THE CHEMISTRY INVOLVED IN BONE LOSS – *TI-Nspire™ Lab Activity*

Background

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 Objectives

In this lab, you 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.

Materials/Equipment

- TI-Nspire or TI-Nspire CAS handheld
- 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
- Three-hole stopper with pressure, temperature, and syringe ports.

Safety Considerations

- 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.

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.

Pre-Lab Questions (embedded within the TI-Nspire file)

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

A. $H_2SO_4(aq) + CaCO_3(s) \longrightarrow CaSO_4(s) + H_2CO_3(aq)$

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

C. $H_2SO_4(aq) + CaCO_3(s) \longrightarrow CaSO_3(s) + H_2CO_4(aq)$

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

Lab Questions (embedded within the TI-Nspire file)

1.12 What was observed about the pressure in this reaction?

1.13 What was the most probable source of pressure change?

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

1.15 Complete the table using data collected from the lab.

1.15 | 1.16 | 1.17 *Bone_Loss...-12

	A labels	B data1	C units	D
◆				
1	temperature		°C	
2	Δ pressure		atm	
3	flask volume		mL	

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

A. $H_2SO_4(aq) + CaCO_3(s) \longrightarrow CaSO_4(s) + H_2CO_3(aq)$

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

C. $H_2SO_4(aq) + CaCO_3(s) \longrightarrow CaSO_3(s) + H_2CO_4(aq)$

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

Lab Analysis (embedded within the TI-Nspire file)

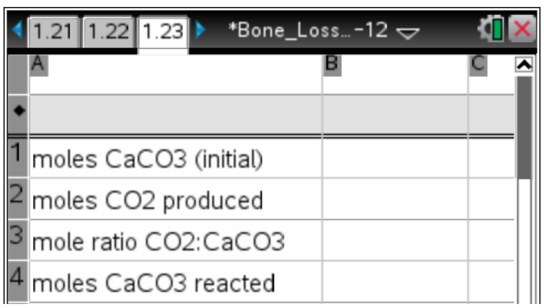
1.18 Calculate the moles of carbon dioxide reacted showing each step in the calculator.

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

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?

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



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

1.24 Calculate the percent of calcium carbonate reacted.

1.25 From your data and percent yield, determine 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?

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

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

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

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