Holy Cross High School
Honors Chemistry Summer Packet
2023-2024

I hope you are enjoying your summer! This packet is designed to help you prepare for chemistry this coming school year. Please write your answers on lined paper (you don't need to write the questions; just the answers, but make sure they are numbered clearly!). **For all math problems, you must show your work to get credit.** The completed packet will be due on the first day of class. **It will count as a quiz grade**. A 10% deduction will be assessed each day the packet is late. There will be a test on these topics about two weeks into the school year.

It is expected that you work on the packet throughout the summer and not at the last minute. There are eight sections, so I recommend setting a goal of **1 section per week.** Tutorials are provided in the packet, but any information that you are unfamiliar with may be sought from other sources such as books, websites or YouTube videos.

Part 1: Units of Measurement

In chemistry we make a lot of measurements and do a lot of calculations with our measurements. By definition, a measurement must have both a **number** and a **unit**. You are probably already familiar with some units, such as miles, pounds, and seconds.

Please answer these questions:

1. Write down some of the units you already know for measuring **distance** (hint: a foot is one).
2. Write down some of the units you already know for measuring **time**.
3. Write down some of the units you already know for measuring **volume**.
4. Write some of the units you already know for measuring **mass**.
5. In science, do you think we should use the **British imperial system** of units, or the **metric system** of units? (If you don't know what these systems are, look them up.)

So as it turns out, in modern science we always use the metric system, because it is internationally accepted and much easier to work with than the English system. So instead of measuring distance in feet, we will be using meters. Instead of measuring mass in pounds, we will be using grams.

Here is a list of common metric base units and what they are used to measure.

Unit	What it measures
grams	mass
meter	distance
liter	volume
second	time

In the metric system, there are **prefixes** for making the base units larger or smaller. The same prefixes can be applied to any base unit. The most important prefixes in chemistry are:

- kilo - 1,000 times bigger
- deci - 10 times smaller
- centi - 100 times smaller
- milli - 1,000 times smaller
- micro - 1,000,000 times smaller
- nano - 1,000,000,000 times smaller

For example:

100 centimeters = 1 meter
1000 meters = 1 kilometer
100 centigrams = 1 gram
1,000 millimeters = 1 meter
1,000,000 microliters = 1 liter
1,000,000,000 nanoliters = 1 liter

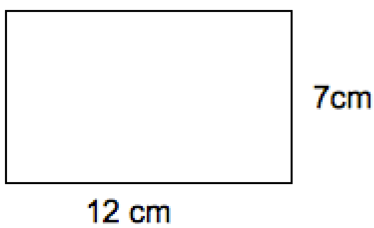
Please answer these questions:

6. How many nanometers are in a meter?
7. How many liters are in a kiloliter?
8. What unit do scientists use to measure **mass**?
9. What unit do scientists use to measure **volume**?

10. How many milligrams are in a kilogram?
11. What is mass? (look it up)
12. What is volume? (look it up)
13. How many millimeters are in a kilometer?

Part Two: Multiplying and Dividing Units

One thing about doing math with units is that the units behave similarly to variables in algebra. For example, suppose we are measuring the area of a rectangle:



The area would just be (7cm)(12cm), giving us 84 cm^2. **Notice that the units multiply together, giving us squared centimeters**.

We can also multiply two or more different units. For example, 12.4 m x 6.2 s = 76.88 m·s

In addition, units can be divided. This happens when measuring speed. For example, if I travel 450 miles in 3 hours, my average speed is: $\frac{450\ \square\square\square\square\square}{3\ h\square\square\square\square}$ = 150 miles/hour (miles per hour).

Finally, units can cancel out if you have the same unit in the numerator and denominator. For example: $\frac{125\ \square\cdot\square}{100\ \square}$ = 1.25 s

Here are some more examples of math with units:

$$3 \text{ ft} \times 4 \text{ lb} = 12 \text{ ft} \bullet \text{lb}$$

$$\frac{5 \text{ miles}}{2 \text{ hr}} = 2.5 \frac{\text{miles}}{\text{hr}}$$

$$7 \frac{\text{miles}}{\text{hr}} \times 4 \text{ hr} = 28 \text{ miles}$$

$$3 \text{ ft} \times 4 \text{ ft} = 12 \text{ ft}^2$$

$$6 \text{ in.} \times 5 \frac{\text{in.}}{\text{s}} = 30 \frac{\text{in.}^2}{\text{s}}$$

$$\frac{6 \text{ grams}}{2 \text{ grams}} = 3 \quad (3 \text{ is a } \textit{dimensionless} \text{ quantity})$$

Please complete the following. Make sure to multiply and/or divide the units.

14. $\frac{(53 \text{ g})}{(4 \text{ L})} =$

15. 39 N x 9.4 m =

16. (2 mL) (0.5 mL) (32 mL) =

17. $\frac{(4.08 \text{ g})}{(0.32 \text{ g})} =$

18. $\frac{1.57 \text{ L}}{2.0 \text{ L}} =$

19. $\frac{(35 \text{ m})(2 \text{ m})}{25 \text{ s}} =$

20. 5.5 cm x 2 cm x 10 cm =

21. $\frac{35 \text{ miles}}{0.5 \text{ hours}} =$

22. $\frac{35 \text{ g}}{0.25 \text{ L}} =$

23. (56 m)(2 m) =

Part Three: Conversion Problems

Doing conversions between units of measurement is an absolutely crucial skill for chemists.

You probably already know how to do simple conversions. For example: How many inches are in three feet? If you know that there are twelve inches in one foot, it is easy to see that two feet would be 24 inches, and three feet would be 36 inches. But instead of counting feet, you could also multiply 12 inches by 3 to get the same answer.

What if I asked you how many inches are in a mile? Maybe you have no idea how to begin this problem; but what if I told you that there are 5,280 feet per mile? Now, you can figure out how many inches in a mile by multiplying 12 inches by 5,280 feet, which gives you 63,360 inches.

In chemistry, converting between units to solve a problem is known as **dimensional analysis**. The main tool for dimensional analysis is called a **conversion factor**. A conversion factor is essentially a ratio of two measurements that are equal. For instance, $\frac{12\ inches}{1\ foot}$ is a conversion factor. $\frac{5{,}280\ feet}{1\ mile}$ is another conversion factor.

Since the numerator and denominator of a conversion factor are equal, we can **invert** the conversion factor. So we could also write $\frac{1\ foot}{12\ inches}$ or $\frac{1\ mile}{5{,}280\ feet}$.

This probably seems unnecessary to you now, but I promise that it will be very useful in chemistry, as the conversions we will do are much more complicated than what you've done before. Most of the time, converting units involves just multiplication and/or division, but without conversion factors it's very easy to get confused about when to multiply and when to divide.

Let's try solving a more complex conversion problem using conversion factors. **How many inches are in 768.9 miles?**

First, we should identify a few things.
What unit is the question asking for? **inches**
What unit is the question giving us? **miles**
What conversion factors can we use to solve this problem?
$\frac{1\ foot}{12\ inches}$ and $\frac{1\ mile}{5{,}280\ feet}$

So we take the number of miles and multiply it by **both** conversion factors to get our answer.

$$768.9\ \cancel{miles}\ x\ \frac{5{,}280\ \cancel{feet}}{1\ \cancel{mile}}\ x\ \frac{12\ inches}{1\ \cancel{foot}} = 48{,}717{,}504\ inches$$

Notice that we always set up the conversion factor so that all of the units cancel, except the unit we want for our answer. And notice that some conversions require multiple steps.

Please do the following metric conversions using conversion factors, making sure that one of the units cancels. Show your work.

24. Convert 4,500 g to kilograms.
25. Convert 2.3 L to milliliters.
26. Convert 1,450,000 centimeters to meters.
27. Convert 35 mm into cm.
28. Convert 9,674,430 grams into kilograms.
29. Convert 3.25 kilograms into milligrams.
30. Convert 6,700 millimeters into kilometers.
31. Convert 4,368 milligrams into kilograms.

Please do the following non-metric conversions as well. Use conversion factors and show your work.

32. How many dozen donuts are there in 244 doughnuts?
33. How many seconds are there in 1 year? (assume 365 days = 1 year)
34. How many dollars would 75 quarters be?
35. How many months are in 200,500 seconds?
36. How many inches are in 6 feet?
37. How many quarts are in 7 gallons? (1 gallon = 4 quarts)
38. How many pounds would 750 ounces be? (16 ounces = 1 pound)
39. Convert $100 into dimes.

Part Four: Density

If we say that something is dense, we mean it has a lot of mass packed into a relatively small volume. We can quantify density mathematically as simply mass divided by volume. Since the units also divide, the units of density are usually some sort of grams over some sort of liters or cubic centimeters.

Examples:

a) An object with a mass of 50g and a volume of 30 cm^3 would have a density of $\frac{50g}{30cm^3}$ = 1.67 g/cm^3

b) A sample of liquid has a volume of 34.2 mL and a mass of 52.3 g. Its density would be $\frac{52.3g}{34.2mL}$ = 1.53g/mL

c) An object has a mass of 14.6 kg and a density of 4.83 g/mL. What is its volume? We can use dimensional analysis to solve this problem, but first we need to convert kilograms to grams. So, $14.6\ kg\ x\ \frac{1{,}000\ g}{1\ kg} = 14{,}600\ g$ Then, we convert grams to milliliters, using the density as our conversion factor.

$14{,}600\cancel{g}\ x\ \frac{1\ mL}{4.83\ \cancel{g}}$ = 3,023 mL Notice that we inverted the density so that grams were in the denominator, so that grams cancel.

Please complete the following:

40. Calculate the density of an object with a mass of 35.0 grams and a volume of 3.55 cm^3.
41. Water has a density of 1.0 g/mL. What volume of water has a mass of 250 g?
42. A block of aluminum occupies a volume of 0.015 L and has a mass of 40.5 g. What is its density?
43. Mercury metal is poured into a graduated cylinder that holds exactly 0.0225 liters. The mercury used to fill the cylinder weighs 306.0 g. From this information, calculate the density of mercury.
44. What is the mass of ethanol that exactly fills a 200.0 mL container? The density of ethanol is 0.789 g/mL.
45. A block of aluminum occupies a volume of 15.0 mL and weighs 40.5 g. What is its density?

Part 5: Scientific Notation

Scientific notation is used often in chemistry to represent really small or really large numbers. Scientific notation looks like this: $A \times 10^b$ where A is a number between one and ten, and b is an exponent.

How to convert from **scientific notation** to **standard form**:

The exponent on the ten tells us how many places to move the decimal.When the exponent on the ten is **positive**, we move the decimal to the **right**. When the exponent on the ten is **negative**, we move the decimal to the left.

Here are some **examples**:

$2.7 \times 10^4 = 27{,}000$

$6.02 \times 10^{23} = 602{,}000{,}000{,}000{,}000{,}000{,}000{,}000$

$4.3 \times 10^{-4} = 0.00043$

$1.34 \times 10^{-6} = 0.00000134$

How to convert from **standard form** to **scientific notation**:

Place the decimal after the first nonzero digit, and figure out how many spaces it would have to move to go back to standard form. The number of spaces becomes your exponent.

Examples:

$0.0023 = 2.3 \times 10^{-3}$

$506{,}000 = 5.06 \times 10^5$

$0.000005683 = 5.683 \times 10^{-6}$

$1{,}230{,}400{,}000 = 1.2304 \times 10^9$

Convert the following numbers into scientific notation:

46. 3,400 ______________________________

47. 0.000023 ______________________________

48. 101,000 ______________________________

49. 0.010 ______________________________

50. 45.01 ______________________________

51. 1,000,000 ________________________________

52. 0.00671 ________________________________

53. 4.50 ________________________________

Convert the following numbers into standard notation:

54. 2.30×10^{4} ________________________________

55. 1.76×10^{-3} ________________________________

56. 1.901×10^{-7} ________________________________

57. 8.65×10^{-1} ________________________________

58. 9.11×10^{3} ________________________________

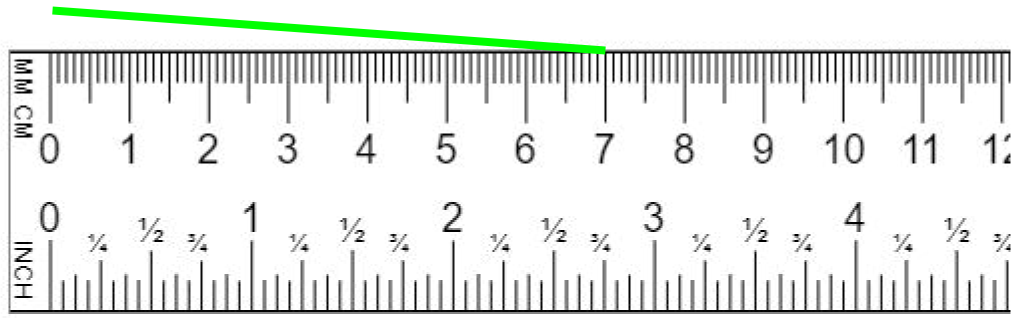
59. 5.40×10^{1} ________________________________

60. 1.76×10^{0} ________________________________

61. 7.4×10^{-5} ________________________________

Part Six: Significant Figures

Significant figures (or significant digits, or sig figs for short), are the digits that are reliable in science. You might be surprised to learn that not all digits are reliable! The distinction has to do with inherent limitations on measurements. Let's say you're measuring a distance with a meter stick that has marking for every millimeter, like this: 4



What is the length of the green bar? Some of you might say 7 cm, or 70 mm (which is the same thing). Others of you might say 6.9 cm (or 69 mm). In reality, the bar is somewhere in between 69 and 70 millimeters. We can estimate it at 69.5 mm, but the last digit is uncertain. The **significant figures** of a measurement are all the digits that are known for sure, plus one that is estimated. So in our measurement above (69.5 mm), all three digits are significant.

But what if we were measuring the diameter of a circle in order to find its circumference? In this case we would multiply the diameter (69.5 mm) times pi, giving us 218.3406…..and it goes on. So where do we round our answer to?

Since there were three significant figures in our original measurement, our calculation can only have three significant figures too. So we would round it to 218 mm. Usually, the number of significant figures in the original measurement is the number of significant figures in our answer.

When reading a measurement, how do we know which digits are significant? There are a few rules.

Rule 1: Every nonzero digit is significant.
Rule 2: Zeros in between nonzero digits are significant.
Rule 3: "Leading zeros" are zeros to the left of nonzeros. They are NOT significant, because they are just placeholders.
Rule 4: "Trailing zeros" are zeros to the right of nonzeros. They are significant IF there is a decimal point anywhere in the number.
Rule 5: If there is no decimal point, trailing zeros are usually not considered significant.

Examples:

a) 248 has 3 sig figs because they are all nonzeros
b) 54008 has 5 sigs figs because they are all nonzeros or "in-between" zeros
c) 45.00 has 4 sig figs because the first two digits are nonzeros and there is a decimal point, making the trailing zeros significant.
d) 0.00056 has only 2 sig figs, because leading zeros are never significant.

e) 0.0340600 has 6 sig figs. Leading zeros are never significant, but since there is a decimal point, the trailing zeros are significant here.
f) 54,000 has two sig figs, because trailing zeros are not significant if there is no decimal.

Please complete the following:

62) 31,000,000 has ______________________________ significant figures

63) 102.3 has ______________________________ significant figures

64) 40,000.0 has ______________________________ significant figures

65) 500 has ______________________________ significant figures

66) 104,000 has ______________________________ significant figures

67) 5.000 has ______________________________ significant figures

68) 231,509 has ______________________________ significant figures

69) 980 has ______________________________ significant figures

70) 807. has ______________________________ significant figures

71) 222,000,200 has ______________________________ significant figures

Part Seven: Thermodynamics (show your work)

72) To convert between Fahrenheit and Celsius, there is a formula. Look it up and write it down here.
73) Convert 54^{o} Fahrenheit to Celsius.
74) Using the same formula, convert 100^{o} Celsius to Fahrenheit.
75) Convert 20^{o} Celsius to Fahrenheit.
76) To convert between Celsius and Kelvin, there is another formula. Look it up and write it here.
77) Convert 15.4^{o} C to Kelvin.

78) Convert 124.9 K to Celsius.
79) Convert 153.2^{o} F to Kelvin.
80) 1 degree K is equal to how many degrees C?

The specific heat capacity is defined as the quantity of heat (in Joules) absorbed per unit mass (in kg) of the material when its temperature increases 1 K, and its units are J/(kg·K).

81) If 34.8 Joules of heat are applied to 1.5 kg of a substance, and its heat goes up 4.9 K, calculate the specific heat capacity of the substance.
82) The specific heat capacity of water is 4182 J/kg·K. How much heat (in Joules) are required to raise the temperature of 1.8 kg of water by five degrees K?
83) The specific heat capacity of iron is 0.450 J/kg·K. Suppose you input 567 Joules of heat into a 4.78 kg piece of iron. How much do you expect its temperature to go up (in Kelvins)?

Part Eight: Solutions

A **solution** is a mixture in which you can't distinguish the individual components. Often, one component of the mixture is dissolved in the other. The stuff that gets dissolved is called the **solute**, and the stuff that does the dissolving is called the **solvent**. The most common solvent is water. Solutions in which water is the solvent are called **aqueous solutions**.

Often, we are interested in the **concentration** of a solution. The concentration of a solution is the amount of solute divided by the total amount of solution.

For example, suppose we take 3.56 g of sodium chloride and dissolve it in 100 mL of water. When we do this, the volume of water may go up a little; let's say its new volume is 101.3 mL. The **concentration** of the solution would therefore be $\frac{3.56\,\square}{101.3\,\square\square}$, which simplifies to 0.0351 g/mL (this is read as "grams per milliliter").

It is important that the volume in the denominator is the volume of the **whole solution**, not just the volume of water we put in. Here is another example:
14.9 mg of protein powder dissolved in a mixture with a volume of 200.0 mL has a concentration of $\frac{14.9\,\square\square}{200.0\,\square\square}$ = 0.0745 mg/mL

You can also use a solution's concentration as a conversion factor to solve for an unknown. Suppose you have a sugar solution with a concentration of 3.5 g/mL. If you have 35.4 mL of it, how many grams of sugar are in it? You can solve it like this:

$$35.4\ \cancel{mL}\ x\ \frac{3.5\ g}{1\ \cancel{mL}} = 124\ g$$

Please answer these questions.

84) Suppose you dissolve 3.65 kg of solute into water. The volume of the mixture is 2.5 L. What is the concentration, in kilograms per liter?

85) What is the concentration of that same solution, in **grams** per liter?

86) Lucy wants to make a solution of known concentration. She carefully weighs out 30.2 g of potassium chloride and dissolves it in 134.4 mL of water. She then calculates her concentration as 0.225 g/mL. What was Lucy's mistake?

87) Suppose you have a solution with a concentration of 1.05 g/mL. If you have 45.6 mL of the solution, how much solute is in it?

88) Suppose you want to make a solution with a concentration of 86.9 g/L. You start with 250 mL of water. How many grams of solute should you put in? (Hint: remember that the concentration is the mass of solute divided by the mass of the **whole** solution.)

89) Let's say you want to make an aqueous solution with a concentration of 5.0 g/mL. If you want to have 100 mL of water, how much solute should you put in?

The concentration of solutions is also sometimes reported as a **percent**. This percent could by mass or by volume. You will often see percent concentration written on the labels of pharmacy products, foods, and beverages. Here are some examples:

a) If 5.6g of solute are dissolved in a mixture and the new mass is 95.6g, then the percent concentration by mass is $\frac{5.6\ \cancel{g}}{95.6\ \cancel{g}} = 5.9\ \%$

b) If you have 14.8 mL of solute in a mixture whose total volume is 92.3 mL, then your percent concentration by volume is $\frac{14.8\ \cancel{mL}}{92.3\ \cancel{mL}} = 16.0\ \%$

Please answer these questions.

90. Suppose you have an alcoholic beverage with a volume of 0.75 L. 0.25 L of it are alcohol. What is the percent alcohol by volume?

91. Suppose you have a jug of vinegar. Its total volume is 5.75 L. Its percent concentration by volume is 5%, meaning 5% is pure vinegar and the rest is water. How many liters are vinegar?
92. Rubbing alcohol is often sold with a percent concentration by volume of about 90%. Suppose you have a bottle of 91% rubbing alcohol (by volume). If the whole bottle has a volume of 875 mL, how many milliliters of rubbing alcohol are in it?
93. Let's say you want to make a 45.7% solution by mass. You start with 100.0g of water. How many grams of solute do you need to add? (Hint: remember that the concentration is the mass of solute divided by the mass of the **whole** solution).