

Chem 115 POGIL Worksheet - Week 1
Units, Measurement Uncertainty, and Significant Figures - Solutions

Key Questions & Exercises

1. Give the names and their abbreviations for the SI units of length, mass, time, and temperature.

length = meter mass = kilogram time = second temperature = kelvin

2. The unit of volume is the liter (L). Why is this not a *base* SI unit? What kind of SI unit is it?

There is no base unit for volume, because volume can always be defined as the product of lengths, giving units of length cubed (e.g., length x height x width). The liter is, therefore, a derived unit.

3. A student is asked to calculate the mass of calcium oxide produced by heating a certain amount of calcium carbonate. The student's answer of 90.32 is numerically correct, but the instructor marks it wrong. Why?

A mass must always have units. Was this 90.32 g, 90.32 kg, 90.32 lbs, or something else?

4. Write the number of seconds in a day (86,400 s) in exponential notation, using a coefficient that is greater than 1 and less than 10. (This form is called *scientific notation* and is generally the preferred form of exponential notation, as explained below).

$$1 \text{ day} = 8.64 \times 10^4 \text{ s}$$

5. The diameter of a helium atom is about 30 pm. Write this length in meters, using standard scientific notation.

$$\text{Note that } 1 \text{ pm} = 10^{-12} \text{ m, so } 30 \text{ pm} = 30 \times 10^{-12} \text{ m} = 3 \times 10^{-11} \text{ m}$$

6. A cubic container is 2.00 cm on each edge. What is its volume in liters? What is its volume in milliliters (mL)? Are your answers reasonable?

$$\text{Note that } 1 \text{ cm}^3 = 1 \text{ mL, and } 10^3 \text{ mL} = 1 \text{ L.}$$

$$\text{The volume of the cube is } V = l^3 = (2.00 \text{ cm})^3 = 8.00 \text{ cm}^3 = 8.00 \text{ mL} = 8.00 \times 10^{-3} \text{ L}$$

The edge length of the cube is 2.00 cm, which is less than an inch (1 in = 2.54 cm), so the volume of the cube is small. An answer of 8.00 mL seems about right.

7. In general, how can you identify whether or not you have written the correct conversion factor for the problem?

If the units of the starting number cancel with the units of the conversion factor, leaving the desired units, then you have set it up correctly.

8. One liter is 1.06 quarts (qt). Write two possible conversion factors from this relationship.

(1.06 qt/L) or (L/1.06 qt)

9. The posted speed limit is 60 mi/hr. You are doing 120 km/hr in your Porsche convertible that you just bought in Germany. Are you speeding? Explain. [1.0 mi = 1.6 km]

$$\left(\frac{120 \text{ km}}{\text{hr}}\right)\left(\frac{1.0 \text{ mi}}{1.6 \text{ km}}\right) = 75 \text{ mi/hr}$$

Yes, you are speeding, potentially costing you about a \$150 fine!

10. In the gym, you slip on two 45-lb barbell plates to a bar that weighs 45 lb. What is the mass of the set-up in kilograms? [1.00 kg = 2.20 lbs]

Total weight in pounds = 135 lbs

$$(135 \text{ lbs})(1.00 \text{ kg}/2.20 \text{ lbs}) = 61.4 \text{ kg}$$

11. A table top is 36 in long and 24 in wide. What is the area of the table top in square meters? [1 in = 2.54 cm, exactly]

$$\text{Area} = (36 \text{ in})(24 \text{ in}) = 864 \text{ in}^2$$

$$(864 \text{ in}^2)\left(\frac{2.54 \text{ cm}}{\text{in}}\right)^2\left(\frac{\text{m}}{10^2 \text{ cm}}\right)^2 = (864 \text{ in}^2)\left(\frac{6.45 \text{ cm}^2}{\text{in}^2}\right)\left(\frac{\text{m}^2}{10^4 \text{ cm}^2}\right) = 0.5574 \text{ m}^2$$

Because the two lengths were quoted to two significant digits, the answer should have only two significant digits; i.e., 0.56 m².

12. A one-gram standard reference weight is repeatedly weighed on an analytical balance. The readings from the balance are as follows: 1.003 g, 0.9998 g, 1.005 g, 0.9995 g. Comment on the precision and accuracy of these data.

The average of the four weights is 1.002 g, with a range of deviation from +0.0003 g to -0.0008 g. The average is very close to the reference weight, and the variation is very small. Therefore this is good accuracy and good precision.

13. The same one-gram reference weight is weighed on another analytical balance. The readings from this balance are as follows: 0.9845 g, 1.0114 g, 0.9879 g, 1.0208 g. Comment on the precision and accuracy of these data.

The average of the four weights is 1.001 g, with a range of deviation from +0.0207 g to -0.0166 g. The average is very close to the reference weight, but this time the data scatter widely. This is a case of good accuracy but poor precision. Data like this would suggest a problem with the balance, in spite of the fortuitously close agreement between the average and the reference mass.

14. The same one-gram reference weight is weighed on a third analytical balance. The readings from this balance are as follows: 1.237 g, 1.243 g, 1.238 g, 1.245 g. Comment on the precision and accuracy of these data.

The average of the four weights is 1.2408 g, with a range of deviation from +0.0042 g to -0.0038 g. The average is significantly off from the reference weight of 1.000 g, an error of +0.2408 g. This represents very poor accuracy. The deviation in the measured weights is relatively small, so the data represent reasonably good precision. We might say, however, that the overall measurement is precisely wrong! This is the kind of result that can be expected when we fail to calibrate a measuring device. The good repeatability (precision) belies the lack of accuracy of the miscalibrated instrument.

15. How is precision represented in reporting a measured value?

In the case of repeated measurements, we use a statistical assessment, such as the standard deviation calculation. For a single number that represents a measured quantity, we use the appropriate number of significant digits, with the understanding that there is some uncertainty in the last digit.

16. How many significant figures are there in each of the following numbers?

0.0037 2 sig. figs. (The two zeroes before the 3 set magnitude and are not significant. The zero before the decimal is there to set it off – a good practice for you to acquire when writing numbers by hand.)

20.03 4 sig. figs. (All digits of a decimal number equal to or greater than 1 are significant.)

300 1 sig. fig. (All digits might be significant, but as this is written the two zeroes might only be indicating magnitude. We must assume the least number of significant digits in such cases.)

300. 3 sig. figs. (The decimal point makes this a decimal number greater than 1, for which all digits are significant.)

3.000×10^2 4 sig. figs. (Standard scientific notation allows us to indicate however many digits may be significant, because the coefficient is always a

decimal number greater than 1. The exponent has no relevance in determining significant digits.)

17. Use your calculator to carry out the following calculations and report the answers to the correct number of significant figures:

$$x = (2)(39.0983) + (2)(51.996) + (7)(15.9994) \quad (\text{The first number in each multiplication is an integer.})$$

$$x = 294.184_4$$

3 decimal places and 6 sig. figs. This is an addition, so the number with the fewest decimal places sets the number of decimal places allowed for the answer. The number of significant figures is determined after setting the proper number of decimal places. The integer multiplications have no effect on either decimal places or significant figures. Think of this as a series of additions of the decimal numbers, each taken the number of times indicated by the multiplying integer. The subscript 4 at the end of the given answer indicates the next non-significant digit, which we might carry along temporarily in a subsequent calculation, rounding down to the proper number of significant figures in the end.

$$x = \frac{1.44 \times 10^4}{2.40 \times 10^8}$$

$$x = 6.00 \times 10^{-5}$$

3 sig. figs. Both numbers have three sig. figs., so the answer must have 3, too. Your calculator shows 6 E-5, meaning 6×10^{-5} , because all calculators drop trailing zeroes after a decimal point. You must know that 3 sig. figs. are needed for this answer, which means you must add on the two trailing zeroes.

$$x = \frac{(3.5 \times 10^{-5})(6.2 \times 10^{12})}{3.3 \times 10^{-15}}$$

$$x = 6.6 \times 10^{22}$$

2 sig. figs. All numbers have 2 sig. figs., so the answer must also.

$$x = \sqrt{(7.56 \times 10^{-5})(0.125)}$$

$$x = 3.07 \times 10^{-3}$$

3 sig. figs. Both numbers have 3 sig. figs., so the answer must also.

$$x = \left[\frac{(0.5622)(3.20 + 8.111)}{621.25} \right]^{1/3}$$

$$x = 0.2171$$

4 sig. figs. The sum $3.20 + 8.111 = 11.31_1$ has 2 decimal places and thus 4 sig. figs. This result and the number 0.5622 limit the answer to 4 sig. figs. The superscript $1/3$ means the cube root of the product inside the braces.

18. A supermarket in London is selling cod for 12.98 £/kg. If the rate of exchange is \$1.6220 = 1.0000 £, what is the price in dollars per pound? 1.000 kg = 2.205 lb

$$\left(\frac{12.98 \text{ £}}{\text{kg}} \right) \left(\frac{\$1.6220}{\text{£}} \right) \left(\frac{1.000 \text{ kg}}{2.205 \text{ lb}} \right) = \$9.548/\text{lb} = \$9.55/\text{lb}$$

This problem illustrates how routine it is to do multiple conversions of units that must be changed in both the numerator and denominator of the given quantity. Also, by using multiple conversion factors, we do not need to get useless intermediate answers, and we minimize the potential for transcription errors.

19. A hollow metal sphere has an outer diameter (o.d.) of 4.366 cm and an inner diameter (i.d.) of 4.338 cm. What is the volume of the metal in the sphere? Express your answer to the proper number of significant figures. [$V = (4/3)\pi r^3$]

The volume of metal in the sphere is the difference between the volume based on the outer diameter (V_{od}) and the volume based on the inner diameter (V_{id}). Be careful when using $V = (4/3)\pi r^3$ for each calculation to recall that $r = \frac{1}{2}d$. Both volume calculations will have 4 sig. figs., based on the given diameters. But the final calculation of the volume of metal is a subtraction, which will be subject to the rules concerning the proper number of decimal places, which may affect the number of significant figures for the final answer.

$$V_{\text{od}} = (4/3)(3.14159)(2.183 \text{ cm})^3 = 43.57_{6246} \text{ cm}^3$$

$$V_{\text{id}} = (4/3)(3.14159)(2.169 \text{ cm})^3 = 42.74_{3223} \text{ cm}^3$$

$$V_{\text{metal}} = V_{\text{od}} - V_{\text{id}} = 43.57_{6246} \text{ cm}^3 - 42.74_{3223} \text{ cm}^3 = 083_{3023} \text{ cm}^3 = 0.83 \text{ cm}^3$$

The final answer can only have two decimal places, so it is also a 2 sig. fig. number, even though both volumes were known to 4 sig. figs.

A slightly more efficient way of carrying out this calculation would be to solve the following equation:

$$\begin{aligned}V_{\text{metal}} &= (4/3)\pi(r_{\text{od}}^3 - r_{\text{id}}^3) = (4/3)(3.14159)[(2.183 \text{ cm})^3 - (2.169 \text{ cm})^3] \\&= (4/3)(3.14159)(10.40_{3062} \text{ cm}^3 - 10.20_{4193} \text{ cm}^3) = (4/3)(3.14159)(0.19_{8869} \text{ cm}^3) \\&= 0.83_{3021} \text{ cm}^3 = 0.83 \text{ cm}^3\end{aligned}$$