Ensuring Complete Combustion by Determining the Optimal O2/Fuel Mixture in a Closed System.

Brian R. Smith M.Ed
Richland High School
930 Long Avenue
Richland, WA 99352
(509) 967-6535
brian.smith@rsd.edu

Abstract
Modern internal combustion engines (automobiles, busses, trucks, etc…) and heating systems use computers and sensors to determine the correct fuel/air mixture so complete combustion occurs.

Incomplete combustion causes lower performance, increase in wear on the engine components and an increase in the amount of CO, CO_2, sulfur compounds, particulate matter, and NO_2 exhausted.

This presentation will show the effects of incomplete combustion by demonstrating that both fuel and oxygen must be present in the correct ratio to ensure complete combustion.

Keywords:
Combustion Fuel Oxygen Ratio

Target audience:
High School, College

Mode of Presentation:
Lecture, video demonstration, hands on demonstration

Prerequisite Knowledge:
Ratios, vocabulary, flammable product safety, gas laws

Objective(s):
To demonstrate the correct ratio of fuel to O_2 to ensure complete combustion. To show that O_2 by itself does not combust, that fuel by itself combusts incompletely, and that a proper ratio will produce spectacular results.

Equipment and Supplies needed:
Several small rubber party balloons, Compressed O_2, Acetylene (both O_2 and Acetylene can be found at any welding supply store or your high school/college welding shop), candle mounted on a long rod (a metal meter stick works well), matches or cigarette lighter, Safety glasses and hearing protection.

Introduction:

Combustion is the act or process of burning. For combustion to occur, fuel, oxygen (air), and heat must be present together. Per definition combustion is the chemical reaction of a particular substance with an oxidant. Generally this will mean atmospheric oxygen. During the demonstration phase of this lab, compressed O_2 will be used.

Procedure
Short lecture on combustion of fuel/O2 in a closed system.

The combustion process is started by heating the fuel above its ignition temperature in the presence of oxygen. Under the influence of heat, the chemical bonds of the fuel are split. If complete combustion takes place, the elements carbon (C), hydrogen (H) and sulphur (S) react with the oxygen content of the air to form carbon dioxide ($CO_{2)}$, water vapor, (H_2O) and sulphur dioxide ($SO_{2\_}$ and, to a lesser degree, sulphur trioxide ($SO_{3)}$.

Show video clip on combustion from the Marymount School

If not enough oxygen is present or the fuel / air mixture is insufficient then the burning gases are partially cooled below the ignition temperature (too much air or cold burner/cylinder walls), and the combustion process stays incomplete. The exhaust gases then still contain burnable components, mainly carbon monoxide CO, carbon C (soot) and various hydrocarbons C_xH_y. Since these components are, along with NO_x, pollutants which harm our environment, measures have to be taken to prevent the formation of them. To ensure complete combustion, it is essential to provide a certain amount of excess air.

The quality of a combustion system is determined by a maximum percentage of complete combustion, along with a minimum of excess air (commonly 5 to 20% above the necessary level for ideal combustion)

AIR	+	**FUEL**	>>>	**FLUE GAS**
Oxygen (O_2)		Carbon (C)		Carbon dioxide (CO_2)
		Hydrogen (H_2)		Carbon monoxide (CO)
Nitrogen (N_2)		Sulphur (S)		Sulphur dioxide (SO_2)
		Oxygen (O_2)		excess O_2
Water vapor		Nitrogen (N_2)		Nitrogen oxides (NOx)
		Water (H_2O)		Nitrogen (N_2)
				Water vapor
				Soot

Exhaust gas will generally contain a certain amount of CH_4 (methane) if the combustion was not complete. Other hydrocarbons will not occur under normal conditions. Higher hydrocarbons are only produced under conditions of high pressure and high temperature such as occur in an internal combustion engine.
(http://www.habmigern2003.info/1_combustion.html)

Demonstration of correct and incorrect fuel air mixes.

Balloon 1—Filled with air. Ignite—Balloon will pop but no flames will be present. This is used to set up the rest of the demo. It is important that students see this because they have to make the connection to plain air and fuel/O2 mixtures.

Balloon 2—Filled with pure O2. Ignite—If you do this correctly, the students will think there is going to be a large explosion. *A little acting ability will go a long way*. Most people have a preconceived notion that Oxygen is explosive. If you play this up, students will be primed for a bang, and nothing will happen. The balloon will pop just like the one with air. After the balloon does not explode, explain that O2 is not flammable and that it just acts as an oxidizer (new vocabulary word?). Talk about rust and oxidation on metals.

Balloon 3—Filled with pure Acetylene. Ignite—This is a very interesting flame. The flame is very large and bright red, very smoky, and loud in a sloooow whoosh kind of way. There is a tremendous amount of excess carbon in the air. It will float around in the form of soot and begin to settle on the audience. Show the meter stick and point out the excess carbon.
There are lot of very interesting comments you can make. The flame is very slow, so acetylene would make a terrible bomb. The tone of the explosion is low, because the rate of combustion is slow. Compare this to the next balloon. Be prepared to repeat this.

Balloon 4—Filled with 50/50 mix of Acetylene-O2. Ignite—This is the grand finale. MAKE SURE the audience is wearing safety glasses and have ear protection. The balloon will ignite explosively and rapidly. There will be a large bang, very rapid and very, very loud. The flame is gone so quickly as to be almost invisible. Of particular note, point out the fragments of balloon that are all over the room. With the other explosions, the balloon just pops a hole in the side. Because this is so quick, the balloon is shredded into thousands of pieces and tiny particles are shot every where. Invariably in my classes, the students want to see this explosion again, so have a 2nd balloon ready with the same 50/50 ratio. You will lose the surprise factor, but you will have the student's undivided attention.

The demonstration must take place in an area where explosions/flames can safely be performed and contained. A traditional metal shop, auto shop, high bay shop or outdoors are acceptable. Do not perform this in a chemistry lab or other classroom. The flames from the pure acetylene and 50/50 mix are quite large and the noise is surprisingly loud.
All participants must wear safety glasses and hearing protection.

Comments
This demonstration is great for a short period (we have ½ days 1 day a month at my school) and for an introduction to gas laws. Students love the explosion and noise. It is certainly an attention grabber.

Evaluation of the activity
Vocabulary, basic questions on gas laws, ratio practice, safety, have students explain the demonstration, any extensions they can think of.

Bibliography:

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