**CHEM1.PS1: Matter and Its Interactions**

1. Understand and be prepared to use values specific to chemical processes: the mole, molar mass, molarity, and percent composition.
2. Demonstrate that atoms, and therefore mass, are conserved during a chemical reaction by balancing chemical equations.
3. Perform stoichiometric calculations involving the following relationships: mole-mole; mass-mass; mole-mass; mole-particle; and mass-particle. Show a qualitative understanding of the phenomenon of percent yield, limiting, and excess reagents in a chemical reaction through pictorial and conceptual examples. (states of matter liquid and solid; excluding volume of gasses)
4. Use the reactants in a chemical reaction to predict the products and identify reaction classes (synthesis, decomposition, combustion, single replacement, double replacement).
5. Conduct investigations to explore and characterize the behavior of gases (pressure, volume, temperature), develop models to represent this behavior, and construct arguments to explain this behavior. Evaluate the relationship (qualitatively and quantitatively) at STP between pressure and volume (Boyle’s law), temperature and volume (Charles’s law), temperature and pressure (Gay-Lussac law), and moles and volume (Avogadro’s law), and evaluate and explain these relationships with respect to kinetic-molecular theory. Be able to understand, establish, and predict the relationships between volume, temperature, and pressure using combined gas law both qualitatively and quantitatively.
6. Use the ideal gas law, PV = nRT, to algebraically evaluate the relationship among the number of moles, volume, pressure, and temperature for ideal gases.
7. Analyze solutions to identify solutes and solvents, quantitatively analyze concentrations (molarity, percent composition, and ppm), and perform separation methods such as evaporation, distillation, and/or chromatography and show conceptual understanding of distillation. Construct an argument to justify the use of certain separation methods under different conditions.
8. Identify acids and bases as a special class of compounds with a specific set of properties.
9. Draw models (qualitative models such as pictures or diagrams) to demonstrate understanding of radioactive stability and decay. Understand and differentiate between fission and fusion reactions. Use models (graphs or tables) to explain the concept of half-life and its use in determining the age of materials (such as radiometric dating).
10. Compare alpha, beta, and gamma radiation in terms of mass, charge, and penetrating power. Identify examples of applications of different radiation types in everyday life (such as its applications in cancer treatment).
11. Develop and compare historical models of the atom (from Democritus to quantum model) and construct arguments to show how scientific knowledge evolves over time, based on experimental evidence, critique, and alternative interpretations.
12. Explain the origin and organization of the Periodic Table. Predict chemical and physical properties of main group elements (reactivity, number of subatomic particles, ion charge, ionization energy, atomic radius, and electronegativity) based on location on the periodic table. Construct an argument to describe how the quantum mechanical model of the atom (e.g., patterns of valence and inner electrons) defines periodic properties. Use the periodic table to draw Lewis dot structures and show understanding of orbital notations through drawing and interpreting graphical representations (i.e., arrows representing electrons in an orbital).
13. Use the periodic table and electronegativity differences of elements to predict the types of bonds that are formed between atoms during chemical reactions and write the names of chemical compounds, including polyatomic ions using the IUPAC criteria.
14. Use Lewis dot structures and electronegativity differences to predict the polarities of simple molecules (linear, bent, trigonal planar, trigonal pyramidal, tetrahedral). Construct an argument to explain how electronegativity affects the polarity of basic chemical molecules.
15. Investigate, describe, and mathematically determine the effect of solute concentration on vapor pressure using the solute’s van ’t Hoff factor on freezing point depression and boiling point elevation

**Introduction**: In the presence of water, citric acid [C6H8O7] and sodium bicarbonate [NaHCO3] (also known as baking soda) react to form trisodium citrate [Na3C6H5O7], water [H2O] and carbon dioxide [CO2].



To keep workers safe, chemical engineers must control the temperature and pressure of the reaction so no explosions occur, and to make a profit, they must produce the most carbon dioxide [CO2] using the least citric acid [C6H8O7].

In groups of two, your engineering task is to test the reaction in the lab before a large scale operation plant is turned on. To keep the plant workers safe and earn profit, you must determine:

1. The temperature change that occurs during the reaction.
2. The amount of CO2 produced.
3. The optimum quantity of reactants to maximize the company's profit.

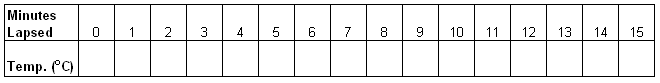
**Procedures- part 1**

1. Collect the following materials (measure as necessary):

* 2 g citric acid (CA)
* 2.6 g sodium bicarbonate (SB)
* 20 ml water
* quart size ziploc bag
* small ziploc bag
* thermometer (Vernier temperature probe)

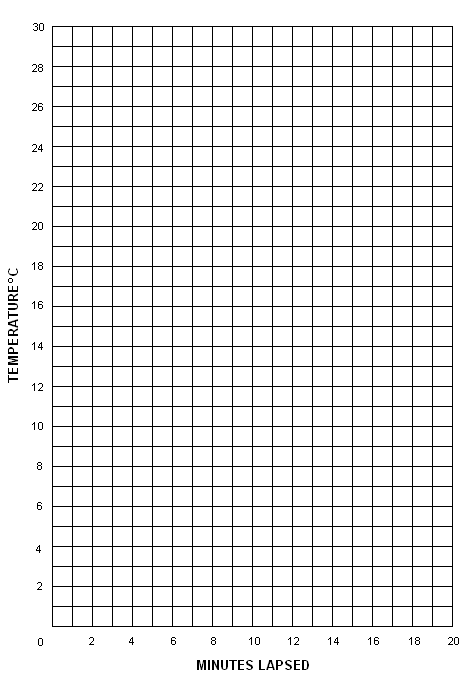
1. Pour the two powders into one corner of the quart sized Ziploc bag.
2. Pour the water into the small bag. Place in the corner of the large Ziploc bag, being careful not to spill the contents.
3. Weigh the bag. Record.
4. **IMPORTANT** to keep the water and powder separate. Have your partner carefully pour the water into the opposite corner of the bag. Have your partner seal the plastic bag, and squeeze as much air out (to make the bag flat).
5. Set the bottom of the bag on the thermometer bulb and record the temperature.
6. When directed, gently spill the small bag into the white powders tilt the bag to permit the water and powder to mix.
7. Do **NOT** shake the bag.
8. In Table 1, record the temperature in 60-second intervals.
9. Open the bag and weigh again. Record.
10. What is the difference in the mass? What does it mean?

**Table 1: Record Temperature Measurements from Day 1 Experiment**



Plot the data from Table 1.

**Chart 1: Plot the data collected in Table 1**



Did the last temperature return to the first temperature?

**Part 2:** You will test the same reaction as yesterday but use different amounts of citric acid and sodium bicarbonate. By collecting data using different amounts of citric acid, we will be able to “optimize” the reaction, or design the reaction to create the most profit.

Depending on your assigned group, you will test using the following quantities of reactants with 20 ml of water.

**Group A:** 1 g CA + 2.6 g SB **Group C:** 2 g CA + 5.2 g SB

**Group B:** 4 g CA + 5.2 g SB **Group D:** 6 g CA + 7.8 g SB

What will happen to the temperature during the reaction?

**Hypothesis:**

What will happen to the quantity of carbon dioxide produced from the reaction?

**Hypothesis:**

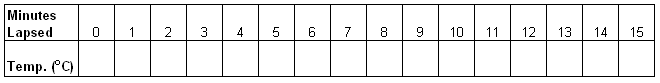
**Procedure:**

1. Collect the following materials (measure as necessary):

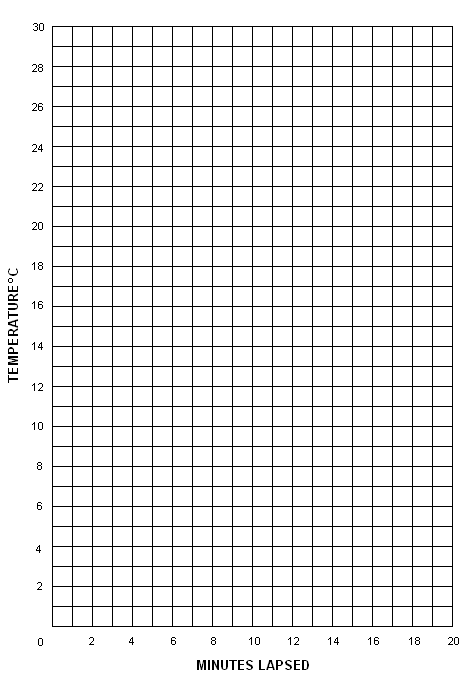
* citric acid (CA)
* sodium bicarbonate (SB)
* 20 ml water
* ziplock bag
* thermometer
* syringe
* piece of **BLUE** tape

1. Conduct the experiment in an identical matter as before.
2. Weight the bag. Record the weight.
3. Set the bottom of the bag on the thermometer bulb and record the temperature.
4. When directed, gently release your hand from around the powder and tilt the bag to permit the water and powder to mix.
5. Do **NOT** shake the bag.
6. In Table 2, record the temperature in 60-seconds intervals.
7. Wait until the reaction is complete and the temperature has returned to the original temperature.
8. Open the bag. Weigh.
9. What is the difference in the mass?

**Table 2: Record Temperature Measurements from Part 2 Experiment**



**Chart 2: Plot the data collected in Table 2**



3. What was the observed difference between the Part 1 results and the Part 2 results? (For example, more or less bubbling, lower or higher temperatures?)

**Part 3:** We ran a series of experiments using citric acid (CA) and sodium bicarbonate (SB). The reaction resulted in two observations: temperature drop and gas production. The gas produced was carbon dioxide (CO2). The goal of this experiment was to know how to choose the best reaction to make the largest profit (the most money). Below is a summary of the amount of chemicals used by each group.

**Group A** used**:** 1 g CA + 2.6 g SB **Group C** used**:** 2 g CA + 5.2 g SB

**Group B** used**:** 4 g CA + 5.2 g SB **Group D** used**:** 6 g CA + 7.8 g SB

**Questions**

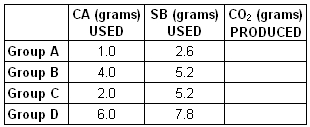
1. For **Group A** the average CO2 production was \_\_\_\_\_\_\_\_\_\_\_\_ gram/bag.

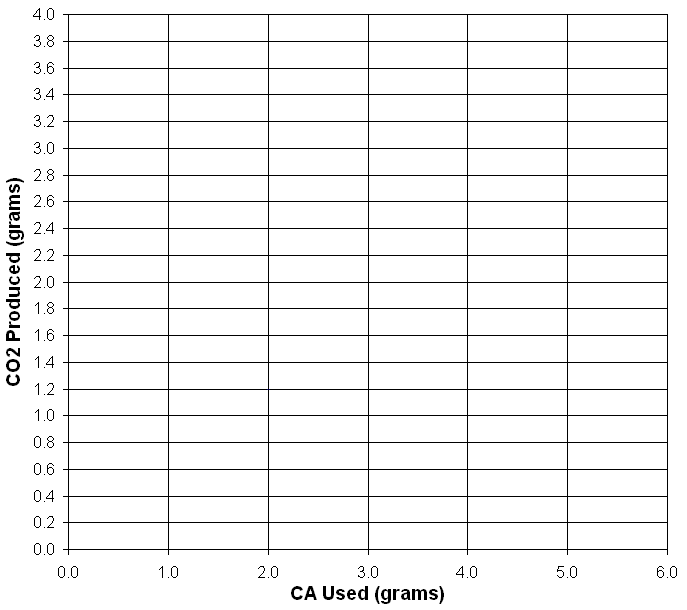
For **Group B** the average CO2 production was \_\_\_\_\_\_\_\_\_\_\_\_ gram/bag.

For **Group C** the average CO2 production was \_\_\_\_\_\_\_\_\_\_\_\_ gram/bag.

For **Group D** the average CO2 production was \_\_\_\_\_\_\_\_\_\_\_\_ gram/bag.

1. Complete Table 3 below, using the average CO2 production given above.





Complete Table 4 below. The cost for Group A has already been done for you.

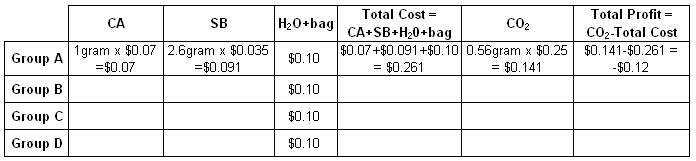
CA costs = $0.07/gram

SB costs = $0.35/gram

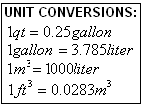
water + bag costs = $0.10

CO2 can be sold for = $0.25/gram

1. Which reaction should be used so that your company will make the most profit?



*Scale-Up*:Instead of running the reaction in a bag, we want to run it in a tank the size of the classroom. Each table: use a measuring tape and work as a team to determine the room size.



1. Length (front of room to back of room): L= \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ feet

Width (side to side): W=\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ feet

Height (floor to ceiling): H=\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ feet

1. What is the volume of the room in ft3 (V=L x W x H)? V=\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ ft3
2. If the volume of the bag was 1 quart, how many bags would be needed to equal the volume of the room? Show your work and write your answer in the box below.

Volume of the classroom = Volume of \_\_\_\_\_\_ bags

1. Using the reaction you picked from question 4, determine the profit of running the experiment in a tank the size of the classroom. (Hint: use your answer from question 7.)