MATH AND SCIENCE @ WORK

AP* CHEMISTRY Educator Edition

CARBON DIOXIDE REMOVAL – STOICHIOMETRY

Note: This problem is related to the chemistry problem *Carbon Dioxide Removal – Thermodynamics* and the biology problem *Respiration in Spaceflight* in the Math and Science @ Work series.

Instructional Objectives

Students will

- find mass and molar ratios through stoichiometry; and
- find moles of gas using the Ideal Gas Law.

Degree of Difficulty

This problem is a straight forward application of concepts taught in AP Chemistry.

- For the average AP Chemistry student the problem is at basic difficulty level.

Class Time Required

This problem requires 20-30 minutes.

- Introduction: 5 minutes
- Student Work Time: 10-15 minutes
- Post Discussion: 5-10 minutes

Background

This problem is part of a series of problems that apply Math and Science @ Work in NASA's Space Shuttle Mission Control Center.

Since its conception in 1981, NASA has used the space shuttle for human transport, the construction of the International Space Station (ISS), and to research the effects of space on the human body. One of the keys to the success of the Space Shuttle Program is the Space Shuttle Mission Control Center (MCC). The Space Shuttle MCC at NASA Johnson Space Center uses some of the most sophisticated technology and communication equipment in the world to monitor and control the space shuttle flights.

Within the Space Shuttle MCC, teams of highly qualified engineers, scientists, doctors, and technicians, known as flight controllers, monitor the systems and activities aboard the space shuttle. They work together as a powerful team, spending many hours performing critical simulations as they

Grade Level
11-12

Key Topic
Stoichiometry
Ideal Gas Law

Degree of Difficulty
Basic

Teacher Prep Time
5-10 minutes

Class Time Required
20-30 minutes

Technology
Calculator

AP Course Topics

States of Matter:
- Gases

Reactions:
- Stoichiometry

NSES
Science Standards

- Unifying Concepts and Processes
- Physical Science
- Science in Personal and Social Perspectives
- History and Nature of Science

prepare to support preflight, ascent, flight, and reentry of the space shuttle and the crew. The flight controllers provide the knowledge and expertise needed to support normal operations and any unexpected events.

One of the flight control positions in the Space Shuttle Mission Control Center is the Emergency, Environmental, and Consumables Manager (EECOM). One of the responsibilities of the EECOM flight controller is to monitor and regulate the cabin atmosphere which includes gas concentrations and pressures within the space shuttle cabin. Maintaining these parameters ensures a habitable cabin atmosphere and temperature on board the space shuttle much like the atmosphere here on Earth.

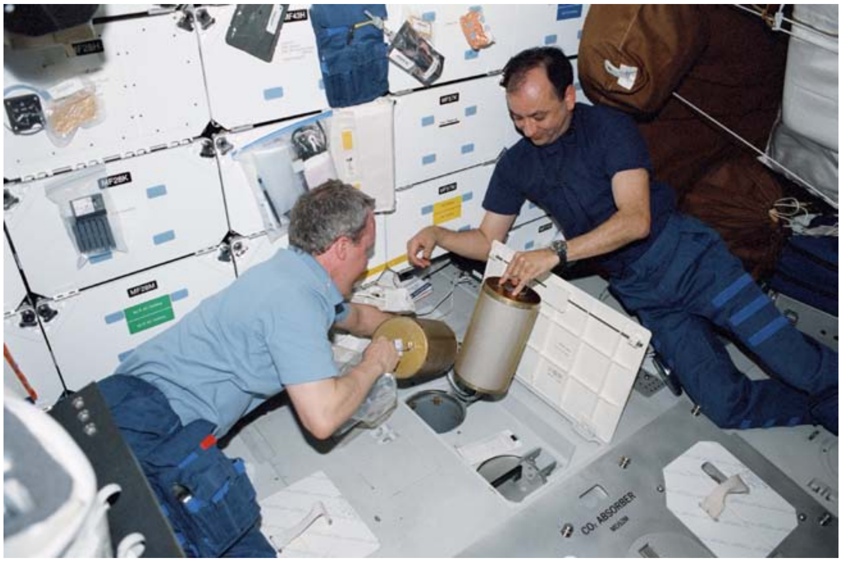

Figure 1: Astronauts Thomas D. Jones, mission specialist, and Mark L. Polansky, pilot, change out lithium hydroxide canisters on the mid deck of the Earth-orbiting Space Shuttle Atlantis.

The space shuttle uses an absorption method to remove carbon dioxide (CO_2). The absorption of carbon dioxide is accomplished in a chemical reaction using a sorbent known as lithium hydroxide (LiOH). This method relies on the exothermic reaction of lithium hydroxide with carbon dioxide gas to create lithium carbonate (Li_2CO_3) solid and water (H_2O). Lithium hydroxide is an attractive choice for space flight because of its high absorption capacity for carbon dioxide and the small amount of heat produced in the reaction. Disadvantages include the irreversibility of the chemical reaction. This causes the replacement of lithium hydroxide canisters to be a daily activity during space shuttle flights. There is also the potential for some toxicity within the space shuttle cabin due to the lithium hydroxide dust that could be ingested by the crew. Before a space shuttle mission, EECOM flight controllers and crewmembers receive training that ensures correct precautions and procedures are followed while replacing the lithium hydroxide canisters.

AP Course Topics

States of Matter

- Gases
  - Law of ideal gases

Reactions

- Stoichiometry
  - Mass and volume relations with emphasis on the mole concept, including empirical formulas and limiting reactants

NSES Science Standards

Unifying Concepts and Processes

- Evidence, models, and explanation
- Change, constancy, and measurement

Physical Science

- Chemical Reactions

Science in Personal and Social Perspectives

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

History and Nature of Science

- Science as a human endeavor

Problem and Solution Key (One Approach)

The Contaminate Control Cartridge (CCC), which contains lithium hydroxide (LiOH), is used to remove carbon dioxide (CO_2) from the space shuttle cabin. The removal of CO_2 is represented by the following equation:

$$2LiOH_{(s)} + CO_{2(g)} \rightarrow Li_2CO_{3(s)} + H_2O_{(g)}$$

A. A typical space shuttle crew consists of six individuals and each CCC contains 750 g of LiOH. Assuming that each crew member expels 42.0 g of CO_2 per hour on average, and that a mission is scheduled to last 18 days, how many CCCs must be carried on board the space shuttle?

$$18 \text{ days} \cdot \frac{24 \text{ hr}}{1 \text{day}} \cdot \frac{42.0 \text{ g}}{1 \text{hr}} = 18{,}100 \text{ g } CO_2 \text{ per person}$$

For a crew of six:

$$6(18{,}100 \text{ g}) = 109{,}000 \text{ g } CO_2 \text{ produced}$$

$$108{,}000 \text{ g } CO_2 \cdot \frac{1 \text{ mol } CO_2}{44.0 \text{ g } CO_2} \cdot \frac{2 \text{ mol LiOH}}{1 \text{ mol } CO_2} \cdot \frac{23.9 \text{ g LiOH}}{1 \text{ mol LiOH}} \cdot \frac{1 \text{ CCC}}{750 \text{ g LiOH}} = 158 \text{ CCCs}$$

B. The CCC on board the space shuttle is changed daily or when the partial pressure of CO_2 reaches 5.0 mm Hg. The space shuttle cabin has a volume of 65.8 m^3 and the total pressure inside is 1.0 atm and the temperature is 25°C. If the partial pressure of CO_2 reaches 5.0 mm Hg, what mass of LiOH would be required to remove the CO_2?

Step 1: Find *n*, number of moles of CO_2

$$PV = nRT$$

$$n = \frac{PV}{RT}$$

$$V = 65.8 \text{ m}^3 \cdot \frac{100^3 \text{ cm}^3}{1 \text{m}^3} \cdot \frac{1 \text{L}}{1000 \text{ cm}^3} = 65{,}800 \text{ L}$$

$$P = 5.00\,\text{mm Hg} \cdot \frac{1\,\text{atm}}{760\,\text{mm}} \cdot = 0.00658\,\text{atm}$$

$$n = \frac{(0.00658\ \text{atm})(65{,}800\ \text{L})}{(0.8206\ \text{L atm/mol K})(298\ \text{K})}$$

$$n = 17.7\,\text{mol CO}_2$$

Step 2: Find grams of LiOH

$$17.7\,\text{mol CO}_2 \cdot \frac{2\,\text{mol LiOH}}{1\,\text{mol CO}_2} \cdot \frac{23.9\,\text{g LiOH}}{1\,\text{mol LiOH}} = 846\,\text{g of LiOH}$$

Scoring Guide

Suggested 7 points total to be given.

Question		**Distribution of points**
A	*3 points*	1 point for correct calculation of grams of CO_2 produced
		1 point for correct calculation of grams of CO_2 produced for 6 people
		1 point for correct calculation of number of cartridges
B	*4 points*	1 point for using *PV=nRT*
		1 point for correct substitution of *P* and *V*
		1 point for correct calculation of moles CO_2
		1 point for correct calculation of grams of LiOH

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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