

# Math Diversion Problem 872

P. Reany

October 29, 2025

It's just you and your opponent at the board and  
you're trying to prove something.

— Bobby Fischer

[Your 'opponent' could be a math problem, right?]

Source:

[https://talk.collegeconfidential.com/ap-tests-preparation/  
233538-hard-stoichiometry-problem.html](https://talk.collegeconfidential.com/ap-tests-preparation/233538-hard-stoichiometry-problem.html)

Title: How Long Will the Lithium Hydroxide Last?

Presenter: collegeconfidential

## 1 Problem: How Long Will the Lithium Hydroxide Last?

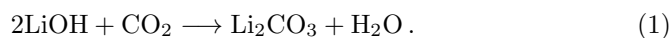
This next problem is taken from the online chemistry site:

PROBLEM:

The space shuttle environmental control system handles carbon dioxide (4% by mass exhaled air) by reacting it with Lithium Hydroxide pellets to form lithium carbonate and water. If there are 7 astronauts on board the shuttle, and each exhales 20 liters of air per minute, how long could clean air be generated if there were 25,000 g of lithium hydroxide pellets available for each shuttle mission? Assume the density of air is 0.0010 g/mL. (Proposed Ans: 4109 minutes.)

SOLUTION: Step 1.

We begin with a balanced equation.



Question: How is this even a stoichiometry problem in the first place? Answer: Because the rate of consumption of the LiOH (which we'll assume to be a constant) is related to the rate of production of the CO<sub>2</sub> (which we'll also assume to be a constant).

Let's make a stoich diagram to help out.

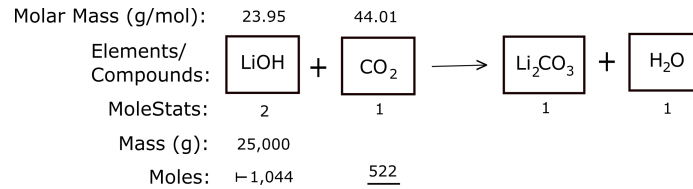


Figure 1. Here we used the underlining of data, which means that its determination required data from at least one other column.

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Now, we apply the Zeroth Rule of Problem Solving and assume that the CO<sub>2</sub> is being consumed at the same rate it's being produced.

Next, we write down the mole proportion between columns 1 and 2:

$$\frac{2}{1} = \frac{\text{moles LiOH consumed}}{\text{moles CO}_2 \text{ consumed}} \quad (2)$$

Now, if we let  $\Delta T$  be the time until the LiOH is consumed, then (2) can be changed to

$$\frac{2}{1} = \frac{(\text{moles LiOH consumed})/\Delta T}{(\text{moles CO}_2 \text{ consumed})/\Delta T} \quad (3)$$

But the numerator of (3) represents the average rate of consumption of LiOH, and the denominator represents the average rate of consumption of CO<sub>2</sub>. But we have assumed that the rate of consumption of CO<sub>2</sub> is equal to its rate of production, hence:

$$\frac{2}{1} = \frac{(\text{moles LiOH consumed})/\Delta T}{(\text{moles CO}_2 \text{ produced})/\Delta T} \quad (4)$$

Therefore, LiOH is consumed twice as fast as CO<sub>2</sub> is produced.

Step 2.

The fundamental question we need to answer is this: What is the duration of time  $\Delta T$  (in minutes) that the LiOH will last, given the rate of production of CO<sub>2</sub>? We can write this down as a simple equation:<sup>1</sup>

$$\Delta T = \frac{\text{moles LiOH}}{\text{rate LiOH is consumed } [\text{mol} \cdot \text{min}^{-1}]} \quad (6)$$

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<sup>1</sup>This equation follows a very common form. Let  $Q(T)$  be some quantity being produced or consumed at a fixed time rate of change  $R$ , then

$$\Delta T = \frac{Q}{R} \quad (5)$$

Next, let's calculate the rate of production of  $\text{CO}_2$  in  $\text{g} \cdot \text{min}^{-1}$  per person,  $R_{\text{CO}_2}^p$ :

$$\begin{aligned} R_{\text{CO}_2}^p &= (20 \text{ L} \cdot \text{min}^{-1} / \text{person}) \left( 0.04 \frac{\text{g CO}_2}{\text{g air exhaled}} \right) (0.0010 \text{ g/mL}) (1000 \text{ mL/L}) \\ &= 0.8 \text{ g} \cdot \text{min}^{-1} / \text{person}. \end{aligned} \quad (7)$$

Therefore, the rate of production for all seven persons,  $R_{\text{CO}_2}$ , is

$$R_{\text{CO}_2} = 5.6 \text{ g} \cdot \text{min}^{-1}. \quad (8)$$

Next, we convert this into a rate of production in moles per minute  $\overline{R}_{\text{CO}_2}$ , using the molar mass of  $\text{CO}_2$ :

$$\overline{R}_{\text{CO}_2} = \frac{5.6 \text{ g} \cdot \text{min}^{-1}}{44.01 \text{ g} \cdot \text{mol}^{-1}} = 0.1272 \text{ mol} \cdot \text{min}^{-1}. \quad (9)$$

But, the molar rate of consumption of  $\text{LiOH}$  is twice the molar rate of production of  $\text{CO}_2$ :

$$\overline{R}_{\text{LiOH}} = 0.2544 \text{ mol} \cdot \text{min}^{-1}. \quad (10)$$

On substituting the calculated values into (6), we get

$$\Delta T = \frac{1044 \text{ mol}}{0.2544 \text{ mol} \cdot \text{min}^{-1}} = 4104 \text{ minutes}. \quad (11)$$

## 2 Appendix: How to interpret the Stoich diagrams

There are four main types of data in the stoich diagrams I make. The most common are data from given information, from the coefficients of the balanced equation, and from data tables, such as a periodic table of elements for molar mass information. This kind of data I do not mark up. The second kind of data in stoich diagrams comes from computations based on data in the same column, for which I use the turnstile ( $\vdash$ ) to indicate. The third kind of data is a result in one column that required data from at least one other column to calculate it, and I indicate that kind of value or result by use of the underlining. The fourth kind of data in the figures is the result of combining given information to derive a secondary value. I indicate this kind of data with a right arrowhead ( $\blacktriangleright$ ).