

KEY for Unit 1 – Your Chemical Toolbox: Scientific Concepts, Fundamentals of Typical Calculations, the Atom and Much More

Answers to various problems in the order in which they occur in the study guide.

Try these:

convert 540.0 inches into yards

$$? \text{ yd.} = \frac{1 \text{ yd}}{36 \text{ inches}} \times 540.0 \text{ inches} = 15.00 \text{ yd.}$$

convert 23.0 kg into micrograms

$$? \mu\text{g} = \frac{1 \mu\text{g}}{1 \times 10^{-6} \text{ g}} \times \frac{1,000 \text{ g}}{1 \text{ kg}} \times 23.0 \text{ kg} = 2.30 \times 10^{+10} \mu\text{g}$$

answer = $2.30 \times 10^{+10}$ micrograms

1. convert 1.00 cubic inch into cubic centimeters

$$? \text{ cm}^3 = \frac{(2.54 \text{ cm})^3}{(1 \text{ in})^3} \times 1.00 \text{ in}^3 = 16.39 \text{ cm}^3 = 16.4 \text{ cm}^3$$

2. given that 1 kg = 2.205 lb (on Earth) and 1 L = 1.057 quart and the density of water as 1.0 gram per cubic centimeter, find the density of water in pounds per gallon

$$? \text{ lb/gal} = \frac{2.205 \text{ lb}}{1 \text{ kg}} \times \frac{1 \text{ kg}}{1,000 \text{ g}} \times \frac{1.0 \text{ g}}{\text{cm}^3} \times \frac{1,000 \text{ cm}^3}{1 \text{ L}} \times \frac{1 \text{ L}}{1.057 \text{ qt}} \times \frac{4 \text{ qt}}{1 \text{ gal}} = 8.34 \text{ lb/gal}$$

Metric and English Systems (you may need to look up some conversion factors):

- | | | | | |
|-----------|----------------------------|---------------------------|-------------------------|-------------------------|
| 1. 2.1 kg | = $2.1 \times 10^{+3}$ g | = $2.1 \times 10^{+6}$ mg | = 4.6 ₃ lb. | = 74.1 oz. |
| 2. 454 mL | = 0.454 L | = 0.120 gal. | = 0.480 qt. | = 15.3 ₆ oz. |
| 3. 233 cm | = $2.33 \times 10^{+3}$ mm | = 0.233 m | = 91.7 ₃ in. | = 2.54 ₈ yd. |

$$4. 40.0 \text{ cm}^3 = \underline{4.00 \times 10^{-2} \text{ L}} = \underline{4.00 \times 10^{-5} \text{ m}^3} = \underline{2.44 \text{ in.}^3} = \underline{5.23 \times 10^{-5} \text{ yd.}^3}$$

Note: the answer in cubic yards and in cubic meters are similar. This is reassuring since a yard and a meter are similar. If we know that a meter is longer than a yard too, then it makes sense that the same volume would be a smaller number of cubic meters vs. cubic yards.

Convert 350.0°F into °C and K.

$$\text{answer} = 176.7^\circ\text{C} = 449.8 \text{ K}$$

$$(350.0^\circ\text{F} - 32^\circ\text{F}) * \left(\frac{5^\circ\text{C}}{9^\circ\text{F}} \right) = 176.7^\circ\text{C}$$

$$176.67^\circ\text{C} * \left(\frac{1\text{K}}{1^\circ\text{C}} \right) + 273.15\text{K} = 449.8 \text{ K}$$

Examples:

(density = mass per unit volume, typically gcm^{-3} for solids/liquids and gL^{-1} for gases)

1. 270.0 g Al (aluminum) occupy a volume of 100.0 cm^3 . density of Al = $\underline{2.700 \text{ g/cm}^3}$
2. $\underline{1.264 \times 10^{+3}}$ mL ethanol (density = 0.791 g/cm^3) has a mass of 1000 g

Approximation Problem:

Scientists often need to make approximations of quantities when they are reading. This is a necessary skill because it is not a wise practice to accept everything you read as truth. For example, when reading a story on global warming, a scientist might read that 1,000,000 metric tons (1 metric ton = 1,000 kg) of CO_2 (carbon dioxide) are produced by cars each year in the USA. A skeptical scientist might want to do an approximate calculation to see if this number is “about right”. In order to do this, a number of assumptions would be made and knowledge of gasoline combustion would be employed. Since we have not yet covered all the topics you need to understand to do this, we will tackle part of this problem.

A first step in doing the approximate calculation above might be to estimate the number of gallons of gasoline consumed per year in the USA. Make a list of the assumptions you must make (for example, how many cars there are on the roads in the USA), come up with and list the values you use, and find the answer in the units of gals of gasoline/year.

After your group is done compare your results with a neighboring group and think about the following: (a) do the numbers found by different groups match? (b) how close do the numbers have to be to “match”, (c) if the numbers do not match, what are the major sources of the discrepancy? Be prepared to discuss this in some detail at the end of a 8 minute period of working and comparing!

The two most common methods employed by students in this class in previous years used some common estimates and then diverged along two different trains of thought:

Common estimated information included:

- # of people in the U.S. - about 300 million people (or 300×10^6 people, or 3.00×10^8 people)
- fraction of the people driving – some said one half (or 50%), you could also simply view this as an estimate of the number of cars in use at any given “average” time

Method (a) –

- estimated ave. distance the ave. car is driven in an ave. year – perhaps 12,500 miles
- estimated ave. mileage for ave. gasoline powered car – perhaps 20 miles per gallon

$$\text{ANS.} = \left(\frac{1 \text{ gallon}}{20 \text{ mile}} \right) * \left(\frac{12,500 \text{ mile}}{\text{car}} \right) * (150 \times 10^6 \text{ cars}) = 9.4 \times 10^{10} \text{ gallons of gas}$$

Method (b) –

- estimated ave. gas consumption per car per week - at 1 tank per week
- estimated ave. volume of ave. tank in ave. gasoline powered vehicle – at 20 gallon per tank

$$\text{ANS.} = \left(\frac{20 \text{ gallon}}{\text{tank}} \right) * \left(\frac{52 \text{ tanks}}{\text{year}} \right) * (150 \times 10^6 \text{ cars}) = 1.6 \times 10^{11} \text{ gallons of gas}$$

The percentage difference between these two estimates can be found by expressing the difference (6.6×10^{10} gallons) between the answers as a percentage of the average of the two answers (1.3×10^{11} gallons):

$$\% \text{ difference} = 100 * \left(\frac{6.6 \text{ gallons}}{13 \text{ gallons}} \right) = 51 \% \text{ difference is the estimates}$$

Practice Conversion Problems

Put everything you learned above to practice in these problems. Write out your set-ups with all units shown. Report answers, with units, to the correct number of significant figures as determined using the “simple rules of thumb” treatment.

1. Convert a mass of 10.29 g into kg. Report the answer in scientific notation.

ANSWER: 0.01029 kg (or 1.029×10^{-2} kg)

2. Convert a volume of 1.500×10^4 μL into liters (or litres if you prefer the French spelling).

ANSWER: 1.500×10^{-2} L

3. Derived units involve a combination of two units. Density is a derived unit ($\frac{\text{g}}{\text{cm}^3}$). Convert the density of mercury ($13.55 \frac{\text{g}}{\text{cm}^3}$) into units of $\frac{\text{Mg}}{\text{m}^3}$. What do you notice about the result?

ANSWER: 13.55 Mg/m³

4. Converting units raised to powers requires raising the conversion factors to powers. Convert 100.0 cm^2 into units of m^2 .

ANSWER: 0.01000 m²

Note: drawing a picture of this may help you visualize why this answer is correct.

5. Convert a temperature of -40.0°F into $^\circ\text{C}$ and K .

ANSWER: -40.0°C

ANSWER: 233.2 K

6. Write each of the following in terms of the SI base unit using scientific notation:

(a) 7.3 mK (b) 275 pm (c) 19.6 ms (d) 45 μm
(a) **7.3x10⁻³ K** (b) **2.75x10⁻¹⁰ m** (c) **1.96x10⁻² s** (d) **4.5x10⁻⁵ m**

7. Ethyl acetate has a characteristic fruity odor and is used as a solvent in paint lacquers and perfumes. An experiment calls for 0.0450 kg of ethyl acetate. If the **density** of ethyl acetate is $0.902 \frac{\text{g}}{\text{mL}}$, what volume in liters is required? (Density is discussed in Chapter 1 – it is a property of a material that can be used to interconvert mass and volume units for a particular material at a specified temperature.)

ANSWER: 0.0499 L

8. A room measures 10.0 ft x 12.0 ft. x 9.0 ft. Find the volume of the room in liters AND the mass of air it contains (assume the density of dry air at typical ambient conditions is about $1.2 \times 10^{-3} \frac{\text{g}}{\text{cm}^3}$)

ANSWER: 3.0₆x10⁴ L and 3.7x10⁴ g or 37 kg

9. A carat is the mass unit used for diamonds and other gemstones. 1 carat = 200 mg. If a 1.0 carat diamond costs \$2,000, what is the cost of diamond per pound (note: the pound is really not a mass unit, but on Earth 1 lb = 0.4536 kg) .

ANSWER: 4.5x10⁶ \$/lb

Another situation that you will encounter in science is the frequent introduction of new concepts coupled with the expectation that you simply “deal with them” based on your more general understanding. This is a reasonable expectation given the vast number of problems that can be solved using similar logic and skill sets. So, let’s try this out:

10. An essential element (one needed by your body to maintain your health) exists in a compound that has a maximum water solubility of 0.0125 g per 100 g of water at 5°C .

[NOTE: this is the new concept but it is expressed using a set of derived units – a now familiar concept – you should be able to interpret what it means].

Your body needs 25.0 mg of this compound each day.

Can one 8 ounce glass of orange juice at 5°C be fortified with enough of this compound to deliver the 25.0 mg that your body needs on a daily basis?

[other relevant facts: 1 fluid ounce = 29.57 mL and 1 mL of water = 1.00 g of water]

For simplicity, assume the compound has the same solubility in orange juice as it has in water at 5°C.

[The use of assumptions in solving problems is ubiquitous in science.]

Why do you think we didn't use the solubility at 20 or 25 or 50°C?

Solubility varies as a function of temperature.

ANSWER: YES (see math below)

Method 1 – prove that maximum solubility produces a glass of orange juice with enough (25.0 mg or more) of the active ingredient.

$$\frac{1,000\text{mg}}{1\text{g}} \times \frac{0.0125\text{g}}{100\text{gwater}} \times \frac{1\text{gwater}}{1\text{mL}} \times \frac{29.57\text{mL}}{1\text{fl.oz.}} \times 8\text{fl.oz.} = 29.6\text{mg}$$

This is about 30 mg per 8 ounce glass. So yes the 8 ounce glass of juice can provide 25.0 mg

Method 2 – prove that dosage specified yields a solution less concentrated than a saturated solution.

$$\frac{1\text{g}}{1,000\text{mg}} \times \frac{25.0\text{mg}}{8\text{fl.oz.}} \times \frac{1\text{fl.oz.}}{29.57\text{mL}} \times \frac{1\text{mL}}{1.00\text{g}} = \frac{0.000106\text{gcompd}}{\text{gwater}} = \frac{0.0106\text{gcompd}}{100\text{gwater}}$$

The solubility of 0.0125 g per 100 g of water is greater than the required dosage of 0.0106 g per 100 g .

Regardless of which of the two methods we employ, we find the answer is YES.