

Experiment 10 – Comparison of the Energy Content of Fuels

Prelab Lecture
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What is the purpose of this experiment?

In this experiment we want to determine how much energy we get by burning various fuels. The fuels will be divided into two classes – hydrocarbons and alcohols. We'll try to discover how energy content changes when we go from hydrocarbons to alcohols, and how it changes as the size of the fuel molecule changes.

Why are we interested in this?

We are interested because of the importance of fuels in everyday life. You know most of the myriad uses for fuels. Most of the fuels we've been using until recently have been carbon based fuels, such as coal or gasoline. Gasoline is a type of fuel composed almost completely of liquid hydrocarbons.

What's a hydrocarbon?

A hydrocarbon is a compound that is composed only of hydrogen and carbon. Gasoline is one example, since it's a mixture of liquid hydrocarbons. The sizes of the hydrocarbons are such that we can approximately treat gasoline as if it were made of octane, C₈H₁₈. Candles, which are made of waxes, are also hydrocarbons. They are solids because the hydrocarbons have significantly longer carbon chains than those in gasoline, and thus the intermolecular forces are significantly stronger than those in gasoline.

How is the energy contained in the chemical bonds released?

Energy is released when a compound is converted to a more stable compound. The reaction by which the energy is released is called combustion. In a combustion reaction all of the atoms in a molecule combine with oxygen to yield their stablest oxides.

What are the stablest oxides of the elements that make up hydrocarbons?

The stablest oxide of carbon is carbon dioxide, CO₂. The stablest oxide of hydrogen is water, H₂O. Because of the temperatures of the environment during typical combustions, carbon dioxide is formed as a gas, while the water is formed as a liquid.

Therefore the balanced reaction for combustion of ethane, the second lightest hydrocarbon, is



The heat that's released in the reaction can be used for many purposes. It can be used to heat a building, can be converted to work in an engine, or can be used to generate light through the chemistry of flames.

Are hydrocarbons the only fuels?

No. There are many many fuels. Older fuels are wood, peat and coal. Hydrazine and hydrogen have been used as rocket fuels. Hydrocarbons have been used in the 20th century because of their high energy content and easy portability.

Recently, in an attempt to reduce the environmental impact of burning hydrocarbon fuels, ethanol has been added to gasoline. Ethanol has the formula C₂H₅OH. It and all alcohols are part of a class of compounds called partially oxygenated hydrocarbons. This is because they can be formed by reaction with oxygen, but in reactions that don't go all the way to combustion.

How do we determine the energy content of the fuels?

We burn the fuels, and use the energy released to heat water, and then use the temperature change of the water to figure out the energy released. We'll then divide this energy by the mass of the fuel consumed to calculate energy released/gram of fuel.

How do we figure out the energy from the temperature change?

It turns out that the energy added to a substance is related to the temperature change using the equation

$$q = C \times \Delta T .$$

Here q is the energy transferred to water in the form of heat, ΔT , the change in temperature, is equal to $T_{\text{final}} - T_{\text{initial}}$, and C is a quantity called the heat capacity.

The heat capacity is a constant which is different for each substance and reflects the amount of heat that is necessary to change the temperature of a substance by 1 degree Celsius.

The heat capacity depends on the amount of the material, so to make things easier, we define a specific heat capacity, C_{sp} , which is the heat capacity of one gram of a substance. This means that we can write

$$C = C_{\text{sp}} \times m$$

where m is the mass of the substance in grams, and therefore

$$q = C_{\text{sp}} \times m \times \Delta T$$

This is a particularly simple equation when the substance is liquid water, since the heat capacity of water near room temperature is 1.00 cal/°C.

Is the heat the number we report?

No, you report energy/gram consumed this is given by:

$$\text{Energy per gram consumed} = q / \text{change in mass of burner}$$

When we do our calculations should we write down all of the numbers our calculators put out?

No, we need to limit ourselves.

How do we decide how many digits to choose?

We only include the meaningful digits, the so-called “significant figures” (sometimes called significant digits.)

What’s a significant figure, and why is it more significant than any other figure?

From one point of view, Michelangelo’s David is a significant figure, and the Madonna and Christ figures in his Pietá are significant figures, but that’s an art historical point of view.

However from a scientific point of view, the concept of significant figure is intimately tied to the process of measurement. Every measurement we make has a number associated with it, and the number of digits in that number that we have read from our device is the number of significant digits.

For example. If we measure length with a meter stick with only centimeter markings on it, we can estimate only to about .2 cm, and a typical reading might be 141.2 cm. This is 4 significant figures. If we have a mm ruler, we can read to .2 mm, and the same measurement might be 141.24 mm, 5 significant figures. So the more precise your measuring device is, the more significant figures there are in your measurement.

How do you know how many significant figures to keep in a calculation?

For multiplication and division the rule is easy – you keep the smaller number of significant figures between the two numbers being multiplied.

I.E. , the number 357 x 26, the answer would have only two significant figures, and would be 9300.

As a second example in the product $.004727 \times .000353$, the first number has 4 significant figures and the second three because leading zeros are not considered significant, so the product will have three significant figures, and would be $.00000167$.

For addition and subtraction, the trick is to identify the last significant figure in each of the numbers being added (or subtracted). Then the last significant figure in the sum (or difference) is the one that was originally farther to the left.

Example

$$\begin{array}{r} 353.3 \\ + 747.2856 \\ \hline \end{array}$$

The final three is the last significant figure in 353.3. The 6 is the last significant figure in the 747.2856. The 3 is farther to the left than the 6, so the last place we will keep in the sum will be one occupied by the .3, so the answer will be 1100.6

Do you have any experimental tips?

1. Be careful working with the flames.
2. Use the Sartorius top loading balances for this experiment. We only have a few so they will have to be shared.
3. Be careful working with the flames.
4. In order for your flames to be reasonable sizes the wicks should be adjusted to a fairly short setting. Test the flame before you start heating your water, and before you weigh your burners.
5. Be careful working with the flames.
6. Remember that after you put out your flame to keep stirring the water and measuring the temperature until the highest temperature is reached.
7. Be careful working with the flames.
8. You'll each have four different samples. After you've completed your calculations for all four samples, put the values you measured on the board. I'll send them to you so you can figure out the average values for each measurement.
9. Be careful working with the flames.
10. It helps to wipe the soot off the bottom of the can after each run. It doesn't have to be perfectly clean, but if you get the loose stuff off it is helpful. Note – this can be extremely messy.
11. Be careful working with the flames.

Lab Report: The lab report will consist of the data sheets on page 69 and 70, the averages you calculated for each substance, and the questions on page 68. Base your answers to questions 1, 2, and 3 on the class averages.

Make sure that you report the correct number of significant figures.

Honor: All material may be done by group members together.