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AP Chemistry p. 3
9 / 28 / 16

Hot Air Balloon Lab

Background Information

According to Charles' Law, gases that are heated will have a greater volume, and therefore a lesser density. This is because a higher temperature means a greater kinetic energy of the gas particles, which move with greater speed and try to spread themselves out greater. With enough hot air, a hot air balloon will have a density low enough compared to the ambient air that the density difference will allow the balloon to rise into the air. This effect can further be augmented by heating gases that are less dense than air, such as hydrogen or helium.

In regular hot air balloons, a large, fire-proofed canvas is used as the balloon, along with a wicker basket for the people with a propane burner as the heat source. In our experiment, the hot air balloon will be made with tissue paper and tape alone and will be unmanned.

Safety Considerations

Tissue paper is flammable. Keep away from open flame or excessive heat.

When using the scissors, be sure to keep the cutting edge away from skin or clothing.

Difference Between Balloons in *Around the World in 80 Days* and *Up*

In *Around the World in 80 Days*, a hot air balloon was used. In *Up*, helium balloons were used. In both cases, the balloons were less dense than air, which displaced more air and allowed them to float up. In a hot air balloon, heat is applied to the particles so that the move faster and create more volume; the same mass per a larger volume means a lower density. In a helium balloon, since there are the same number of moles of any gas at the same temperature and pressure conditions, there are the same number of helium atoms as there would be oxygen molecules in the same volume; however, because the helium atoms have a much lesser mass per the same volume, it has a lower density as well.

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AP Chemistry p. 3
10 / 18 / 16

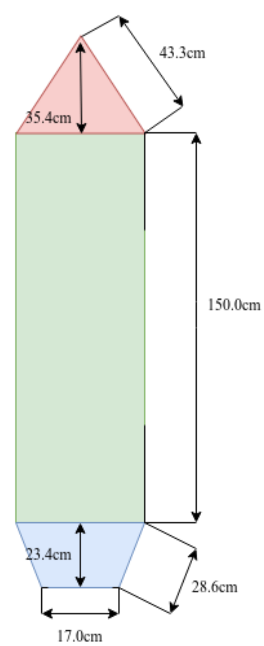
Project Progress Report

Background Research

Hot air balloons fly because they are less dense than air. To be less dense than air means that there is a greater volume than air compared to its respective mass. Hot air is less dense than air because the particles are moving faster and want to spread out more, and thus occupy more volume. This is known as Charles's gas law: a greater temperature with a constant pressure corresponds with a greater volume of air. A similar effect can be created by using gases that are less dense than regular air at room temperature; helium and hydrogen, for example, much less dense than air and can be used to fly a balloon. However, because hot air balloons use an open flame, hydrogen is generally not a good choice of gas to use because, although very light, it has the tendency to ignite and cause damage to the balloon and to the passengers.

One factor to continue was whether or not to use tape or glue to bind the different sections together. We chose tape because it would better seal holes fully and is more convenient to use. It also is applied evenly, does not have a drying time, and can resist heat better than glue. Glue, however, is lighter, but is worse than tape in the aforementioned ways. Another factor to continue when making the balloon was the shape of the balloon: some shapes, such spheres, would have a larger volume per amount of tissue paper (more volume per mass) than other shapes, such as most platonic solids. Constructing a cylindrical shape and a cone or hemispherical top would be difficult, however; a simple square and pyramid would be much easier to design and assemble, while not losing too much volume. Similarly, the overall size was something to consider: it had to fit the size dimensions, and we had unlimited amount of tissue paper. Theoretically, it is possible to create a balloon of a very great width and therefore contain a significantly greater volume, but it is impractical to do so. Simply making a balloon one panel wide (50cm) and four panels tall (approximately 2m) is a simple approach that fits the size requirements.

Diagram (on right)



Timeline

< 10/4

- Research balloon designs and why it floats (kinetic molecular theory)

10/4, 10/5

- Begin construction of balloon (determining dimensions, drawing, cutting, and beginning to tape)

10/7

- Complete construction of balloon (taping and checking for holes)
- Begin calculations for packet

10/8-10/10

- Finish calculations
- Begin drafting responses for poster

10/13

- Meet during study to plan poster

10/17

- Print out poster requirements and complete poster

10/18

- Poster due. Hand it in

Materials

The materials used in this project were 50.8cm x 50.8cm tissue paper and Scotch tape. The tape was used to connect the tissue paper into the shape of the balloon in the diagram. We chose tape over glue because of its convenience and because of its better ability to cover holes. We decided that having tape visibly cover the seams would be more reliable for air-trapping than glue. Glue also takes time to set, which would reduce the efficiency of our project and make it more difficult to finish on time.

Assembly

When connecting the pieces of tissue paper, 0.8cm of the sheet was overlapped on either side in order to hide the 0.8cm margins and fit the 50cm dimensions. We first assembled the side panels by taping three sheets of tissue paper together. To assemble the balloon, we then assembled the top pyramid because we thought that would be the most difficult shape to assemble. Then, we taped the side body panels to the bottom of the pyramid. To hold our balloon up while taping each of the sides together, we taped a hoe and a long cardboard tube together so that the balloon would be extended fully, making it easier to connect the pieces. Lastly, we attached the truncated bottom pyramid by taping it to the bottom of the body of the balloon.

Theory

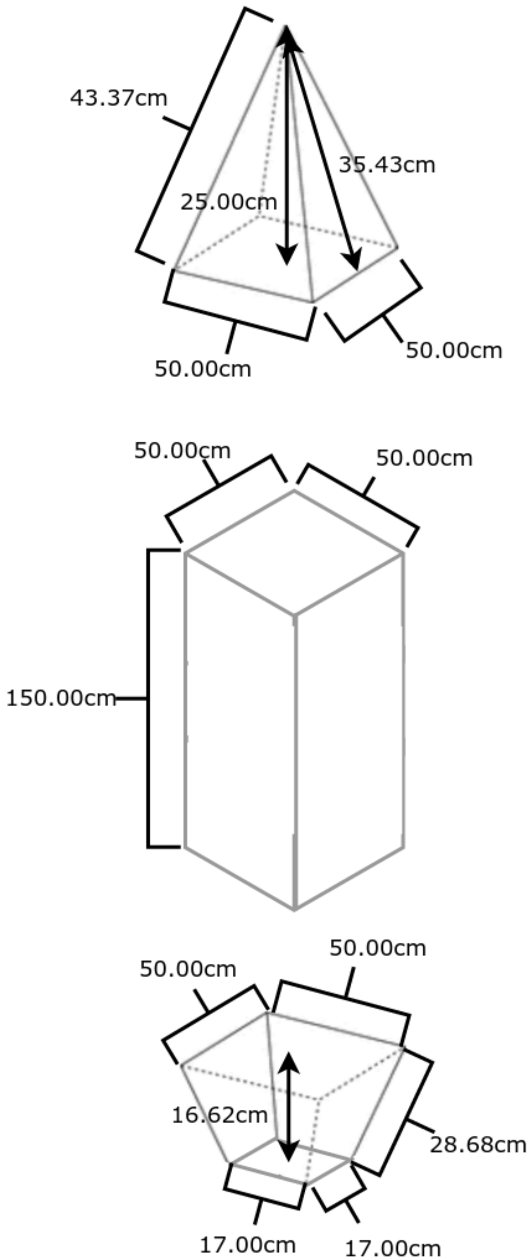
According to Charles's Law, one of the laws of the Kinetic Molecular Theory, gases that are heated will have a proportionally greater volume, and therefore a lesser density. This is because a higher temperature (average kinetic energy) of the gas particles with a constant pressure and number of moles of gas means that the particles will attempt to spread themselves out further. Because the balloon is flexible (the volume is not fixed) and the pressure stays constant (at room temperature), the gas expands to a larger volume, thus inflating the balloon. By increasing the volume with a the same moles and mass of gas, the density is decreased. With a high enough temperature, a hot air balloon will have a density low enough compared to the ambient air that the density difference will allow the balloon to rise into the air. This is because substances or objects (in this case, the balloon with the hot air inside it) that have a lighter density than the fluid around them (the ambient air at room temperature and pressure) displace enough of the fluid and therefore are buoyant enough to float. This principle can be seen with boats and submarines; if their density is lower than water (if they displace more water for their respective masses) they will float, and will sink if their density is too

low; the same is true for the hot air balloon, in which the balloon must be less dense than air in order to float.

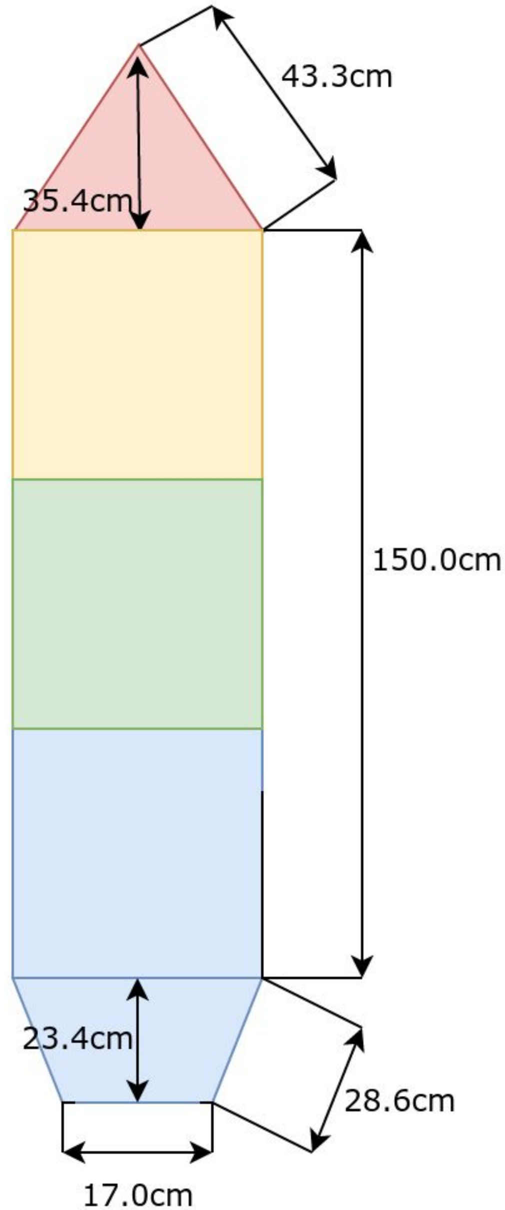
Novelty Information

- The first passengers in hot air balloons were a sheep, a duck, and a chicken.
- Hot air balloons were the first air travel mankind developed.
- The highest height a balloon has reached is 21000 meters and additional oxygen is needed from the 5000 meter mark and up — this is the "flight ceiling," which is the general limit for safe ballooning in terms of temperature (before it gets too cold) and oxygen (before it gets too scarce).
- Richard Branson has the record for farthest flight in a hot air balloon, traveling from Japan to Canada and also flying the fastest balloon at 245 mph.
- It's impossible to fly a hot air balloon in the rain because the heat from inside the balloon can make the rain falling on it to boiling temperature, thus destroying the balloon fabric.
- There is a hot air balloon tradition that includes sharing a bottle of champagne that originated from farmers thinking that the balloons were dragons and in order to appease these farmers, the pilots of the balloons shared a bottle of champagne with them.
- Any hot air balloon requires a chase crew that drives a "chase vehicle" that follows the hot air balloon in flight and has to be big enough to carry the balloon, the basket, and the passengers aboard the vehicle.
- The first pilot to fly in a hot air balloon was also responsible for the first air related accident. He used 50% regular air and 50% hydrogen gas in his balloon, this resulted in an explosion that killed him and his copilot within 30 minutes of flying.

3D Deconstructed Diagram



Flat Panel Diagram



Volume of the Balloon

$$V_{pyramid} = \frac{1}{3}bh = \frac{1}{3}(50.00cm \times 50.00cm)(25.00cm) = 208\bar{3}3.33cm^3$$
$$V_{body} = lwh = (50.00cm)(50.00cm)(150.00cm) = 375\bar{0}000cm^3$$
$$V_{truncated\ pyramid} = \frac{1}{3}(b_1h_2 - b_1h_2) = \frac{1}{3}((50.00cm \times 50.00cm)(25.00cm) - (17.00cm \times 17.00cm)(8.50cm))$$
$$= 200\bar{1}4.5cm^3$$
$$V_{balloon} = V_{pyramid} + V_{tube} + V_{body} + V_{truncated\ pyramid} = 208\bar{3}3.33cm^3 + 375\bar{0}000cm^3 + 200\bar{1}4.5cm^3$$
$$= 41\bar{5}848cm^3 = 4.16 \times 10^5 cm^3$$

Molar Mass of Air

$$M_{air} = \sum(M_{gas} \times RA_{gas}) = (28g/mol \times 0.7808) + (32g/mol \times 0.2095) + (44g/mol \times 0.0004) +$$
$$(40g/mol \times 0.0093) = 2\bar{8}.956g/mol = 29g/mol$$

Density of Air

$$D_{air} = \frac{PM}{RT} = \frac{(101.3kPa)(2\bar{8}.956g/mol)}{(\frac{8.314kPa\times L}{mol\times K})(273K+20K)} = 1.\bar{2}04g/L = 1.2g/L\ (at\ 20^oC)$$
$$D_{air} = \frac{PM}{RT} = \frac{(101.3kPa)(2\bar{8}.956g/mol)}{(\frac{8.314kPa\times L}{mol\times K})(273K+75K)} = 1.\bar{0}14g/L = 1.0g/L\ (at\ 75^oC)$$
$$D_{air} = \frac{PM}{RT} = \frac{(101.3kPa)(2\bar{8}.956g/mol)}{(\frac{8.314kPa\times L}{mol\times K})(273K+81.7K)} = 0.9\bar{9}47g/L = 0.99g/L\ (at\ 81.7^oC)$$

Moles of Gas in Balloon

$$PV = nRT$$
$$4.16 \times 10^5 cm^3 \times \frac{mL}{cm^3} \times \frac{L}{1000mL} = 4.16 \times 10^2 L$$
$$(101.3kPa)(4.16 \times 10^2 L) = n(\frac{8.314kPa\times L}{mol\times K})(273K + 75K)$$
$$n = \frac{(101.3kPa)(4.16\times10^2 L)}{(\frac{8.314kPa\times L}{mol\times K})(273K+75K)} = 14.\bar{5}65mol\ (at\ 75^oC)$$
$$(101.3kPa)(4.16 \times 10^2 L) = n(\frac{8.314kPa\times L}{mol\times K})(273K + 81.7K)$$
$$n = \frac{(101.3kPa)(4.16\times10^2 L)}{(\frac{8.314kPa\times L}{mol\times K})(273K+81.7K)} = 14.\bar{2}90mol\ (at\ 81.7^oC)$$

Mass of Air in Balloon

$$m_{balloon\ air} = 14.\overline{5}65mol \times \frac{\overline{2}8.956g}{mol} = 422g\ (at\ 75^{o}C)$$

$$m_{balloon\ air} = 14.\overline{2}90mol \times \frac{\overline{2}8.956g}{mol} = 414g\ (at\ 81.7^{o}C)$$

<u>Mass of Balloon</u>

$$m_{balloon} = 85.04g\ (measured)$$

<u>Density of Balloon with Air</u>

$$D_{balloon} = \frac{422g+84.04g}{4.16\times10^{5}cm^{3}} \times \frac{cm^{3}}{mL} \times \frac{1000mL}{L} = 1.22g/L\ (at\ 75^{o}C)$$

$$D_{balloon} = \frac{414g+84.04g}{4.16\times10^{5}cm^{3}} \times \frac{cm^{3}}{mL} \times \frac{1000mL}{L} = 1.19g/L\ (at\ 81.7^{o}C)$$

<u>Notes on Diagrams</u>

- There are four identical panels that follow the diagram above.
- The body section is composed of three sheets of tissue paper.
- All edges are taped together.
- 35.4cm and 23.4cm are the *slant heights* of the top and bottom pyramids, respectively. The *altitudes* (true heights) of the top and bottom pyramids are 25cm and 16.6cm, respectively. This can be seen on the 3D diagram.
- Perspectives may not be correct on 3D diagram

Flying and Calculating the Density of a Hot Air Balloon

(The Story Behind *Rainbow Pop*)

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