1 MATTER AND MEASUREMENTS

LECTURE NOTES

This material ordinarily requires two lectures (100 minutes), allowing for a 10–15 minute introduction to the course in the first lecture. If you're in a hurry, this can be cut to $1\frac{1}{2}$ lectures by discussing only quantitative material (significant figures, unit conversions, density, solubility).

A few points to keep in mind:

- Virtually all of your students will be familiar with the metric system and prefixes. It may be worth discussing the rationale for SI, but you don't have to dwell on it.
- Students readily learn the rules of significant figures, but typically ignore them after Chapter 1. It may help to emphasize that these are common-sense (albeit, approximate) rules for estimating experimental error.
- Many (typically, the weaker) students resist using conversion factors, preferring instead a rote method. It may be useful to point out that conversion factors will be a recurring tool throughout the text, so are well worth learning at this point.
- Students often have trouble with solubility calculations. The approach in the text involves conversions (Example 1.8). The solubility is considered to be a conversion factor relating grams of solute to grams of solvent.

Lecture 1

I. Types of Substances

A. Elements

Cannot be broken down into simpler substances. Examples: nitrogen, lead, sodium, arsenic. Symbols: N, Pb, Na, As.

B. Compounds

Contain two or more elements with fixed mass percents. Glucose: 40.00% C, 6.71% H, 53.29% O. Sodium chloride: 39.34% Na, 60.66% Cl.

C. Mixtures

Homogeneous (solutions) vs. heterogeneous. Separation by filtration, distillation.

II. Measured Quantities

A. Length

Base unit is the meter. 1 km = 10^3 m; 1 cm = 10^{-2} m; 1 mm = 10^{-3} m; 1 nm = 10^{-9} m. Dimensions of very tiny particles will be expressed in nanometers.

B. Volume

1 L = 10^3 mL = 10^3 cm^3 = 10^{-3} m^3. Buret, pipet, volumetric flask.

C. Mass

1 kg = 10^3 g; 1 mg = 10^{-3} g. Two different kinds of balances will be used in the lab. An analytical balance ($\pm$0.001 g) should be used only for accurate, quantitative work.

D. Temperature

$t_{^\circ F} = 1.8\,t_{^\circ C} + 32^\circ$; $T_K = t_{^\circ C} + 273.15$.

Convert 68°F to °C and K: $t_{^\circ C} = (68^\circ - 32^\circ)/1.8 = 20^\circ C$ $T_K = 293$

Lecture 2

III. Experimental Error; Significant Figures

Suppose an object is weighed on a crude balance to $\pm$0.1 g and the mass is found to be 23.6 g. This quantity contains three significant figures, that is, three experimentally significant digits. With an analytical balance, the mass might be 23.582 g (five significant figures).

A. Counting significant figures

1. Volume of liquid = 24.0 mL; three significant figures. Zeroes at the end of the measured quantity are significant when they follow nonzero digits.

2. Volume = 0.0240 L; three significant figures (note that 0.0240 L = 24.0 mL). Zeroes at the beginning of a measured quantity are not significant when they precede nonzero digits.

B. Multiplication and division

Keep only as many significant figures as there are in the least precise quantity. Density of a piece of metal weighing 36.123 g with a volume of 13.4 mL = ?

$$\text{density} = \frac{36.123\ \text{g}}{13.4\ \text{mL}} = 2.70\ \text{g/mL}$$

C. Addition and subtraction

Keep only as many digits after the decimal point as there are in the least precise quantity. Add 1.223 g of sugar to 154.5 g of coffee:

total mass = 1.2 g + 154.5 g = 155.7 g

Note that the rule for addition and subtraction does not apply to significant figures. The number of significant figures may well decrease after subtraction.

mass beaker + sample =	52.169 g	(five significant figures)
mass empty beaker =	52.120 g	(five significant figures)
mass sample =	0.049 g	(two significant figures)

D. Exact numbers

One liter means 1.000000... L.

IV. Conversion Factors

A. One-step conversion

A rainbow trout is measured to be 16.2 inches long. What is its length in centimeters?

$$\text{length in cm} = 16.2\ \text{in} \times \frac{2.54\ \text{cm}}{1\ \text{in}} = 41.1\ \text{cm}$$

Note the cancellation of units. To convert from centimeters to inches, use the conversion factor 1 in = 2.54 cm. (Here, there are *exactly* 2.54 cm in one inch.)

B. Multiple conversion factors

A thrown baseball has speed 89.6 miles per hour. What is its speed in meters per second?

$$1\ \text{mile} = 1.609\ \text{km} = 1.609 \times 10^3\ \text{m}; \quad 1\ \text{h} = 3600\ \text{s}$$

$$\text{speed} = \left(89.6\ \frac{\text{mile}}{\text{h}}\right) \times \left(1.609 \times 10^3\ \frac{\text{m}}{\text{mile}}\right) \times \left(\frac{1\ \text{h}}{3600\ \text{s}}\right) = 40.0\ \text{m}/\text{s}$$

V. Properties of Substances

Distinguish between intensive and extensive, and between chemical and physical.

A. Density

An empty flask weighs 22.138 g. Pipet 5.00 mL of octane into the flask, producing a total mass of 25.598 g. What volume is occupied by ten grams of octane?

$$d = 3.460\ \text{g}/5.00\ \text{mL} = 0.692\ \text{g}/\text{mL}$$

$$V = 10.00\ \text{g} \times \frac{1\ \text{mL}}{0.692\ \text{g}} = 14.5\ \text{mL}$$

Note that for density calculations, 1 mL = 1 cm^3.

B. Solubility

This is often expressed as grams of solute per 100 g of solvent.

Solubility of sugar at 20°C = 210 g sugar/100 g water.

A solution containing 210 g sugar/100 g water is saturated.

A solution containing less than 210 g sugar/100 g water is unsaturated.

A solution containing more than 210 g sugar/100 g water is supersaturated.

1. How much water is required to dissolve 52 g of sugar at 20°C?

$$52\ \text{g sugar} \times \frac{100\ \text{g water}}{210\ \text{g sugar}} = 25\ \text{g water}$$

2. A solution at 20°C contains 25 g sugar and 125 g water. Is it unsaturated, saturated or supersaturated?

$$\text{mass sugar/100 g water} = \frac{25\text{ g sugar}}{125\text{ g water}} \times 100\text{ g water} = 20\text{ g sugar} \qquad \text{(unsaturated)}$$

DEMONSTRATIONS

1. Scientific method: GILB H 29
2. Decomposition of mercury(II) oxide: GILB A 8
3. Separation of a mixture: GILB A 14
4. Reaction of sodium with chlorine: GILB A 24, A 25; SHAK 1 61; J. Chem. Educ. 73 539 (1996)
5. Chromatography: GILB Q 3, Q 13
6. Significant figures: J. Chem. Educ. 69 497 (1992)
7. Density of liquids: GILB C 13; SHAK 3 229
8. Supersaturation: GILB F 11; SHAK 1 27

SUMMARY PROBLEM

(a) K, Mn, O

(b) density, melting point, solubility, color

(c) $\text{mass} = 2.703\ \frac{\text{g}}{\text{cm}^3} \times 48.7\text{cm}^3 = 132\text{ g}$

(d) $2.703\ \frac{\text{g}}{\text{cm}^3} \times \frac{1\text{ lb}}{454\text{ g}} \times \frac{(2.54)^3\text{ cm}^3}{1^3\text{ in}^3} \times \frac{(12)^3\text{ in}^3}{1\text{ ft}} = 169\text{ lb/ft}^3$

(e) $°\text{F} = \frac{9}{5}(°\text{C}) + 32 = \frac{9}{5}(2.40 \times 10^2) + 32 = 464°\text{F}$

$(2.40 \times 10^2) + 273 = 513\text{ K}$

(f) $38.5\text{ g H}_2\text{O} \times \frac{6.38\text{ g KMnO}_4}{100\text{ g H}_2\text{O}} = 2.46\text{ g KMnO}_4$

(g) At 60°C: $65.0\text{ g H}_2\text{O} \times \frac{25\text{ g KMnO}_4}{100\text{ g H}_2\text{O}} = 16\text{ g KMnO}_4$

The solution is unsaturated.

At 20°C: $65.0\text{ g H}_2\text{O} \times \frac{6.38\text{ g KMnO}_4}{100\text{ g H}_2\text{O}} = 4.15\text{ g KMnO}_4$ can be dissolved.

The solution is supersaturated.