Think Like a Scientist: Back of the Envelope Calculations

One of the singular features of the book *The Martian* by Andy Weir is the way the author explains astronaut Mark Watney's thinking process. As Watney struggles to survive, we are given an insight into his approach to solving problems. As "the mission's fix-it man" with degrees in botany and mechanical engineering, Watney is highly skilled in problem solving.

One type of computation/problem solving is sometimes referred to as "back of the envelope calculations." This type of calculation is characterized by taking facts you know, making estimated assumptions for those you don't, and doing a rough calculation to derive an answer.

Example Calculation

How much might it cost to buy pizza for a ChemClub meeting? If your club had 25 members and each member ate 3 pieces of pizza that would mean you need 75 pieces. Let's estimate that a large pizza could be cut into 8 slices each. To make the math easier, round the 75 pieces you need up to 80 pieces. Then it is easy to divide 80 slices by 8 slices per pizza and estimate you need 10 pizzas.

$$\text{25 students} \times \frac{\text{3 slices}}{\text{1 student}} = \text{75 slices} \quad \text{(round up to 80 slices)}$$

$$\text{80 slices} \times \frac{\text{1 pizza}}{\text{8 slices}} \times \frac{\$10}{\text{1 pizza}} = \$100$$

If each pizza costs $10 this means your bill would be about $100. This is just a ballpark estimate, and it would not be a surprise if the real bill was somewhat higher or lower. But it is unlikely the bill will be $1,000 or $10 total. This is the value of a back of the envelope calculation—it gives you a reasonable estimate for what to expect and plan for.

The Challenge

Do your own back of the envelope calculations for one problem that Mark Watney confronts during his stay on Mars. You could even do your calculation on the back of an actual envelope, other scrap of paper, or a napkin to correspond with the conditions presented in the book, where there was only a small amount of paper available.

You have the option to choose from one of the suggestions below, or choose your own from other scenarios that occur in the book. Feel free to add an explanation to justify any of the assumptions you make.

Page numbers used are from: Weir, Andy. *The Martian*. Classroom edition, Broadway Books, 2014.

- In his Sol 25 log entry, p.18, Watney calculates he needs to create 1,100 calories per day to survive until the rescue ship arrives. He says, "I'll spare you the math." Do the math!
- On Sol 6, p.3, Watney observes the MAV can make 13 kg of fuel from 1 kg of hydrogen brought to Mars. This is based on the Sabatier process that uses CO_2 from the atmosphere on Mars. $CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O$. Does the 1:13 ratio by mass make sense?
- Mark Watney has to build a ramp out of rocks and sand on Sol 83, p.103, to help load the lander Sojourner on top of his rover. He experiments and can manage to pull it up a 30° angle. If the rover is 2 meters tall, how does he know what the length of the ramp should be?
- Although most of the science presented in *The Martian* is viewed by scientists as being relatively accurate, there are some who quibble with a handful of the calculations.
  → One example is the claim mentioned in Log Entry: Sol 30, p. 26 that 1 L of liquid hydrazine (and excess of oxygen) could make 2 L of liquid water. Check this claim.

Submit Calculation for a Chance to Win

Choose one of the suggestions above or choose your own example from the book. Write your calculations on the back of an envelope or other scrap of paper. Make sure all the numbers and labels are clear and legible. Take a photo and upload it to Facebook, Twitter, or Instagram with #ACSChemClubBook & your school name. Only ChemClubs registered for the virtual book club will be eligible to win. Entries received before the virtual book club chats in April/May 2017 will be entered in a drawing for a movie prize pack.

Additional Resources

Kathy de Antonis. Space Food, *ChemMatters*, December 2009, p 11–13.
This is an interesting article about how food is adapted for use in space travel. The article ends with an estimate of how much food might be required for a mission to Mars. This might serve as a good warm up calculation to practice back of the envelope thinking.

Although it comes from a business management journal, this article explains some of the basics of back of the envelope problem solving. https://managementconsulted.com/case-interviews/case-interview-question/