MATH AND SCIENCE @ WORK

AP* CHEMISTRY Educator Edition

THE CHEMISTRY INVOLVED IN BONE LOSS

TI-Nspire™ Lab Activity

The Math and Science @ Work problem, Dietary Impacts on Astronauts' Bones, may be used to reinforce and assess the material learned from this lab.

Instructional Objectives

Students will

- balance reactions with carbonates;
- calculate the number of moles of carbon dioxide released using the ideal gas law;
- use stoichiometry to determine the mass of calcium removed in a reaction; and
- calculate the number of the moles of lost calcium.

Teacher Preparation

- Distribute the TI-Nspire file, *Bone_Loss.tns*, to the students' handhelds.
- Prepare 200 mL of 1.0 M sulfuric acid.
  - Add 11.1 mL of 18.0 M sulfuric acid to 150 mL of distilled water, and then add enough water to reach 200 mL of solution. (This is for a class of 30 students working in pairs.)
- Have the following available for each lab station:
  - TI-Nspire Lab Cradle or Vernier EasyLink cable
  - Temperature probe
  - Pressure probe
  - Syringe
  - 5.0 mL of 1.0 M sulfuric acid
  - 0.5 g of calcium carbonate
  - 1 three-hole stopper with pressure, temperature, and syringe ports
  - Safety glasses and aprons

Grade Level
10–12

Key Topic
Acid Reactions

Teacher Prep Time
20 minutes

Lab Time
45–55 minutes

Materials/Equipment
- TI-Nspire handhelds
- TI-Nspire Lab Cradle or Vernier EasyLink™ cables
- TI-Nspire file: *Bone_Loss.tns*
- Safety glasses and aprons

See Teacher Preparation section for additional materials

AP Course Topics
States of Matter:
- Gases

Reactions:
- Reaction types
- Stoichiometry

Laboratory

NSES Science Standards
- Physical Science
- Science in Personal and Social Perspectives

Safety Considerations

Students should be aware of safety considerations (also found on the student handout).

- Wear safety glasses and aprons.
- Avoid contact with sulfuric acid. Sulfuric acid is corrosive to body tissue and is slightly toxic by ingestion. The solution of sulfuric acid used in this lab is highly concentrated. If spilled on skin, thoroughly rinse exposed region. Refer to an MSDS sheet when using this material.

Class Time Required

This lab requires 45–55 minutes.

- Introduction: 5–10 minutes
- Student Work Time: 35 minutes
- Post Discussion: 5–10 minutes

AP Course Topics

States of Matter

- Gases
  - Law of ideal gases

Reactions

- Reaction types
  - Acid-based reactions; concepts of Arrhenius, Bronsted-Lowery, and Lewis; coordination complexes; amphoterism
- Stoichiometry
  - Mass and volume relations with emphasis on the mole concept, including empirical formulas and limiting reactants

Laboratory

- Making observations of chemical reactions and substances
- Recording data
- Calculating and interpreting results based on the quantitative data obtained
- Communicating effectively the results of experimental work

NSES Science Standards

Physical Science

- Chemical reactions

Science in Personal and Social Perspectives

- Science and technology in local, national, and global challenges

Background

This lab activity is part of a series of activities that applies Math and Science @ Work in NASA's scientific labs.

The primary goal of NASA's Nutritional Biochemistry Laboratory is to maintain astronaut health by determining the nutritional requirements for long-duration spaceflight. Using research from spaceflight and ground-based studies, researchers can develop, evaluate, and validate nutritional countermeasures (or preventions) to minimize the negative effects of long-duration spaceflight on the human body.

Figure 1: A scientist processing urine samples in the Nutritional Biochemistry Laboratory at NASA Johnson Space Center

The Nutritional Biochemistry Laboratory monitors the dietary intake and body mass of astronauts during their four to six-month-long missions on the International Space Station (ISS). In addition to general dietary intake issues, the metabolic properties of specific nutrients in spaceflight are also considered.

Researchers are exploring the amino acids in animal proteins and their effects on calcium metabolism. Excessive amounts of sulfur-containing amino acids (cysteine and methionine) can metabolize to create a slightly acidic environment in the body. Basic components of the diet, such as potassium salts—found in fruits and vegetables—can help neutralize these acid loads. Because bone itself is a large reservoir of calcium-containing base, an increase in acidity can affect calcium metabolism when there is not enough base in the diet. While this is just one factor which may contribute to the loss of bone mineral density in astronauts, it is a serious issue. Space exploration to destinations requiring more extended stays could be limited, unless effective countermeasures are established.

The benefits of using nutrition and altering dietary patterns as countermeasures include lowered risks for side effects, lowered costs, and minimal crew time required during flight. Research studies in other discipline areas (i.e., cardiovascular, muscle, bone, immunology, and radiation) have indicated nutrition as integral in determining successful countermeasures, and confirm that additional efforts in nutrition research are still needed.

However, countermeasures for maintaining astronaut health in space are not limited to nutrition and dietary plans alone. Exercise and medication are two other countermeasures that are often used to address various spaceflight-related health concerns. It is this multi-disciplinary approach that will be necessary to ultimately enable safer human exploration of space.

Lab Procedure

With your lab partner, gather the required materials and equipment. On your TI-Nspire handhelds, open the file, *Bone_Loss*. Read the provided information and answer the pre-lab questions (TI-Nspire pages 1.1–1.5). You will then be ready to start the lab activity. Go to TI-Nspire page 2.1 and follow the provided instructions. Following the lab activity, proceed to the lab analysis on TI-Nspire pages 2.13–2.20.

Solution Key

Throughout this activity, students are given most of the information and questions in the TI-Nspire file, *Bone_Loss.tns*. Students are also provided with the questions on the student handout. Some screenshots have been provided throughout the solution key to show what students will be reading on their handhelds. A TI-Nspire file with the solutions, *Bone_Loss_Solutions.tns*, is also provided enabling discussion of the solutions (using TI-Nspire software and a projector).

Mission (TI-Nspire pages 1.2–1.3)

Astronauts have a high rate of bone mineral density loss due to physiological impacts from a number of factors. In this lab, we will focus on one of those potential impacts—the acid reaction with calcium carbonate.

A person's blood can become slightly acidic by consuming a diet high in animal protein, while low in fruits and vegetables. Animal protein has a high level of amino acids. These amino acids contain sulfur which breaks down, forming sulfuric acid and influencing blood pH. Small decreases in blood pH make the blood more acidic and can activate the process of bone resorption (breakdown). This process occurs when the sulfuric acid reacts with calcium carbonate, the chemical that makes up bones. In this lab, you will explore a similar reaction and relate your findings to related concerns associated with spaceflight.

Pre-Lab Questions (TI-Nspire pages 1.4–1.5)

1.4 Choose the balanced chemical reaction between sulfuric acid and calcium carbonate.

$$H_2SO_4(aq) + CaCO_3(s) \longrightarrow CaSO_4(s) + CO_2(g) + H_2O(aq)$$

1.5 What is the mole ratio between calcium carbonate and sulfuric acid?

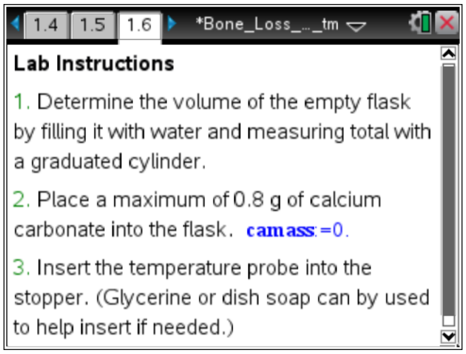
1:1

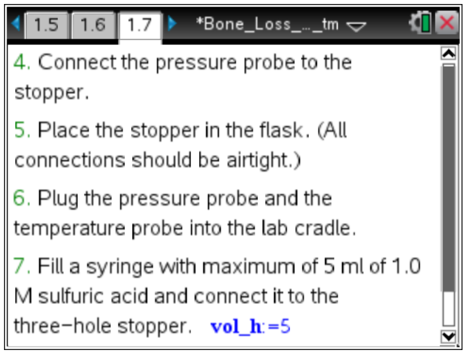
Lab Activity (TI-Nspire pages 1.6–1.10)

Students are given lab instructions in the TI-Nspire file. Screenshots are provided below ordered from left to right.

As students set up the lab, they should make sure all connections are airtight. Glycerine or dish soap can be used to help insert the temperature probe into the stopper.

Also note that calcium sulfate is relatively insoluble. Even though students will see bubbling during the reaction, they may assume the white powder left behind is still calcium carbonate. However, most of the calcium carbonate will have reacted off and the remainder will be solid calcium sulfate.





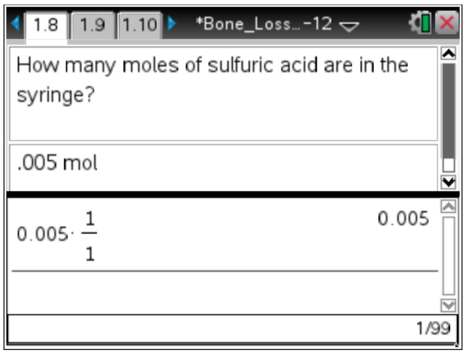
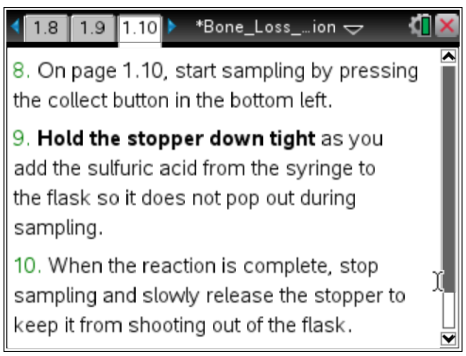
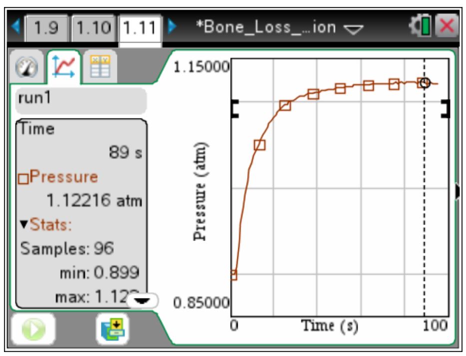


Figure 2: Lab set-up
(also on TI-Nspire page 1.9)





Lab Questions (TI-Nspire pages 1.12–1.17)

1.12 What was observed about the pressure in this reaction?

The pressure increased.

1.13 What was the most probable source of pressure change?

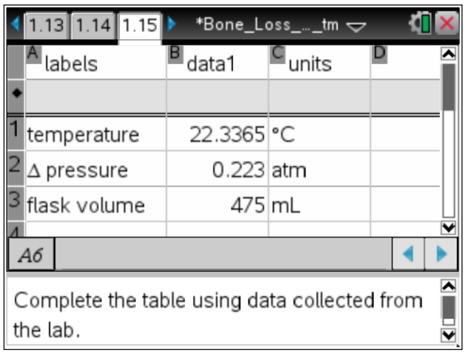
Increase in CO_2 production

1.14 Assuming the pressure change was caused by the carbon dioxide, what data is needed to determine moles of carbon dioxide released?

Pressure change, temperature of the air in the flask, and volume of the flask

1.15 Complete the table using data collected from the lab.

To find the change in pressure, students can use the min and max pressures that are found given in the left box on page 1.10.



1.16 Which reaction is the balanced chemical reaction between sulfuric acid and calcium carbonate?

$$H_2SO_4(aq) + CaCO_3(s) \longrightarrow CaSO_4(s) + CO_2(g) + H_2O(aq)$$

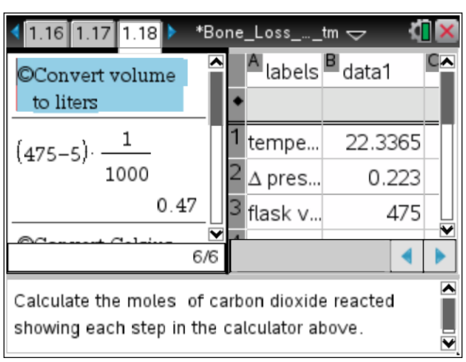
1.17 What is the mole ratio between calcium carbonate and carbon dioxide?

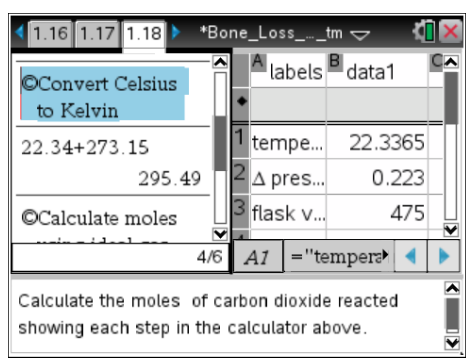
1:1

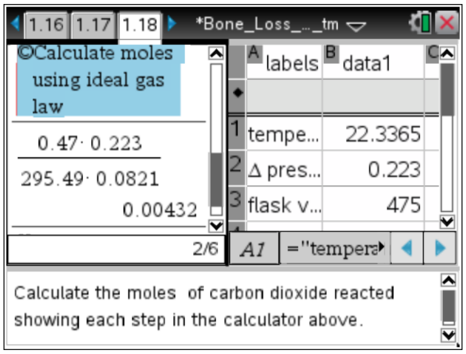
Lab Analysis (TI-Nspire pages 1.18–1.24)

1.18 Calculate the moles of carbon dioxide reacted showing each step in the calculator.

Data will vary depending on the student's precision and quantity of calcium carbonate and sulfuric acid used. The following is example data.

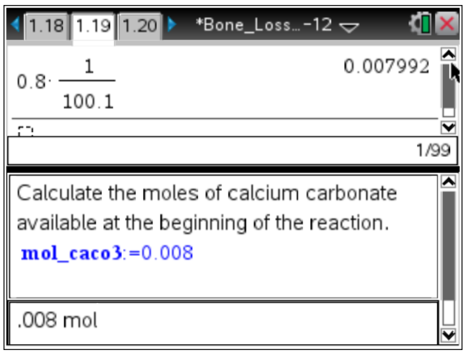




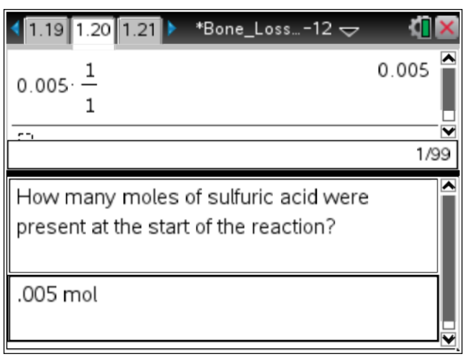


1.19 Calculate the moles of calcium carbonate available at the beginning of the reaction.

Have students calculate the moles based on the mass of calcium carbonate they massed. The results will vary depending on their mass.



1.20 How many moles of sulfuric acid were present at the start of the reaction?

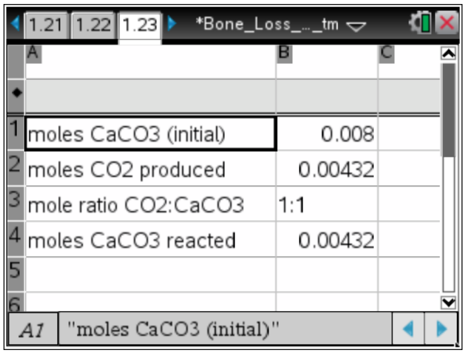


1.21 Which substance should be the limiting reactant based on your calculations?

Sulfuric acid

1.22 Complete the table on page 1.23 to determine the actual moles of calcium carbonate that reacted.

Using the mole ratio between CO_2, students can calculate the quantity of $CaCO_3$ reacted.



	A	B	C
1	moles CaCO3 (initial)	0.008	
2	moles CO2 produced	0.00432	
3	mole ratio CO2:CaCO3	1:1	
4	moles CaCO3 reacted	0.00432	
5			

1.24 Calculate the percent of calcium carbonate reacted.

Solutions will vary. Answer is the result of dividing the moles reacted by the moles of calcium carbonate placed in the flask.

1.25 From your data and percent yield, determine the limiting reactant.

Solutions will vary. In this particular experiment, the percent is less than 100%. Assuming very little experimental error, the sulfuric acid would be the limiting reactant.

1.26 Based on your learning from the lab, answer the following questions:

a. What weaknesses were there in your lab setup?

Answers will vary.

b. What would you change if you were to do this lab again?

Answers will vary.

c. What are some sources of acid in the body?

Answers will vary, but should include sulfuric acid resulting from animal protein.

d. What are some sources of calcium carbonate in the body?

Answers may vary, but should include bone.

e. Why should bone demineralization be a concern to humans on Earth and to astronauts in space?

Answers will vary. Possible answers include: osteoporosis, greater risk of bone fractures, and increased risk of developing renal stones. In space, these concerns are greater since bone density loss is faster than it is on Earth. Limited availability of medical treatment options in space further increases the concerns.

Contributors

This problem was developed by the Human Research Program Education and Outreach (HRPEO) team with the help of NASA subject matter experts and high school AP Chemistry instructors.

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