CH 151 Summer 2023:
"Problem Solving" *(online)*
Lab *- Instructions*

Note: **This is the lab for section W1 of CH 151 only.**

- *If you are taking section 60 of CH 151*, please use this link:

  http://mhchem.org/t/2a.htm

Step One:

Watch the lab video for the "Problem Solving" lab, found here:
http://mhchem.org/t/g.htm
There is no data to record in this lab video.

Step Two:

Complete pages Ib-2-3 through Ib-2-12 using the "Problem Solving" video and the actual lab instructions on pages Ib-2-3 through Ib-2-11. Include your name on page Ib-2-3!

Step Three:

Submit your lab (pages Ib-2-3 through Ib-2-11 *only* to avoid a point penalty) **as a *single* PDF file to the instructor via email (mike.russell@mhcc.edu) on Friday, June 30 by 9 AM.** I recommend a free program (ex: CamScanner, https://camscanner.com) or a website (ex: CombinePDF, https://combinepdf.com) to convert your work to a PDF file.

If you have any questions regarding this assignment, please email (mike.russell@mhcc.edu) the instructor! Good luck on this assignment!

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Problem Solving (online) **Lab**

Name:

Being able to convert units is essential to chemistry and all of the sciences. We will use the example of the **mole** to demonstrate the usefulness of both the dimensional analysis method (also known as "factor label method") and significant figures ("sig figs".)

The mole started with an inspiration from Amadeos Avogadro. He knew that an atom of oxygen (16 amu where 1 amu is very very small unit of mass) had sixteen times the amount of mass as hydrogen (1 amu). He reasoned that 16 grams of oxygen would have the same number of atoms as 1 gram of hydrogen. He called that amount of atoms a **mole**.

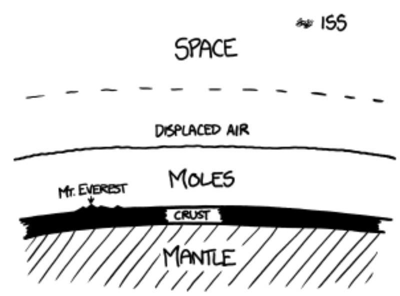
One mole of any substance = **6.022×10^{23}** particles

6.02×10^{23} is called **Avogadro's number**. If you wrote the entire number out, it would be 602,200,000,000,000,000,000,000! This is about 600 billion trillion!

Avogadro's number is greater than…

- The entire human population (about 7 billion or 7.0×10^9)
- Jeff Bezos, the world's richest man's net worth: $114 billion ($1.14 \times 10^{11}$) (in 2020)
- All the grains of sand present on the Earth. (est. 7.5×10^{18})

A mole of any substance contains a massive number of particles. As a visual, XKCD.com estimated that if you dropped a *mole of moles* on the Earth's surface, it would form a layer about 80 kilometers thick – about the same as the thickness of our entire atmosphere!



Numbers this big are expressed using **scientific notation.** Large numbers are reduced to something between 0-9, and the number of decimal places afterwards are indicated by powers of 10.

Convert each of these to scientific notation:

1. 45,000 ____________________

2. 138,000,000 ____________________

3. 305 ____________________

4. 720,000,000,000 ____________________

To use these numbers in your calculator, ***use the EE button*** *in place of the (x10) part. For example, 6.022×10^{23} would appear in your calculator like this:* ***6.022E23****.*

Numbers that are very small can also be expressed using **scientific notation.** Small numbers are reduced to something between 0-9, and the number of decimal places you move are indicated by a negative power of 10. 0.0035 would be represented by 3.5×10^{-3}.

Convert each of these to scientific notation:

5. 0.010 ____________________

6. 0.0000473 ____________________

7. 0.00202 ____________________

8. 0.00044 ____________________

Practice

Convert each of these to scientific notation. Indicate whether this amount is **greater than** or **less than** a mole.

9. The total width of the United States is about 2,680 miles.

   Scientific Notation: _________________ (Greater Than / Less Than) one mole.

10. The distance from the Earth to the Sun is about 93,000,000 miles.

    Scientific Notation: _________________ (Greater Than / Less Than) one mole.

11. The Earth has a mass of 5,970,000,000,000,000,000,000,000 kg.

    Scientific Notation: _________________ (Greater Than / Less Than) one mole.

12. The Moon has a mass of 73,500,000,000,000,000,000,000 kg.

    Scientific Notation: _________________ (Greater Than / Less Than) one mole.

13. There are about 31,500,000 seconds in one year.

    Scientific Notation: _________________ (Greater Than / Less Than) one mole.

14. The total number of humans that ever existed is estimated to be about 108,000,000,000.

    Scientific Notation: _________________ (Greater Than / Less Than) one mole.

15. The Earth is estimated to be 4,540,000,000 years old.

Scientific Notation: ________________ (Greater Than / Less Than) one mole.

16. The Universe is estimated to be 13,800,000,000 years old.

Scientific Notation: ________________ (Greater Than / Less Than) one mole.

17. A typical adult human contains about 37,000,000,000,000 cells.

Scientific Notation: ________________ (Greater Than / Less Than) one mole.

18. The body of a 155-pound person has about 7,000,000,000,000,000,000,000,000,000 atoms.

Scientific Notation: ________________ (Greater Than / Less Than) one mole.

Dimensional Analysis

To solve problems in science, you will often need to use **Dimensional Analysis** to convert one type of unit into another.

You often do this in your life without thinking about it; for example, 12 hours is half a day, but to determine this formally, you would:

12 hours * (1 day / 24 hours) = 0.5 days

The "1 day / 24 hours" is called a "**conversion unit**" and it is essential if you wish to convert hours into days. There are many kinds of conversion units: four quarters per dollar, 60 seconds per minute, and 12 donuts per 1 dozen donuts. We will use different kind of conversion units in chemistry as we proceed through the course.

Conversion units can be "flipped" to find different quantities. Instead of writing "1 day / 24 hours" you could write "24 hours / 1 day" if you wanted to convert days into hours.

"Dimensional Analysis" means, essentially, to "watch your units". You want to convert your original unit (hours) into a new type of unit (days). Remember that you can "flip" your conversion unit as necessary.

Time for some practice!

Solve each of these problems using scientific notation and dimensional analysis.

19. There are about $1x10^{12}$ stars in our galaxy. There are about $10x10^{12}$ galaxies in the universe. Assuming each galaxy has the same number of stars, how many total stars are there in the universe?

20. There are about 7 billion people ($7x10^{9}$) on the Earth. Assuming that each person has the number of atoms indicated in question #18 earlier, how many total atoms are present in all of humanity?

21. How many days are in a millennium (1000 years)?

22. How many nickels could be had for $24,305?

Significant Figures

In chemistry, **significant figures** ("sig figs" for short) are the digits of value which carry meaning in a measurement. Experimental measurements always have a level of uncertainty associated with them; better experiments create better experimental values (and lower quality experiments will create inferior numbers.) In order to ensure precision and accuracy in measurements, a fixed method to compensate for these uncertainties has been developed…. hence, significant figures!

To tell how many significant figures a number has, keep these things in mind:

- all non-zero numbers are significant
- zeroes between non-zero numbers are significant
- a trailing zero or final zero in the decimal portion only as significant

You can probably see that zeroes are weird! :) So let's see some examples:

- Those digits which are non-zero are significant. For example, in **6575** cm there are **four** significant figures and in **0.543** there are **three** significant figures.

- If any zero precedes the non-zero digit then it is not significant. The preceding zero indicates the location of the decimal point; so, in **0.005** there is only **one** sig fig and the number **0.00232** has **3** sig figs.
- If a dot follows a large number ending in zero(es), the zeroes are significant; so 120. would be 3 sig figs (the dot means "the zero is significant") while 120 would be 2 sig figs (the zero is not meaningful.)
- If there is a zero between two non-zero digits then it is also a significant figure. For example; **4.5006** have **five** significant figures.
- Zeroes at the end or on the right side of the number are also significant. For example; **0.500** has **three** significant figures.
- Counting the number of objects (i.e. 5 bananas or 10 oranges) have **infinite** significant figures as these are exact numbers. Some definitions are also considered exact (i.e. 10 mm = 1 cm) and are considered to have infinite sig figs (so don't base your sig fig calculations on them, see below.)

Let's try some examples!

Tell how many significant figures are in each of these numbers:

23. 45,000 ____________________

24. 4308 ____________________

25. 4.00 ____________________

26. 0.00500 ____________________

27. 40.05 ____________________

Multiplying and dividing using significant figures is very important in chemistry. Most of the calculations that chemists do invoke Dimensional Analysis, which is essentially multiplying and dividing of numbers.

When you multiply or divide numbers in chemistry, the answer must reflect the smaller number of significant figures. So if you multiply two numbers with three sig figs each, the answer should have 3 sig figs. However, if you multiply two numbers, one with 2 sig figs and the other with 3 sig figs, the answer should have only 2 significant figures…. the smaller number of sig figs is carried through to the final answer. This is why it is critical to use the best sig figs possible in order to get better answers!

Here are some examples of multiplying and dividing numbers using significant figures:

3.0 x 4.0 = **12** (both 3.0 and 4.0 are 2 sig figs, so the answer must have only 2 sig figs)

3 x 4 = **10** (both 3 and 4 are 1 sig fig, so the final answer should have only 1 sig fig. 12 rounded to one sig fig is 10 (the zero does not count)…. this is not practical in the "real world", but it does provide a good example of how sig figs work.)

2.5 x 3.42 = **8.6** (in the calculator, the number is 8.55 but we **round up** to 8.6 - two sig figs since the 2.3 is a 2 sig fig number. **Round up only if the first number dropped is between 5 and 9**.)

2.5 x 3.41 = **8.5** (in the calculator, the number is 8.525 but we do not round up to 8.6 since the first number dropped (2) is not between 5 and 9.)

$4.52x10^4$ x $3.980x10^6$ = **$1.80x10^{11}$** (in scientific notation, all showing numbers are significant, so 4.52 would be 3 sigs and 3.980 would be 4 sigs. The number from the calculator ($1.79896x10^{11}$) is rounded up to $1.80x10^{11}$ because the first digit dropped (and 8) is between 5 and 9… so 1.79 becomes 1.80)

Time for some practice!

Perform the calculation and express the answer to the correct number of significant figures:

28. 6.0 x 7.0 ____________________

29. 6 x 7 ____________________

30. 7 x 7 ____________________

31. 37.41 x 8.3001 ____________________

32. (3.4617×10^7) ÷ (5.61×10^{-4}) ____________________

Adding and subtracting using significant figures is different from multiplying and dividing. In chemistry, add or subtract in the normal fashion, then round the answer to the LEAST number of places to the decimal point of any number in the problem. The last significant figure is called the "doubtful digit", so you essentially wish to cut the answer off at the "largest doubtful digit".

Here are some examples:

3.52 - 1.47 = **2.05** (all digits stop at the "hundredths spot" (the doubtful digit), so the answer stops at the hundredths spot as well.)

1.2 + 1.135 = **2.3** (1.2 stops at the "2" (the "tenths spot") while 1.135 stops at the "thousandths spot" (the 5). In sig figs, stop the answer at the largest doubtful digit (only one place to the right of the decimal), so 2.335 (the calculator answer) is rounded to 2.3. We did not round up because the first digit dropped (a 3) is not between 5 and 9.)

1520 + 0.1 - 0.001 = **1520** (the 1520 has a doubtful digit of tens (the "2") - this is the largest doubtful digit, so the answer stops there. the calculator reports 1520.099, but we stop the value at 1520 due to the sig figs.)

Perform these calculations and express the answer to the correct number of significant figures:

33. 32500 + 1424 + 120 ____________________

34. 1.55 - 0.2245 ____________________

35. 120 + 241 - 13.5 ____________________

36. 121.1 + 3.22 ____________________

37. $1.0 \times 10^3 + 111.5$ ____________________

The Metric System

Most of the world uses the metric system to express quantities of mass, volume, distance, and much more. The metric system is based upon powers of ten, each of which has its own prefix, and these are related back to the "base unit" (m for length, g for mass, etc.) For example, the metric prefixes we will use in chemistry are mostly these five:

kilo (k)	10^3
centi (c)	10^{-2}
milli (m)	10^{-3}
micro (μ)	10^{-6}
nano (n)	10^{-9}

For length, the "base unit" is the meter (m). You write the base unit name after the metric prefix and the unit (m) after the number; so re-writing the above for length, we get:

kilometer = km = 10^3 m
centimeter = cm = 10^{-2} m
millimeter = mm = 10^{-3} m
micrometer = μm = 10^{-6} m
nanometer = nm = 10^{-9} m

Since 10^3 is 1000, we can say that 1 km = 1000 m! Pretty easy!

Conversions between metric prefixes are consider exact (unlimited sig figs), so they are not used when calculating the number of sig figs. Example:

422 m * (1 km / 1000 m) = 0.422 km (3 sig figs due to 3 sigs in 422)

Time for some practice!

Perform these calculations and express the answer to the correct number of significant figures:

38. 1300 m to km ____________________

39. 462 g to μg ____________________

40. 3.75 L to mL ____________________

41. 469.5 nm to m ____________________

42. 3.7 x 10^3 cm to km ____________________

Final Practice!

Perform the following calculations. Express the answer to the correct number of significant figures and in scientific notation.

43. The average female has 4500 mL of blood. What is this volume in gallons? (1 gallon = 3.7856 L)

44. How many mg in 33 kg?

45. You need to make 2,125 copies of a sporting event flyer, and copies cost 5.0 cents. How many dollars ($) will it take to make this many copies?

46. If a bumblebee weighs 0.0022 kg, how many bees weigh 5.0 lb? (453.6 g = 1.0 lb)

47. How many quarters would you need to travel 495 miles? Gas costs $2.65 per gallon, and your vehicle gets 22 miles per gallon.

You're done! Way to go! Email this assignment to mike.russell@mhcc.edu.

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