Lab #5 – Rocket Science

NOTE: Wearing safety glasses will be required at all times for the duration of this lab.

In this lab you will use a chemical build-up of pressure to launch a plastic rocket into the sky. The effervescent tablets that will be used contain approximately a 2:1 mixture of sodium bicarbonate and citric acid. When dissolved in water these produce sodium citrate and carbon dioxide gas. The carbon dioxide gas causes a rapid build-up of pressure, which will launch the rocket.

Materials list:

- 1 safety glasses
- 1 plastic canister
- 1 3D printed rocket body
- 4 effervescent tablets (2 packets)
- 1 reservoir of water
- 1 stopwatch
- 1 triple beam balance

1) **Put on your safety glasses.**

2) Prepare your lab notebook entry by putting the lab number, title, and today's date. Also include the names of your lab partners.

3) Carefully review the full launch procedure before performing any steps, and be sure you understand it. If you have any questions, ask! The launch procedure is:

a) Fill the plastic canister about $\frac{1}{4}$ full of water.

b) Place the plastic canister into the 3D printed rocket body.

c) Break off half of an effervescent tablet.

d) In one rapid step, place the half-tablet into the water, put the lid on the canister, and place the rocket on a flat area of ground with the lid side down. Make sure it is stable! Do not knock it over!

e) Do not, under any circumstances, lean over the rocket or look down at the rocket after it is set. Keep your face away from it.

f) Back a few steps away from the rocket, being careful not to back into anyone else's rocket.

g) It will only take a couple seconds to launch, so have your stopwatch ready! Press start as soon as it launches, and press stop when it lands on the ground again.

h) Record your time value and mark which launch it was for.

i) Recover your rocket and lid, and dump out any excess water or tablet material.

4) Rehearse the above launch procedure steps in your mind before continuing to the next step.

5) First launch the plastic canister 3 times without including the rocket body. Keep track of the travel time.

6) Then launch the rocket 3 times with the plastic canister inserted into the rocket body. Keep track of the travel time.

7) You should have 2 half-tablets left at the end. You can use these to retry any values that you think could have been better.

8) Determining the heights:

a) To reduce the effect of outlier values, select the "median" travel time, which is the middle of your three travel times. Do this both for the plastic canister alone, and for the full rocket.

b) We will ignore air resistance for this analysis.

c) Because all of the rocket's acceleration came in an initial burst, it followed what is called a "ballistic trajectory", like that of a thrown ball. In a ballistic trajectory, the object spends the same amount of time going up, as it spends going down. So first figure out how much time the rocket spent falling from the maximum height for each of your two conditions.

d) The height, h, an object fell from is related to its travel time, t, by $h = \frac{1}{2}at^2$, where the acceleration of gravity a is $9.8\,\mathrm{m/s^2}$. Use this to find the height your plastic canister alone reached, and the height your full rocket reached.

9) Using the triple beam balance determine the mass of your dry plastic canister (without lid) and the mass of your printed rocket body.

10) Thinking about launch energy:

a) In principle we could estimate the launch energy as $E = PV$, where P is the pressure in the canister at launch compared to the air outside, and V is the volume of the gas inside. This is where the launch energy comes from. However, we don't know the pressure inside the canister right at the instant it launches, so we can't use this.

b) The gravitational potential energy is $U_g = mgh$, where m is the mass of the object, g is the acceleration of gravity, and h is the height. Conservation of energy also tells us that at the maximum height the launch energy went entirely into gravitational potential energy. Using the height you got for your canister and the mass of the canister, calculate an estimate for your launch energy.

c) Assume the launch energy was the same with the rocket body, and use the gravitational potential energy equation to estimate the height it will go to. You will need the mass of both the printed rocket body and the canister.

d) Compare the predicted launch height to the one calculated from your time values.

11) Newton's Third Law states, "For every action there is an equal and opposite reaction; or the forces of two bodies on each other are always equal and directed in the opposite direction." What were the action and reaction that made the rocket launch work?

12) What were the important sources of error that affected your values? (**NOTE:** Be sure not to include "mistakes". You want to come up with legitimate sources of error that are unavoidable parts of the way the experiment was performed.)