CO_2 Emission

Subject: Chemistry

Grade Level: 11^{th}

Rational or Purpose: This activity is intended to strengthen students' concepts on scientific notation, unit conversion, and moles. The content will help students connect the content in chemistry to contemporary environmental and social problems.

Materials: Graph paper

Lesson Duration: 45 minutes

TEKS Objectives:

§112.45. Chemistry

(c) Knowledge and skills.

(2) Scientific processes. The student uses scientific methods during field and laboratory investigations. The student is expected to:

- (A) plan and implement investigative procedures including asking questions, formulating testable hypotheses, and selecting equipment and technology;
- (B) collect data and make measurements with precision;
- (C) express and manipulate chemical quantities using scientific conventions and mathematical procedures such as dimensional analysis, scientific notation, and significant figures;
- (D) organize, analyze, evaluate, make inferences, and predict trends from data; and
- (E) communicate valid conclusions.

(4) Science concepts. The student knows the characteristics of matter. The student is expected to:

- (A) differentiate between physical and chemical properties of matter;
- (B) analyze examples of solids, liquids, and gases to determine their compressibility, structure, motion of particles, shape, and volume;
- (C) investigate and identify properties of mixtures and pure substances; and
- (D) describe the physical and chemical characteristics of an element using the periodic table and make inferences about its chemical behavior.

Background Information:

Emission of carbon dioxide and other greenhouse gases (GHG) is one of the major issues that our global society must deal with now, not at some future date. GHG have caused greatly impacted the global climate. Temperatures worldwide have been increasing over decades. Scientific data supports the notion that the concentration of GHG will only increase at the current rate of CO_2 emissions. This is mainly due to the burning of nonrenewable fossil fuels to generate electricity. If burning of fossil fuel is not replaced by alternative, environmental friendly methods for electricity production, most of the animals in this planet, including humans, will eventually suffer.

In this exercise, you will gather some actual data of past years. You will be asked to perform calculations dealing with moles, unit conversion and scientific notation. Before you start the activity, let's take 5 minutes to review some essential concepts for the activity.

Mole (mol)

A mole is a quantifying unit that is mostly used to count chemical particles. A mole is similar to a dozen, a pair, etc because they represent a number. While dozens and pairs represent 12 and 2, respectively, a mole represents 6.02×10^{23}. This number is also known as Avogadro's number. Students have always asked, "Why is a mole 6.02×10^{23}?" (However, they would never ask why a dozen is 12!). The reason is that, there are 6.02×10^{23} Carbon-12 atoms to make up 12 grams of carbon. Therefore, we justify that, the molar mass of carbon is 12 grams per mole.

When calculating amount of molecules, some students always use weight to quantify molecules. This is absolutely wrong! This situation is analogous to, when someone asks you how many students are in the classroom, you would never answer, "There are 350kg of students in the classroom." Instead, you would answer, "There are 8 students in the classroom."

In Chemistry, students must be familiar with inter-conversion from weight to mole. There will be examples in "Unit Conversion" section below.

Scientific Notation

When you were reading from previous section, do you understand what 6.02×10^{23} is? To be specific, do you know what 10^{23} is? Scientific notation is a neat way to present a huge number. In our daily life, we do not usually encounter numbers with scientific notation. But actually, it is implicitly applied throughout our lives, which makes our lives much easier. Let's begin with the basic concept of scientific notation.

$$10 \times 10 \times 10 = 1000 \qquad \textbf{Eqn. (1)}$$

$$10 \times 10 \times 10 = 10^3 \qquad \textbf{Eqn. (2)}$$

Students should have no problem understanding the two equations listed above. Let's take a look at the following equation:

$$10 \times 10 \times 10 \times 10 \times 10 \times 10 \times 10 \times 10 = \_\_\_\_\_\_\_\_ \qquad \textbf{Eqn. (3)}$$

Write down your answer for Eqn. (3) without using any electronic device. Is your answer similar Eqn. (1) that you write down the actual number of zeros in your answer? If so, now try to represent your answer by using power, like Eqn. (2). What is your answer? Do you have the eighth power of 10 as your answer?

Now, take a look between 100000000 and 10^8. Although they represent the same number, it is much convenient to write 10^8 instead of writing the zeros over and over again. Especially when we have to deal with number as large as 10^{23}, do you think it would be easier to write the number to 23 zeros? Probably not! This is why we should learn to represent numbers with scientific notation.

It is mentioned that scientific notation is implicitly used in our daily lives. Where is it specifically? Answer the following question and you will find out!

Q1. How many grams in a kilogram? ______________

Q2. Answer Q1 again, but write your answer in power form. ______________

Q3. Take a guess, what does kilo- mean? ______________

Answer: Q1: 1000; Q2: 10^3;

We always see prefixes such as giga-, mega-, kilo-, milli-, nano-, etc. These prefixes all represent a power of 10. Take a look on the table below. You will see the prefixes and their equivalent values (1.0E+3 is the same as 1.0×10^3; the number is written that way because it is easier to designate the power with a single alphabet "E," rather than superscripting the number in the computer.)

FACTOR	...or in full ...	or in words	SI PREFIX	SI SYMBOL
1.0E+12	1 000 000 000 000	trillion	tera-	T
1.0E+9	1 000 000 000	billion	giga-	G
1.0E+6	1 000 000	million	mega-	M
1.0E+3	1 000	thousand	kilo-	k
1.0E+2	100	hundred	hecto-	h
1.0E+1	10	ten	deca-	da
1.0E-1	0.1	tenth	deci-	d
1.0E-2	0.01	hundredth	centi-	c
1.0E-3	0.001	thousandth	milli-	m
1.0E-6	0.000 001	millionth	micro-	µ
1.0E-9	0.000 000 001	billionth	nano-	n
1.0E-12	0.000 000 000 001	trillionth	pico-	p
1.0E-15	0.000 000 000 000 001	quadrillionth	femto-	f

After reading the table, you should understand what scientific notation means. It is now time to introduce the rules of scientific notation. Before doing that, let's take a look on some examples below:

$6,000 = 6.0\times10^3$ **Eqn. (4)**

$83,000 = 8.3\times10^4$ **Eqn. (5)**

$256,000 = 2.6\times10^5$ **Eqn. (6)**

$110,000 = 1.1\times10^5$ **Eqn. (7)**

The formal name of the number that will be multiplied by the power of 10 is Mantissa. The superscript on the right hand side of 10, which indicate the power of 10, is called Characteristic. Therefore the general form of scientific notation would be:

$$\text{Mantissa} \times 10^{\text{characteristic}}$$

If you are careful enough, you may notice that Mantissa is a number that ranges from 1 to 10, not including 10 itself. The characteristic is an integer indicating the number of places the decimal moved. Look at Eqn. (7). The decimal point is hidden next to the right most zero. It can be written as:

110,000.

Now you have to move the decimal point so that you can create a mantissa (remember it must be greater or equal than 1, but smaller than 10). You move the decimal point to the left for 5 times. The mantissa you have will be 1.1. The characteristic is 5. Therefore, you have the scientific notation as shown in Eqn. (7).

When will a characteristic become a negative number? It will be a negative number when you move the decimal point to the right. This happens when you have a number that is smaller than 1. (Refer to the table above).

Unit Conversion

Unit conversion is a very useful technique to interchange units of a quantity. Before going any further, keep in mind that unit conversion is changing the unit ONLY. It will never change the value of a measure (in other words, when you change 1 minute to seconds, you have 60 seconds. The value with new unit is equivalent to the previous one. It will not be 1.1 min when you convert 1 minute into seconds).

Changing 1kg to 1000g can be done by convert the prefix “k” to 1000 since you have already learned scientific notation. There is another way to convert it:

1kg × (1000g/1kg) = 1~~kg~~ × (1000g/1~~kg~~) = 1000g

To succeed in unit conversion, you must understand where (1000g/1kg) comes from. First, the fraction is called a conversion fact. It is well-known that 1000g is equal to 1kg. Since they are equal, the fraction is actually 1. Remember same value divided by same value will give you 1. Therefore, unit conversion is just multiply the number by 1 (this explains why the value would never change). However, the value “1” can have many different faces. For example, (1000g/1kg), (1hour/60min), ($1/100cents), etc. all have a value of 1. Now the question would be: What numbers should I put in the numerator and denominator? Should I put (1000g/1kg) or (1kg/1000g)?

In unit conversion, the major step required is canceling common units, as seen in the example above. The unit “kg” is canceled because there is one of each in numerator and denominator. To better illustrate the concept, let’s see the following:

$$\text{Quantity with undesired unit} \times \frac{\text{Value with desired unit}}{\text{Value with undesired unit}} =$$

The undesired unit will cancel out. Multiply and/or divide any numbers you have in the equation and you will get your answer. Reminder: the absolute value of any conversion factor MUST BE equal to 1. No exceptions! List below are examples to make sure you understand before moving on to the activity.

1.5 Dozen of Eggs × (12 Eggs / 1Dozen of Eggs) = 18 Eggs

30 Eggs × (1 Dozen of Eggs / 12 Eggs) = 2.5 Dozens of Eggs

144 lbs × (1kg / 2.2lbs) = 65.5 lbs

Activity

Please take a look at the following data:

Table 1 – Emission of CO_2 (in thousand metric tons) from 1994 to 2005

Year	Carbon Dioxide (CO_2)
2005	2,513,609
2004	2,456,934
2003	2,415,680
2002	2,395,048
2001	2,389,745
2000	2,429,394
1999	2,326,559
1998	2,313,008
1997	2,223,348
1996	2,155,452
1995	2,079,761
1994	2,063,788

(Note: 1 metric tons = 1000 kilogram)

Data taken from US Department of Energy

Questions:

1. What is the mass of CO_2 (in grams) emitted to the atmosphere by power plants in 1997? (Write down ALL digits. Use comma to separate every 3 digits.)

   ____

2. Rewrite your previous answer with proper scientific notation.

   ____

3. What is the molecular weight of CO_2 (in grams/mole)?

   ____

4. Calculate the number of moles of CO_2 emitted by power plants in 1997. (Show your work)

   ____

   ____

   ____

   ____

5. Calculate the number of CO_2 molecules emitted by power plants in 1997. (Show your work)

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____

____

6. In the table below, fill in the amount of emission in grams with scientific notation.

Year	**Carbon Dioxide (CO_2)**
2005	
2004	
2003	
2002	
2001	
2000	
1999	
1998	
1997	
1996	
1995	
1994	

7. On a graph paper, plot the data of the table above. Connect the data points with a smooth line.

8. What is the rate of increase between 1996 and 2006?

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9. Carbon dioxide is also known as a greenhouse gas. Greenhouse gases help trap heat within our planet. However, the emission of greenhouse gases has been over the limit in recent years. What famously known phenomenon is caused by serious emission of greenhouse gases? Explain.

10. *Critical Thinking*

Read the following paragraph by John A. Turner published in *Energy* in 1999.

… the ability of PV technology alone to provide all of the energy needs of the United States. This calculation assumes a 10% solar-to-electrical system efficiency and the use of fixed flat-plate collectors; tracking to follow the sun would lower the area required. A square ~161 km (~100 miles) on a side would, during 1 year, produce the energy equivalent to that used annually in the entire United States. Although 25,921 km2 (10,000 square miles) is a large area, it is less than one quarter of the area that this country has covered with roads and streets. If wind is added to the energy mix, this area for PV is reduced (in fact, the United States also contains enough usable wind resources to produce all of the electricity used by the nation); if geothermal energy is added, the PV area is even smaller, and if hydroelectric energy is added, the area is again smaller. The point is clear—we can gather more than enough renewable energy to power our society.

In a TWO paragraphs, discuss why United States still relies on traditional electricity generation AND briefly introduce one source of renewable energy. The introduction of renewable energy should include its method of operation, cost, barriers, and other related information.