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Applied Math in Introductory Chemistry

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Applied math in introductory chemistry for non-science majors

Introduction

Students, particularly those who are non-science majors, often struggle with college-level science courses required for graduation due to the applied mathematics needed to successfully complete the course. This resource includes four activities on the topics of *units and measurements*, *dimensional analysis*, *density*, and *gases*. These topics were specifically designed to teach the mathematics embedded in these topics in a culturally responsive way. Throughout the activities, we incorporate these four elements of culturally relevant pedagogy (Ladson-Billings, 2009) in order to engage students in successfully solving basic mathematics in chemistry while promoting their interest in learning chemistry:

1. **Sustaining students' cultural and linguistic competence** (Paris, 2012) by allowing students to share how they might have learned in other country or cultural contexts
2. **Building academic success** (Ladson-Billings, 2009) by having students analyze and discuss their thinking as it relates to their personal identity and value for mathematics in their daily life.
3. **Empowering students to construct knowledge** (Hernandez et al., 2013) by giving them the authority to tackle problems through multiple approaches
4. **Building on students' prior experiences** (Gay, 2018) by finding meaningful situations that are relevant to their lives.

REFERENCES

Gay, G. (2018). *Culturally responsive teaching: Theory, research, and practice*. Teachers College Press: New York.

Hernandez, C. M., Morales, A. R., & Shroyer, M. G. (2013). The development of a model of culturally responsive science and mathematics teaching. *Cultural Studies of Science Education*, *8*(4), 803-820.

Ladson-Billings, G. (2009). *The dreamkeepers: Successful teachers of African American children*. John Wiley & Sons: Chicago.

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Activity 1: Units and Measurements

This activity covers: understanding prefixes, being able to convert it to its corresponding value, introducing unit conversion (dimensional analysis); understanding scientific notation, exponents, and its operations; and metric units. Notably, this activity builds on students' linguistic and cultural competence by highlighting the different way that reading and writing numbers is in the USA compared to other countries.

Warmup: True/False? Poll and discuss.

1. Students of color and females are underrepresented in STEM fields like chemistry, even though STEM workers earn more on average than non-STEM workers.

2. All students can succeed in a math/chemistry/science class. *(Lead into discussion on why students don't succeed in chemistry, and how this class will address those challenges.)*

Basics of reading and writing numbers in USA vs. other countries

Source: TODOS: MATHEMATICS FOR ALL. [MATHEMATICAL NOTATION COMPARISONS BETWEEN U.S. AND LATIN AMERICAN COUNTRIES](). Harris County Department of Education, Houston, Tx.

How do you read these numbers in American English?

1) **89,520,000,000,000**
2) **23,467,891,705**

Answers: 1) 89trillion, 520billion 2) 23billion, 467million, 891thousand, 705

Whole class discussion: **Do any of you come from countries where you read these numbers differently? For example, how would you read the second number in Spanish?**[1]

Answer: In Spanish the second number is 23mil 467millones, 891mil, 705. And in many Latin American countries and in the old British long scale, it would be read as 23 thousand million, 467million, 891thousand, 705.

3) **In the US, commas are used to separate groups of 3. For example 9,435,671. But how do you write this number in Latin American countries?**

   Answer: It could be written as 9.435.671 or 9 435 671 or 9'435,671 or 9;435,671

4) **How can you write the decimal 4.56 in Latin American countries?**

   Answer: 4,56 In some Latin American countries, the comma is used to separate the whole number from the fraction

Numbers and Exponents: Review

1) How can you rewrite 2+2+2+2+2 in an abbreviated form?
2) How can you rewrite 2x2x2x2x2 in an abbreviated form?

KEY TAKEAWAY #1: Multiplication is repeated addition. Exponents is repeated multiplication.

3) What happens when you multiply 2.0 times 10? Times 100? Times 1000? Or 2.5 times 10, or 100, or 1000?
4) What happens when you divide 2.0 by 10? By 100? By 1000? Or 2.5 by 10, or 100, or 1000?
5) What happens when you multiply 2.0 by 0.1 (one tenth)? Or 0.01 (one hundredth)? Or 0.001 (one thousandth)? Or 2.5 by one tenth, one hundredth, or one thousandth?

KEY TAKEAWAY #2: Multiplying a number by 10 is equivalent to decimal point to the right, while dividing by 10 is equivalent to moving decimal point to the left (and filling in blank spaces with 0's).

6) How do you write 10, 100, and 1000 in exponent form? How do you write one tenth, or one hundredth, or one thousandth in exponent form?

KEY TAKEAWAY #3: Numbers greater than 1 are considered large numbers, and are written with a positive power of ten (e.g., 10^3). Numbers less than 1 are considered small numbers and are written with a negative power of ten (e.g., 10^{-4}). The specific power of 10 indicates just how big or how small the number is.

7) How do you write 1 billion as a number? And in exponent form?

KEY TAKEAWAY #4: Some Latin American countries write 1,000,000 as 10^{12}, but in the US, it is 10^9.

Metric systems

Think pair share: How many people or your families come from countries that use a different metric system (e.g. for height or weight)? What are other common usages of these prefixes in the real world (e.g. kilogram is one thousand grams)?

Possible answers: gigabyte, megapixel, megadeath (1 million deaths), megawatt, kilometer, deciliter (often used in Europe for flour, water, etc.), nanosecond, picogram (mass of bacterial cell)

TABLE 1.2 The Most Common Metric Prefixes

Prefix	Symbol	Value
giga	G	10^9 = 1,000,000,000 (one billion)
mega	M	10^6 = 1,000,000 (one million)
kilo	k	10^3 = 1000 (one thousand)
deci	d	10^{-1} = 0.1 (one-tenth)
centi	c	10^{-2} = 0.01 (one-hundredth)
milli	m	10^{-3} = 0.001 (one-thousandth)
micro	μ	10^{-6} = 0.000001 (one-millionth)
nano	n	10^{-9} = 0.000000001 (one-billionth)
pico	p	10^{-12} = 0.000000000001 (one-trillionth)

4. Complete the following table of **Prefix** values (refer to Table 1.2):

Prefix	Symbol	Factor of 10
giga		
	M	10^6
kilo		
	d	
	c	10^{-2}
milli		
	m	
		10^{-9}

Using the table of prefix multipliers, complete the following to rewrite each symbol to the corresponding value:

Example: 1 **k**m = _1×10^3_____ m (note that the last letter **m** is the **unit** of length, **meter**)

1 cg = _____________ g
1 dm = _____________ m
1 GL = _____________ L

1 mL = _____________ L
1 mg = _____________ g
1 nm = _____________ m

Significant figures: Review

Source: Columbia University's Center for Teaching and Learning, Frontiers of science, Chapter 5

Significant digits give us useful information about the accuracy of a measurement.

1. **All non-zero numbers ARE significant.** The number 33.2 has THREE significant figures because all of the digits present are non-zero.

2. **Zeros between two non-zero digits ARE significant.** 2051 has FOUR significant figures. The zero is between a 2 and a 5.

3. **Leading zeros are NOT significant.** Leading zeros are just "place holders." The number 0.54 has only TWO significant figures. 0.0032 also has TWO significant figures.

4. **Trailing zeros to the right of the decimal ARE significant.** There are FOUR significant figures in 92.00.

5. **Trailing zeros in a whole number with the decimal shown ARE significant.** Placing a decimal at the end of a number is usually not done. By convention, however, this decimal indicates a significant zero. For example, "540." indicates that the trailing zero IS significant; there are THREE significant figures in this value.

6. **Trailing zeros in a whole number with no decimal shown are NOT significant.** Writing just "540" indicates that the zero is NOT significant, and there are only TWO significant figures in this value.

1. You try

a. The number 0.00430 has __________ significant figures.

b. Round the number 0.08535 to two significant figures.

2. With a partner: Fill in the 2nd column of the table below.

Decimal Notation	Number of Significant Figures	Scientific Notation
0.00682	_____	_________
1.072	_____	__________
300	_____	__________
300**.**	_____	__________
300**.**0	_____	__________
0.0000678	_____	__________
___________	_____	2.54×10^{6}
___________	_____	3.6×10^{-4}

Scientific Notation

Adapted from: Purple Math, Exponents: Scientific Notation Module

Scientific notation allows us to write in shorthand very big or very small numbers. The format for writing a number in scientific notation is fairly simple: (first digit of the number) followed by (the decimal point) and then (all the rest of the digits of the number), times (10 to an appropriate power).

To figure out the power of 10, think "how many places do I move the decimal point?"

- When the number is 10 or greater, the decimal point has to move to the left, and the power of 10 is positive.
- When the number is smaller than 1, the decimal point has to move to the right, so the power of 10 is negative.

Example:

1. Write 126 in scientific notation
2. Write 650 million in scientific notation
3. Write 0.0055 in scientific notation

REMEMBER: A negative on an exponent and a negative on a number mean two *very* different things!

$37{,}000 = 3.7 \times 10^{4}$

$-37{,}000 = -3.7 \times 10^{4}$

$0.00037 = 3.7 \times 10^{-4}$

$-0.00037 = -3.7 \times 10^{-4}$

3. With your partner: Go back and fill in the 3rd column of the table above.

4. The USA takes a national census every 10 years, including this year 2020. Below are approximate populations of the following countries based on their census data as reported by Worldometer.

a. Write each population in scientific notation.

Country	Population in standard notation	Population in scientific notation
USA	331,002,651	
Mexico	128,932,753	
Dominican Republic	10,847,910	
Trinidad and Tobago	1,399,488	
India	1,380,004,385	

b. How can you use scientific notation to find the total population of these countries?

c. Find the total population using scientific notation.

Operations with scientific notation

Multiplication and division

When multiplying numbers expressed in scientific notation, you can add the exponents together.

Multiplication Example:

$10^1 \times 10^2 = 10 \times 100 = 1{,}000 = 10^3$

$10^1 \times 10^{-3} = 10^{1-3} = 10^{-2} = 0.01$

Example

$(4.0 \times 10^5)(3.0 \times 10^{-1})$

$= 12 \times 10^4$

$= 1.2 \times 10^5$

Check your answer:

$(4 \times 10^5) \times (3 \times 10^{-1})$

$= 400{,}00 \times 0.3$

$= 123{,}000$

$= 1.2 \times 10^5$

Operations with scientific notation (continued)

Division Example:
$(6.0 \times 10^8) \div (3.0 \times 10^5)$
You can rewrite this as $\frac{(6.0 \times 10^8)}{(3.0 \times 10^5)}$
First divide the 6 by the 3, to get 2. The exponent in the denominator is then moved to the numerator, and you reverse the sign.
$= 2 \times 10^8 \times 10^{-5}$
$= 2.0 \times 10^3$ or 2,000

Addition and Subtraction
The key to adding or subtracting numbers in Scientific Notation is to make sure the exponents are the same.

Addition Example
$(2.0 \times 10^2) + (3.0 \times 10^3)$
$= (0.2 \times 10^3) + (3.0 \times 10^3)$
$= 3.2 \times 10^3$ or 3,200

Check your answer:
$(2.0 \times 10^2) + (3.0 \times 10^3)$
= 200 + 3000
= 3,200

Subtraction Example
$(2.0 \times 10^7) – (6.3 \times 10^5)$
$=(200 \times 10^5) – (6.3 \times 10^5)$
$= 193.7 \times 10^5$
$= 1.937 \times 10^7$

Check your answer:
$(2 \times 10^7) – (6.3 \times 10^5)$
= 20,000,000 – 630,000
= 19,370,000
$= 1.937 \times 10^7$

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5. Try the following operations first *without* using your scientific calculator, using your brain, pencil, and paper alone. Report your final answer in scientific notation.

a. $(1 \times 10^8)(5 \times 10^{-5})$

b. $(3 \times 10^9) \div (1 \times 10^6)$

c. $\frac{6.0 \times 10^8}{3.0 \times 10^6}$

d. $(4 \times 10^{-5})(4 \times 10^{-2})$

e. $3 \times 10^4 – 5 \times 10^4$

f. $3 \times 10^4 – 2 \times 10^2$

g. $2.5 \times 10^2 + 5.2 \times 10^3$

REFERENCES

Columbia University's Center for Teaching and Learning, Frontiers of science, Chapter 5

Purple Math, Exponents: Scientific Notation Module

TODOS: MATHEMATICS FOR ALL. MATHEMATICAL NOTATION COMPARISONS BETWEEN U.S. AND LATIN AMERICAN COUNTRIES. Harris County Department of Education, Houston, Tx.

Activity 2: Dimensional analysis (conversion factors)

This activity on conversion factors demonstrates revisions to typical dimensional analyses problems to become more culturally relevant by representing more diverse backgrounds and cultural contexts (highlighted in yellow and denoted with CRP) from which students may hail. The activity also tries to break down dimensional analysis in simple terms and visually using the cross multiplication method that many students find more accessible.

Unit Dimensional Analysis

Adapted from: [A step by step guide to dimensional analysis]

Dimensional analysis is a method to convert from one rate to another.

1. Ask yourself, "What units of measure do I want to know or have in the answer?"
2. Ask, "What do I know to start with?"
3. Ask, "What key conversion facts or ratios (that equal 1) do I know?"
4. Cross multiply and cancel units until you end up with the units you want.

EXAMPLES OF KEY CONVERSION FACTS:		
1 m = 3.28 ft	12 inches = 1 ft	5,280 ft = 1 mile
1 kg = 2.2 lb	1 ton = 2000 lbs	____seconds = 1 minute
____ minutes = 1 hour	24 hours = ____ day	____ days = 1 year

Comprehension check: Using the conversion facts above, how many minutes are there in a year?

BONUS:

a. How many feet are in 3 meters?	b. How many pounds are in 12 kilograms?
c. How many seconds are in 5 minutes?	d. How many feet are in 7 miles?
e. How many kilograms are in 2000 pounds?	f. How many kilograms are in 1 ton?

Compare the two questions CRP neutral vs CRP

Example

1. Your friend weighs 244 lbs. What is his mass in kilograms? (1.00 lbs = 453.592 g)

CRP: Jose is from Mexico. He is not familiar with English system, and his classmate, Tashana wants to help him convert his weight, 76 kgs to pounds (lbs).

$$\frac{76\,kg}{1} \times \frac{1\,lb}{453.592\,g} \times \frac{1000\,g}{1\,kg} =$$

Answer: 167.551 lbs

1. Sito is 6 feet tall in America. When he travels to the rest of the world however, he needs to report his height in centimeters. If 1 inch equals 2.54 centimeters, how tall is Sito, to the *nearest centimeter?*

2. A Vt C tablet is found to contain 0.500 g of Vt C. How many milligrams of Vt C does this tablet contain?

   CRP: The Ataulfo mangoes originate in the Mexican state of Chipas. They are golden yellow and weigh on average 6 ounces. Convert its weight using grams, milligrams. Note: **1 ounce** (oz) is equal to 28.34952 grams (g).

$$\frac{6\,oz}{1} \times \frac{28.34952\,g}{1\,oz} =$$

Answer: 170.09712 g or 170,097.12 mg

3. Analysis shows the presence of 203 μg of cholesterol in a sample of blood. How many grams of cholesterol are present in this blood sample?

CRP: Rosabel has a healthy Mexican shrimp recipe, wants to cook for her boyfriend coming back from Peru. but her cousin Itzel says "Shrimp contains the high levels of cholesterol, about 189 milligrams (mg) of cholesterol per 100 grams of shrimp. But it is recommended to consume around 100-300 mg of cholesterol per day. If Rosabel wants to cook 200 grams of shrimp, how many milligrams of cholesterol would be consumed? Also express in micrograms (μg). (Remember 1,000 micrograms = 1 milligram)

$\frac{200\ g}{1} \times \frac{189\ mg}{100\ g} = 378$ mg $\times\ \frac{1{,}000\ \mu g}{1\ mg} = 378{,}000$ micrograms

4. The ozone layer is a region in the upper atmosphere, at altitudes between 25 and 35 km, where the concentration of ozone is several times higher than at ground level. Express the altitude 35 km in centimeter units.

CRP: The Science News reports that the ozone layer develops a hole above Antarctica in September that lasts till early December. However, in November 2009, that hole shifted its position, leaving the southern tip of South American exposed to UV light at level much greater than normal. The layer of ozone normal stretches roughly 11 to 40 kilometers. Express the layer in centimeter units.

$\frac{11\ km}{1} \times \frac{1000\ m}{1\ km} \times \frac{100\ cm}{1\ m} = 1{,}100{,}000$ cm = 1.1×10^6 cm

$\frac{40\ km}{1} \times \frac{1000\ m}{1\ km} \times \frac{100\ cm}{1\ m} = 4{,}000{,}000$ cm = 4.0×10^6 cm

REFERENCES

A step by step guide to dimensional analysis

Activity 3: Lab on Density

This activity explores the concept of density, which is defined as the ratio of the mass of a substance to its volume. It tells us something about the substance independent of the amount of that substance, and is therefore called a *characteristic property* of matter. This lab will investigate the densities of several solid materials of various shapes and sample sizes. Note that rather than beginning with the density formula, this activity guides students to clearly understand the concept of density in real-world terms, including linguistic differences in how density is translated in other languages.

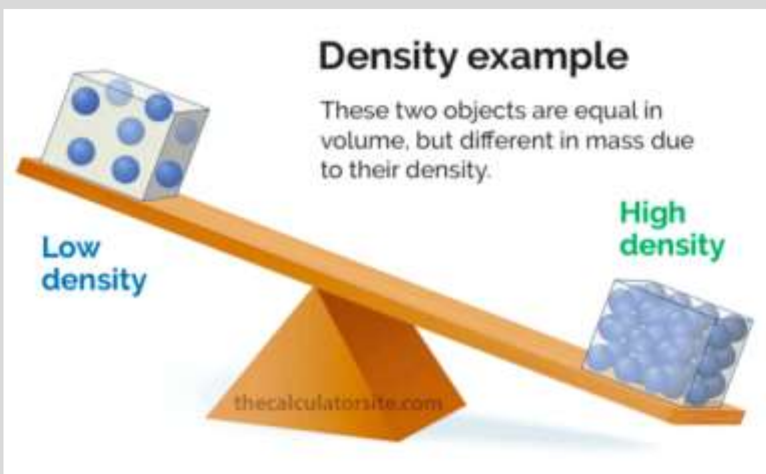
Warmup

Think, pair share: Which weighs more - a pound of feathers or a pound of lead?

Density = mass / volume   Units: g/mL (liquid), g/cm^3 (solid), g/L (gas)

Whole class discussion:

- How would you explain what mass is to your younger brother/sister? What about volume?
- Is density the same as weight?



Real-world ways to think of density

- True or False: Density is how compact or compressed something is
- Do some people float easier than others?
- Is tres leches or bizcocho cake more dense?
- How do you say density in another language? Does that translation give you a different way to think of density (e.g. Density in Chinese literally translates to “the degree of closeness”)?

Materials:

- 50ml or 100 ml graduated cylinder
- Top loading balance
- Water
- Calculator
- 5 pennies
- 10-15 paper clips

Procedure:

1. Form teams of 3 students. Each team will be provided with a graduated cylinder, a top loading balance, and three pennies.
2. Each team should measure the mass (**m**) of its 5 pennies by using the top loading balance (report it to your data sheet).
3. Each team should measure the volume (**V**) of its 5 pennies by using the graduated cylinder and immersing it in water to see how much water it displaces. Start with the cylinder about half filled with water. The water level should be measured before (this is your initial volume, V_i, report it to your data sheet) and gently add the pennies to the cylinder, read the final volume (V_f, report it to your data sheet) and the difference between the two readings is the volume of the object (**V**, report it to your data sheet).
4. Calculate the ratio **m/V** (the density) and enter it into the data sheet below,

   Density = mass / volume or **d = m/V**

   The equation shows that the units in which density is measured (the *dimensions* of density) are **g/ml**, or equally, **g/cm³**.
5. Repeat Steps 2-4 with 10-15 paper clips provided.

Data sheet: Please show your work to get full credit

Name:

Lab Partners:

Table 1.1: Density

Material	mass, m (g)	volume, V (cm^3)	Density, m/V (g/cm^3)
		Vi Vf V	
pennies			
Paper clips			

Note: Vi = initial volume; Vf = final volume; V = Vf – Vi

Table 1.2 comparison of class density data

Group number	Density of pennies	Density of paper clips

Rearranging the density formula

$$d = \frac{m}{v}$$

1. Can you solve the equation for m?

2. Can you solve the equation for v?

3. Check your formulas for #1 and #2 by supposing d=2, m=6 and v=3. When you plug in these values, do your formulas make sense?

Post-lab Question:

1. How do different teams' values of density (**m/V**) compare for a given material? Is there much variation among them? Explain your reasoning.

2. Find the density of a mineral sample that has a mass of 25g and a volume of 3 cm^3.

3. Find the mass of a piece of quartz which has a known density of 2.7 g/cm^3 and a volume of 14 cm^3.

4. Methane, a gas that is naturally present in the Earth's atmosphere in small amounts, has a density of 0.714 g/L at a particular temp. and pressure. What is the volume, in liters, of 10.0 g of methane?

5. A student determines that the mass of a 20.0 mL sample of olive oil is 18.4g

    a. what is the density of the olive oil in grams per milliliter?

    b. predict where the olive oil layer will on top or bottom in unshaken oil and vinegar salad dressing

6. The density of lead is 11.3 g/mL.
    a. Find the mass of 0.2 mL of lead.
    b. Find the volume of 30.8 g of lead.

Challenge

- Explore how fish manage to rise and sink in water and what this has to do with density. This can lead to an exploration of density, buoyancy, and gravity
- Why do giant yachts or ships made of metal float? Would they still float if you crushed them into a ball?

REFERENCES

The Calculator Site, Density Formula – How to calculate density

Activity 4: Gases

Similar to Activity 2, this activity on gases demonstrates revisions to problems on the gas law to become more culturally relevant by representing more diverse backgrounds and cultural contexts (highlighted in yellow and denoted with CRP).

1. Properties
2. Pressure
3. Boyle's Law (P&V)
4. Charles' Law (T&V)
5. Combined gas Law (P, V, & T)

1. Observed properties of matter

This theory explains the behavior of gases.

- Gases consist of very small particles (molecules) which are separated by large distances.
- Gas molecules move at very high speeds - hydrogen molecules travel at almost 4000 mph at 25^{o}C.
- Pressure is the result of molecules hitting the container. At 25 ^{o}C and 1 atm, a molecule hits another molecule and average of 10^{10} times/sec.
- No attractive forces exist between ideal gas molecules or the container they are in.
- Energy of motion is called kinetic energy. Because gas molecules hit each other frequently, their speed and direction is constantly changing.

2. Gas pressure

Gases exhibit pressure on any container they are in.

Pressure is defined as a force per unit of area.

Pressure = Force / Area

Several common units

1.00 atm = 760 torr
760 mm Hg
29.9 in Hg
14.7 lb/in^2
1.01 x 10^5 Pa

3. The gas laws

Since gases are highly compressible and will expand when heated, these properties have been studied extensively.

The relationships between volume, pressure, temperature and moles are referred to as the gas laws.

Units we will be using

Volume **L** (liters), **mL** (milliliters)

Temperature Must use an absolute scale.

^{0}**C** (Celsius)**, K** (Kelvin)

Note: Kelvin is most often used. (K = 273 + ^{0}C)

Pressure **Atm** (standard atmosphere), **torr**, **mm$_{Hg}$** (millimeters of mercury), **lb/in^2** (pound-force per square inch), **kPa** (kilopascal)

Note: Use what is appropriate.

Comprehension check: Identify the property of gas (temperature, volume or pressure) that is measured below. You can write T, V or P in the blank.

- 120 mL: _______
- 325 K: _______
- 775mmHg: _______
- 9.0 L: _______
- 1.2 atm: _______
- -9^o C: _______

Boyle's law: Pressure and volume

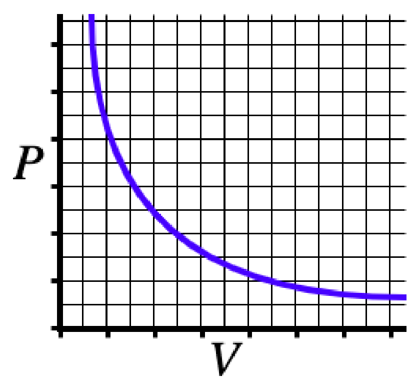
The volume of a gas is inversely proportional to its pressure.

PV = k, where k is a constant

or

$P_1 V_1 = P_2 V_2$

Temperature must be held constant!



Charles' law: Temperature and volume

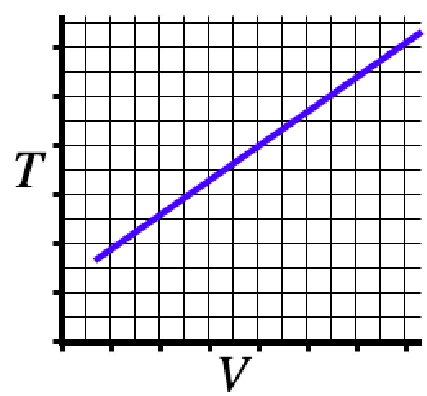
The volume of a gas is directly proportional to the absolute temperature (K T?)

$\frac{V}{T} = k$, *where k is a constant*

or

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

Pressure must be held constant!



Combined gas law

An expression obtained by mathematically combining Boyle's law and Charles' law

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

Part A:

Understanding the following phenomena in our daily lives by using an appropriate gas law.

1. When you take a sealed bag of chips to a higher altitude, it does expand, why?
2. When you take a breath of air, does your rib cage expand?
3. On a cold, wintry morning, the tires on a car appear flat, why?
4. Aerosol containers can explode if they are heated. Why?
5. How can the tires on a car look flat on a cold, winter morning, but have a blowout when the car is driven on hot pavement in the desert?
6. Food cooks more quickly in a pressure cooker.
7. What happens to the volume of a bicycle tire or a basketball when you use an air pump to add air?
8. When ascending from depth, if a diver holds breath, the gases in the lung will shrink or expand?

Part B:

Understanding the Gas Law from the mathematical perspectives:

1. A mountain climber inhales 486 mL of air at -8 ^{o}C. What volume in mL will the air occupy in the lungs if the climber's body temperature is 37 ^{o}C?

CRP: Pedro is planning to climb Guatemala's Volcan Tajumulco (anyone know this is the tallest mountain in Central America). He inhales 486 mL of air at -8 ^{o}C. What volume in mL will the air occupy in the lungs if the climber's body temperature is 37 ^{o}C?

2. The heater used to heat 1000 L of air in a hot -air balloon is turned off. What happens to the final volume of gas, the same, larger, or smaller than the initial volume?

CRP: Up, Up, and Away! The Albuquerque International Balloon Fiesta is the world's famous ballooning event. Guess why Albuquerque? Do you know that the heater used to heat 1000 L of air in a hot -air balloon? That is huge amount of gases inside. What happens to the final volume of gas when the heater in the hot-air balloon is turned off? Is it the same, larger, or smaller than the initial volume? Discuss your thoughts.

3. On a winter day, a person takes in a breath of 425 mL of cold air (-12 ^{0}C). The atmospheric pressure is 682 mmHg. What is the volume of this air in the lungs where the temperature is 37 ^{0}C and the pressure is 684 mmHg?

4. A gas with a volume of 4.0L at a pressure of 205kPa is allowed to expand to a volume of 12.0L. What is the pressure in the container if the temperature remains constant?

5. A 40.0 L tank of ammonia has a pressure of 12.7 kPa. Calculate the volume of the ammonia if its pressure is changed to 8.4 kPa while its temperature remains constant.

6. A container containing 5.00 L of a gas is collected at 100 K and then allowed to expand to 20.0 L. What must the new temperature be in order to maintain the same pressure (P1 = P2).

7. A basketball can contain 900.0 mL at a temperature of 27.0 °C. What is the volume inside at 132.0 °C?

8. A 100 mL bubble of hot gases at 225 ^{o}C and 1.8 atm escapes from an active volcano. What is the new volume of the bubble outside the volcano where the temperature is -25 ^{o}C and the pressure is 0.8 atm?

CRP: The most active volcanoes in Central America include Santa Maria with its flank cone Santiaguito, Pacaya and Fuego in Guatemala, and Arenal in Costa Rica. Suppose that a 100 mL bubble of hot gases at 225 ^{o}C and 1.8 atm escapes from an active volcano. What is the new volume of the bubble outside the volcano where the temperature is -25 ^{o}C and the pressure is 0.8 atm?

9. In the fermentation of glucose (wine making), 780 mL of carbon dioxide gas was produced at 37 ^{o}C and 1.0 atm. What is the volume of the gas when measured at 22 ^{o}C and 675 mmHg?

CRP: Do you know Montevideo in Uruguay and Parras Valley in Mexico are among the best wine regions in Latin America? Do you know how wine is produced? It is a fermentation process of grapes. In the fermentation process, 780 mL of carbon dioxide gas was produced at 37 ^{o}C and 1.0 atm. What is the volume of the gas when measured at 22 ^{o}C and 675 mmHg?