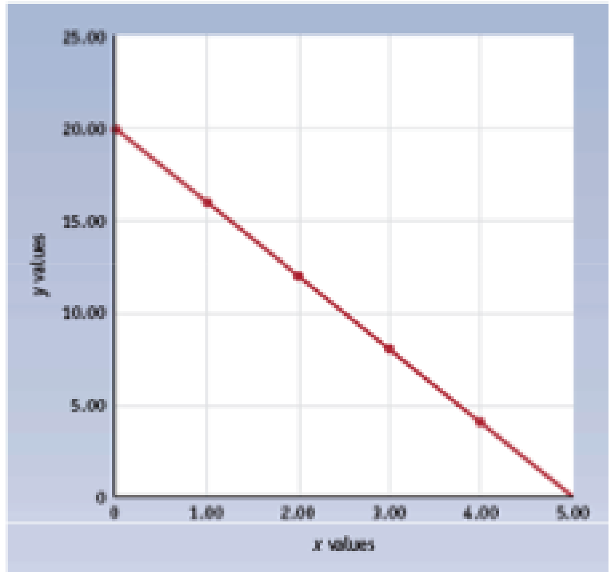
$$\frac{20.00 - 0.00}{0.00 - 5.00} = -4.00$$

The intercept (b) is the y value when the x value is zero (0). Substituting into the equation for the line:

Y = (-4.00)(0) + b

We can read this value from the graph (20.00). The equation for the line is:

Y = -4.00x + 20.00



(b) The value of y when x = 6.0 is:

Y = (-4.00)(6.00) + 20.00 or -4.00.

Solving Equations

27. Solving the equation for "C":

(0.502)(123) = (750.)C and rearranging the equation by dividing by 750. gives

$$\frac{(0.502)(123)}{750.} = C = 0.0823 \text{ (3 sf)}$$

29. Solve the following equation for T:

The equation: (4.184)(244)(T-292.0) + (0.449)(88.5)(T-369.0) = 0

Expanding the equation gives:

(4.184)(244)T - (4.184)(244)(292.0) + (0.449)(88.5)T - (0.449)(88.5)(369.0) = 0

1,020.896T - 298,101.632 + 39.7365T - 14,662.769 = 0

grouping the terms (1,020.896T + 39.7365T) gives 1,060.6325T likewise

(- 298,101.632 + - 14,662.769) gives -312,764.401.

The equation now is equivalent to 1,060.6325T -312,764.401= 0. If we add the negative term to both sides:

1,060.6325T = 312,764.401and T = 312,764.401/1,060.6325 or 294.884797986.

This is clearly too many significant figures. Rounding to 3sf, gives a value of 295.

General Questions

31. Express the length 1.97 Angstroms in nanometers? In picometers?

$$\frac{1.97\text{ Angstrom}}{1} \bullet \frac{1\text{x}10^{-10}\text{m}}{1\text{ Angstrom}} \bullet \frac{1\text{x}10^{9}\text{ nm}}{1\text{ m}} = 0.197\text{ nm}$$

$$\frac{1.97\text{ Angstrom}}{1} \bullet \frac{1\text{x}10^{-10}\text{m}}{1\text{ Angstrom}} \bullet \frac{1\text{x}10^{12}\text{pm}}{1\text{m}} = 197\text{ pm}$$

33. Diameter of red blood cell = 7.5 µm

(a) In meters: $\frac{7.5\ \mu\text{m}}{1} \bullet \frac{1\text{ m}}{1\text{x}10^{6}\mu\text{m}} = 7.5\text{ x }10^{-6}\text{m}$

(b) In nanometers: $\frac{7.5\ \mu\text{m}}{1} \bullet \frac{1\text{ m}}{1\text{x}10^{6}\mu\text{m}} \bullet \frac{1\text{ x }10^{9}\text{nm}}{1\text{m}} = 7.5\text{ x }10^{3}\text{nm}$

(c) In picometers: $\frac{7.5\ \mu\text{m}}{1} \bullet \frac{1\text{ m}}{1\text{x}10^{6}\mu\text{m}} \bullet \frac{1\text{x}10^{12}\text{pm}}{1\text{m}} = 7.5\text{ x }10^{6}\text{ pm}$

35. Mass of procaine hydrochloride (in mg) in 0.50 mL of solution

$$\frac{0.50\text{ mL}}{1} \bullet \frac{1.0\text{ g}}{1\text{ mL}} \bullet \frac{10.\text{ g procaine HCl}}{100\text{ g solution}} \bullet \frac{1\text{ x }10^{3}\text{ mg procaine HCl}}{1\text{ g procaine HCl}} = 50.\text{ mg procaine HCl}$$

37. The volume of the marbles is the initial question, since its volume will add to the volume of water initally present (61 mL). The final volume is about 99 mL, so the volume occupied by the marbles is 99 ml – 61 ml, or 38mL. Knowing that marbles have a collective mass of 95.2 g, the density is : $D = \frac{M}{V} = \frac{95.2\text{ g}}{38\text{ mL}} = 2.5\text{ g/mL}$ (to 2 sf).

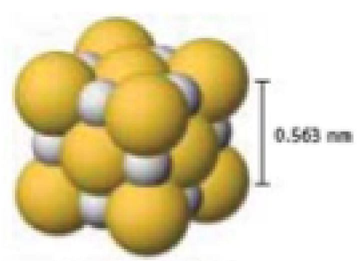
39. For the sodium chloride unit cell:

(a)The volume of the unit cell is the (edge length)^3

With an edge length of 0.563 nm, the volume is (0.563 nm)^3 or 0.178 nm^3 The volume in cubic centimeters is calculated by first expressing the edge length in cm:

$$\frac{0.563\text{ nm}}{1} \bullet \frac{1\text{ x }10^{2}\text{cm}}{1\text{ x }10^{9}\text{nm}} = 5.63\text{ x }10^{-8}\text{cm}$$

The volume is $(5.63\text{ x }10^{-8}\text{ cm})^3$ or $1.78\text{ x }10^{-22}\text{ cm}^3$



sodium chloride, NaCl

(b) The mass of the unit cell is:

$M = V \bullet D = 1.78\text{ x }10^{-22}\text{cm}^3 \bullet 2.17\text{ g/cm}^3 = 3.86\text{ x }10^{-22}\text{g}$

(c) Given the unit cell contains 4 NaCl "molecules", the mass of one "molecule is:

$$\frac{3.86 \text{ x } 10^{-22} \text{ g for 4 NaCl pairs}}{\text{4 NaCl pairs}} = 9.66 \text{ x } 10^{-23} \text{ g/ion pair}$$

41. The accepted value for a normal human temperature is 98.6 ˚F. On the Celsius scale this corresponds to:

$$˚\text{C} = \frac{5}{9}(98.6 - 32) = 37\ ˚\text{C}$$

Since the melting point of gallium is 29.8 ˚C, the gallium should melt in your hand.

43. The heating of popcorn causes the loss of water.

(a) The percentage of mass lost upon popping:

$$\frac{(0.125\text{g} - 0.106\text{g})}{0.125\text{g}} \text{ x } 100 = 15\%$$

(b) With an average mass of 0.125 g, the number of kernals in a pound of popcorn:

$$\frac{\text{1 kernal}}{\text{0.125 g}} \bullet \frac{\text{453.6 g}}{\text{1 lb}} = \text{3628.8 kernals or 3630 (to 3 s.f.)}$$

45. The mass of NaF needed for 150,000 people for a year:

This problem can be done many different ways. One way is to begin with a factor that contains the units of the "answer" (mass NaF in kg). Since NaF is 45% fluoride (and 55 %Na), we can write the factor: $\frac{\text{100.0 kg NaF}}{\text{45.0 kg F}^-}$. Note that the expression of kg/kg has the same value of g/g—and provides the "desired" units of our answer. A concentration of 1ppm can be expressed as: $\frac{\text{1.00 kg F}^-}{1.00 \text{ x } 10^6 \text{ kg } H_2O}$ [We could use the fraction with the masses expressed in **grams**, but we would have to convert grams to kg. Note this factor can be derived from the factor using grams if you multiply BOTH numerator and denominator by 1000.]. Using the data provided in the problem, plus conversion factors (found in the rear inside cover of your textbook)

$$\frac{\text{100.0 kg NaF}}{\text{45.0 kg F}^-} \bullet \frac{\text{1.00 kg F}^-}{1.00 \text{ x } 10^6 \text{ kg } H_2O} \bullet \frac{1 \text{ kg } H_2O}{1 \text{ x } 10^3 \text{ cm}^3 H_2O} \bullet \frac{1 \text{ x } 10^3 \text{ cm}^3 H_2O}{1.0567 \text{ qt } H_2O} \bullet \frac{4.00 \text{ qt } H_2O}{1 \text{ gal } H_2O} \bullet$$

$$\frac{170 \text{ gal } H_2O}{\text{1 person-day}} \bullet \frac{1.50 \text{ x } 10^5 \text{person}}{1} \bullet \frac{\text{365 day}}{\text{1 year}} = 8.0 \text{ x } 10^4 \text{ kg NaF/year}$$

Note that 170 gal of water per day limits the answer to 2 s.f.

47. Mass of sulfuric acid in 500. mL (or 500. cm^3)solution.

$$\frac{38.08 \text{ g sulfuric acid}}{100.00 \text{ g solution}} \bullet \frac{1.285 \text{ g solution}}{1.000 \text{ cm}^3 \text{ solution}} \bullet \frac{500.\text{cm}^3\text{solution}}{1} = 244.664 \text{ g sulfuric acid}$$

or 245 g sulfuric acid (3 sf—note 500. has 3 sf)

49.(a) Volume of solid water at –10°C when a 250. mL can is filled with liquid water at 25°C:

The volume of liquid water at 25 degrees is 250. mL (or cm^3). The mass of that water is:

$$\frac{0.997 \text{ g water}}{1.000 \text{ cm}^3 \text{ water}} \bullet \frac{250. \text{ cm}^3}{1} = 249.25 \text{ g water (249 to 3 s.f.)}$$

That mass of water at the lower temperature will occupy:

$$\frac{1.000 \text{ cm}^3 \text{ water}}{0.917 \text{ g water}} \bullet \frac{249.25 \text{ g water}}{1} = 271.81 \text{ (or 272 cm}^3 \text{ to 3 sf)}$$

(b) With the can being filled to 250. mL at room temperature, the expansion (an additional 22 mL) can not be contained in the can. (Get out the sponge—there's a mess to clean up.)

51. Calculate the density of steel if a steel sphere of diameter 9.40 mm has a mass of 3.475 g:
The radius of the sphere is 1/2(9.40mm) or 4.70mm. Since density is usually expressed in cm^3, express the radius in cm (0.470cm) and substitute into the volume equation:

$$V = \frac{4}{3}\Pi r^3 = \frac{4}{3}(3.1416)(0.470\text{cm})^3 = 0.435 \text{ cm}^3 \text{(to 3 s.f.)}$$

The density is 3.475 g /0.435 cm^3 = 7.99 g/cm^3.

53. (a) Calculate the density of an irregularly shape piece of metal:

$$D = \frac{M}{V} = \frac{74.122 \text{ g}}{(36.7 \text{ cm}^3 - 28.2 \text{ cm}^3)} = \frac{74.122 \text{ g}}{8.5 \text{ cm}^3} = 8.7 \text{ g/cm}^3$$

Note that the subtraction of volumes leaves only 2 s.f., limiting the density to 2 s.f.

(b) From the list of metals provided, one would surmise that the metal is **cadmium**. Since the major uncertainty is in the volume, one can substitute 8.4 and 8.6 cm^3 as the volume, and calculate the density (resulting in 8.82 and 8.62 g/cm^3 respectively). The hypothesis that the metal is cadmium is reasonably sound.

55. Mass of Hg in the capillary:

Mass of capillary with Hg	3.416 g
Mass of capillary without Hg	3.263 g
Mass of Hg	0.153 g

To determine the volume of the capillary, calculate the volume of Hg that is filling it.

$$\frac{0.153 \text{ g Hg}}{1} \bullet \frac{1 \text{ cm}^3}{13.546 \text{ g Hg}} = 1.13 \text{x } 10^{-2} \text{ cm}^3 (3 \text{ sf})$$

Now that we know the volume of the capillary, and the length of the tubing (given as 16.75 mm—or 1.675 cm), we can calculate the radius of the capillary using the equation:

Volume = $\pi r^2 l$.

$1.13 \text{ x } 10^{-2} \text{ cm}^3 = (3.1416)r^2(1.675 \text{ cm})$, and solving for r^2:

$$\frac{1.13 \text{ x } 10^{-2} \text{ cm}^3}{(3.1416)(1.675 \text{ cm})} = 2.15 \text{ x } 10^{-3} \text{ cm}^2 = r^2$$

So **r** is the square root of ($2.15 \text{ x } 10^{-3} \text{ cm}^2$) or $4.63 \text{ x } 10^{-2}$ cm. The diameter would then be twice this value or $9.27 \text{ x } 10^{-2}$ cm.

Copper

57.(a)The number of Cu atoms in a cube whose mass is 0.1206g.

$$\frac{0.1206 \text{ g}}{\text{cube}} \bullet \frac{1 \text{ atom Cu}}{1.055 \text{ x } 10^{-22} \text{g}} = 1.143 \text{x } 10^{21} \text{ atoms Cu}$$

Fraction of the lattice that contains Cu atoms:

Given the radius of a Cu atom to be 128 pm, and the number of Cu atoms, the total volume occupied by the Cu atoms is the volume occupied by ONE atom ($4/3\ \Pi r^3$) multiplied by the total number of atoms:

Volume of one atom: $4/3 \bullet 3.1416 \bullet (128\text{pm})^3 = 8.78 \text{ x } 10^6 \text{ pm}^3$

Total volume: ($8.78 \text{ x } 10^6 \text{ pm}^3$/Cu atom)($1.143 \text{ x } 10^{21}$ atoms Cu) = $1.00 \text{ x } 10^{28} \text{ pm}^3$

The lattice cube has a volume of $(0.236 \text{ cm})^3$ or $(2.36 \text{ x } 10^9 \text{pm})^3$ or $1.31 \text{ x } 10^{28} \text{ pm}^3$

The fraction occupied is: total volume of Cu atoms/total volume of lattice cube:

$$\frac{1.00 \text{ x } 10^{28} \text{ pm}^3}{1.31 \text{ x } 10^{28} \text{ pm}^3} = 0.763 \text{ or } 76\% \text{ occupied (to 2 sf)}$$

The empty space in a lattice is due to the inability of spherical atoms to totally fill a given volume. A macroscopic example of this phenomenon is visible if you place four marbles in a square arrangement. At the center of the square there are voids. In a cube, there are obviously repeating incidents.

(b) Estimate the number of Cu atoms in the smallest repeating unit:

Since we know the length of the smallest repeating unit (the unit cell), let's calculate the volume (first converting the length to units of centimeters:

$L = 361.47 \text{ pm so } L = 361.47 \text{ pm} \bullet \frac{1 \times 10^{2} \text{ cm}}{1 \times 10^{12} \text{ pm}} = 361.47 \times 10^{-10}\text{cm}$

$V = L^3 = (3.6147 \times 10^{-8})^3 = 4.723 \times 10^{-23} \text{ cm}^3$

Since we know the density, we can calculate the mass of one unit cell:

$D \times V = 8.960 \text{ g/ cm}^3 \times 4.723 \times 10^{-23} \text{ cm}^3 = 4.23 \times 10^{-22} \text{ g}$

Knowing the mass of one copper atom (1.055×10^{-22} g) we can calculate the number of Cu atoms in that mass: $\frac{4.23 \times 10^{-22} \text{ g}}{1.055 \times 10^{-22} \text{ g/Cu atom}} = 4.0$ Cu atoms

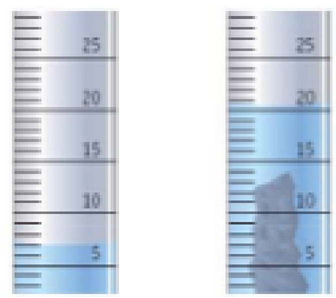
As you will learn later, the number of atoms for a face-centered cubic lattice is 4.

IN THE LABORATORY

59. The metal will displace a volume of water that is equal to the volume of the metal.

The difference in volumes of water (20.2-6.9) corresponds to the volume of metal. Since 1 mL = 1 cm^3, the density of the metal is then:

$\frac{\text{Mass}}{\text{Volume}} = \frac{37.5 \text{ g}}{13.3 \text{ cm}^3} = \text{or } 2.82 \frac{\text{g}}{\text{cm}^3}$



Graduated cylinders with unknown metal (right)

From the list of metals provided, the metal with a density closest to this is **Aluminum**.

61. The plotted data result in the graph below:

Using Cricket Graph™ to plot the "best straight line" , one gets the equation:

$y = 248.4x + 0.0022$.

The concentration when Absorbance = 0.635 is (from the graph) 2.55×10^{-3} g/L

The slope of the line is the coefficient of x or 248.4.