Stoichiometry Rockets

The objective of this lab is to to:

- calculate the needed volume of fuel to react with a given volume of gas and result in a productive explosion
- determine the heat of the reaction
- determine the amount of work and heat produced from their reaction.

We will begin this exercise with a combustion equation for a substance of interest. For example, when acetylene, C_2H_2, is burned in oxygen, carbon dioxide and water are the only products giving the balanced equation for the reaction:

$$2C_2H_2(g) + 5O_2(g) \rightarrow 4CO_2(g) + 2H_2O(g)$$

Using the properly balanced equation, it is possible to calculate the volume of both acetylene and oxygen needed to fill a 10-ml syringe, and produce the desired outcome.

If we establish that an unknown amount, x is equal to the volume of acetylene (ethyne), and then 10-x = volume of oxygen. So how do we determine the correct value of x among the many possibilities? In order to do so, we must use the balanced reaction equation, which indicates that two moles of acetylene require 5 moles of oxygen to react. If you are wondering how we can correlate number of moles to volume, it is important to remember that volume is directly proportional to number of moles of gas! This allows us to set up the ratio shown below and to solve for x. From the proportion, we can calculate the volume of each gas needed to produce the correct stoichiometric ratio in a ten milliliter syringe.

$$\begin{array}{ccccc} x \text{ ml } C_2H_2 & & (10 - x) \text{ ml } O_2 & & \\ 2C_2H_2(g) & + & 5O_2(g) & = & 4CO_2(g) + 2H_2O(g) \\ 2 \text{ moles } C_2H_2 & & 5 \text{ moles } O_2 & & \end{array}$$

$$\frac{x \text{ ml of } C_2H_2}{2 \text{ moles of } C_2H_2} = \frac{(10 - x) \text{ ml of } O_2}{5 \text{ moles of } O_2}$$

$$5x = 2(10 - x) = 20 - 2x$$

$$7x = 20$$

$$x = 2.9 \text{ ml of } C_2H_2$$

Given this solution for, the explosive mixture is prepared by filling the syringe with oxygen and quickly injecting 2.9 milliliters of acetylene into the oxygen displacing the excess oxidizing agent. The mixture is then ignited with the spark from a piezoelectric igniter.

The ignition and subsequent combustion will be carried out at standard temperature and pressure: 298 Kelvin and 1.0 atm. These values, in addition to volume of the gas combusted will be used to determine the moles of gas combusted.

For example, in the acetylene example above, 2.9mL would be used in the ideal gas law as shown below.
PV=nRT
(1.0 atm) (.0029 L)=n (.0821 atm*L/K*mol)(298K)

1.2×10^{-4} moles of gas

Using the standard heat of combustion of ethyne, which indicates that 2 moles of ethyne generate 2600.00 KJ, it can be determined that the $\Delta H \; combustion \; of \; ethyne \; = 1300 \; \frac{KJ}{mol}$.

Written by Mark Langella, 1/13/2010

Combining this information with the number of moles previously calculated, the heat released from the reaction in our 10mL syringe can be calculated as shown below!

Then $\frac{x\ KJ\ of\ reaction}{1300\ KJ\frac{}{mol} of\ ethyne} = \frac{1.2*10^{-4}\ mol\ of\ ethyne}{1\ mol}$

X= .154 KJ is $\Delta\ H\ of\ reaction$ based on using 2.9 ml of ethyne

Materials:

Assigned gaseous fuel, 10-ml syringe with sealed electrodes, 2-3 ml syringes, metal syringe extender, extra 10-ml syringe, tank of oxygen, thermometer, measuring tape.

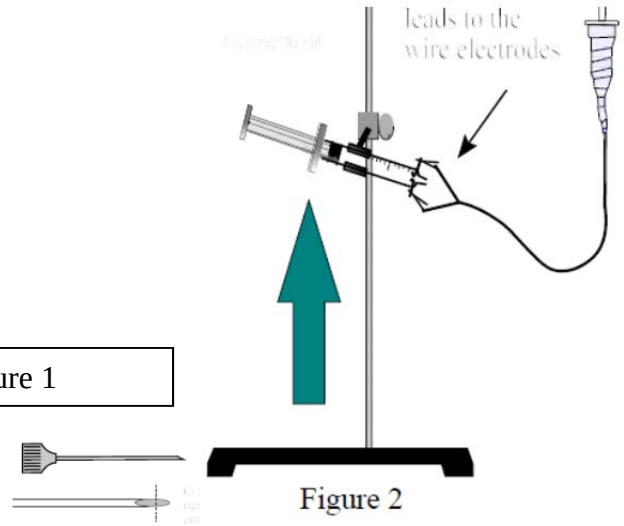


Figure 1

Figure 2

Figure 3

Some Possible Fuel Gases:

Butane, C_4H_{10}
Methane, CH_4
Propane, C_3H_8
Propyne, C_3H_4

Procedure:

1. Write the balanced equation for the complete combustion of your hydrocarbon fuel with oxygen.

2. Using thermodynamic tables, heats of formation, determine the heat of combustion for your combustion reaction using Hess's Law.

3. Using the acetylene example above, calculate the volume of your gaseous hydrocarbon needed to form a stoichiometric mixture with oxygen in a completely filled ten milliliter

syringe. Fill the ten ml syringe with just over 10 ml of oxygen. Expel the excess oxygen and secure the 10-milliliter syringe full of oxygen with a clamp on a ring stand (Figure 2). Cap the syringe to keep the gas in the syringe until you are ready to ignite. **Be certain to aim the syringe piston away from and members of the class of towards the most distant part of the classroom**.

4. Fill a 3-ml. syringe (Figure 3) with your assigned fuel and attach the fine metal extender (Figure 1). Label metal extender on figure 1. Adjust the volume of gas in this syringe until it contains the exact amount you calculated in procedure #1.

5. Insert the tip completely into the open end of the syringe on the ring stand and quickly inject the fuel gas.

6. Remove the syringe tip and warn the other members of the class that you are about to ignite the mixture.Cap the rocket syringe to make sure no gases will leak until you are ready . When everyone is ready, remove the cap , insert the thermocouple wire and push the button on the igniter. If your math is correct, the explosion should throw the piston across the room.

7. Measure the height of the syringe ignition point from the ground and the distance that the syringe traveled before bouncing.

8. Weigh the syringe plunger you are using as the rocket.

9. Record the temperature in the room.

10. Return the syringes and the gas collection apparatus to their designated storage area.

Data:

Height of Syringe (meters)	
Mass of Syringe (Kilograms)	
Volume of assigned Fuel (Liters)	
Distange Plunger Projected (meters)	
Temperature of Fuel (Kelvin)	
Atmospheric Pressure (atm)	
Name of Fuel	

Questions and Calculations: (Answer the questions and show all your calculations on a separate sheet)

Q1. Give the balanced equation and the calculations you performed determining the volumes of reacting gases for each combination studied. Using thermodynamic data from your text determine the Molar heat of combustion for your reaction, Entropy Change of Reaction and Gibbs free Energy of Reaction.

Q2. One of the objectives in this experiment was to verify Avogadro's Hypothesis. Explain briefly how you utilized Avogadro's Hypothesis in your calculations.

Q3. Using the ideal gas equation determine the number of moles of fuel. Assume 1 atm pressure.

Q4. Using stoichiometry determine the enthalpy of your reaction.

Q5. The work energy released onto the surroundings in this explosion is equal to the Kinetic energy of the rocket if you exclude any other forms of energy loss.

$KE = \frac{1}{2}\, mv^2$ m=mass of plunger in Kg v=initial velocity of plunger

In order to calculate the initial velocity you need to know the distance the syringe plunger traveled and divide this value by the time the syringe was traveling.

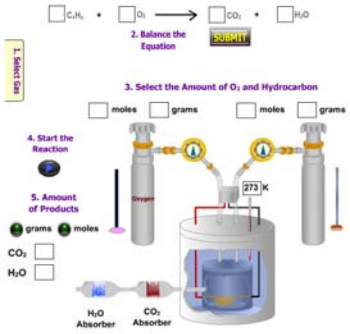
$v = \frac{d}{t}$ d= distance plunger traveled in meters t=time (sec)

$$time = \sqrt{((2 * Height)/(9.8\, m/sec^2)}$$

Determine the work energy for your combustion reaction

Q6 Determine the heat released from your reaction by subtracting from the calculated Enthalpy of reaction the work energy produced.

Online Internet Practice:
http://group.chem.iastate.edu/Greenbowe/sections/projectfolder/flashfiles/stoichiometry/stoic_select_both.htm



Given Selected gases determine heat of reaction for each trial.

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Name	Mol. Form.	Mol. Wt.	$\Delta H_f°$(g)/ kJ mol^{-1}	$\Delta G_f°$(g)/ kJ mol^{-1}	S°(g)/ kJ mol^{-1}
Ethyne	C_2H_2	26.037	227.4	209.20	.20094
Butane	C_4H_{10}	58.122	-125.7	-15.6	.3101
Carbon dioxide	CO_2	44.01	-393.5	-394.39	.21374
Methane	CH_4	16.043	-74.6	-50.8	.18626
Propane	C_3H_8	44.096	-103.8	-24.4	.2703
Propyne	C_3H_4	40.064	184.9	194.2	.2481
Water	H_2O	18.015	-241.8	-228.61	.18884

The combustible gases were chosen by their ease of preparation or availability. The heat of the formations. Reference: *Handbook of Chemistry and Physics: Special Student Edition*, 73 Ed., 1992-1993, CRC, p

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