Investigation of the Potential Energy Released by the Combustion of Liquids Adsorbed on Paper

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ABSTRACT:
The purpose of this lab was to determine the energy density of various household liquids by testing how efficiently they burn paper. The motivation for this experiment was derived from a concern over the current means of energy production. Currently, the most popular ways to generate energy are with nonrenewable resources that are burned to heat water to produce steam that will turn a turbine to generate electrical power. Projected trends suggest that the United States won't stray away from fossil fuels, the nonrenewable resources, to generate electricity for many more years. Due to their limited nature, it would be beneficial to know which fossil fuel produces the most heat when burned. Unfortunately, access to some of these resources (such as uranium and coal) wasn't possible for this experiment. Instead, different household liquids were used and tested as to which would produce the most heat when burned after being soaked with paper. For this lab, pieces of paper were soaked in six household liquids and then burned one at a time under a calorimeter. The burn rate was recorded as well as the temperature of the water inside the calorimeter both before and after burning; and the energy density of each substance was subsequently calculated. It was hypothesized that two of the liquids, ethanol and petroleum jelly, would have the highest potential energy due to their flammable nature, thereby burning the hottest and releasing the most energy. However, it was found that there were no such trends**.** Due to laboratory inconsistencies, the results from this lab were concluded to be inaccurate because water, which does not burn, had the most potential energy in the lab.

INTRODUCTION:
This lab determined the potential energy of specific liquids and related those results to each liquid's potential output efficiency. Potential energy, or energy density, is the amount of energy stored in materials that can be released through several different reactions, including nuclear, chemical, electrochemical, and electrical. The methods applied in this lab can be used to determine the efficiency of today's most common energy resources including coal, natural gas, oil, and uranium. These resources are all used in power plants to produce energy. Each substance is burned (except for uranium) at high temperatures which, in turn, boils water to form steam. The fast-moving steam particles from the boiling water are then used to turn a turbine that creates electricity in a generator that is transferred across the country to be used commercially and industrially. Usually the resource with the most potential energy is the likeliest to produce the highest energy output. However much of the heat created during the first stages of production

is lost and the burnt material releases harmful chemicals into the atmosphere. Although the materials listed above are not available for experimentation, this lab focuses on how the potential energy of several household materials affect their efficiency to burn paper, and how those calculations may be used to determine the most efficient energy source for the large scale energy production needs of the physical world. It is hypothesized that both the ethanol and petroleum jelly will have the highest potential energy due to their flammable nature, thereby burning the hottest and releasing the most energy.

METHODS:

The necessary experimental data was obtained by using the procedure below, which provided the amount of potential heat energy stored within the tested substances, allowing for the calculation of energy density of each liquid. This procedure was designed based on available resources, time constraints, and simplicity and efficiency of design and was conducted in a general chemistry lab at Fort Lewis College in Durango, Colorado.

Hazards:

Standard safety procedures were followed, including the use of safety goggles, rubber gloves, and a fume hood. Ethanol, which was used in the experiment, is hazardous when in contact with the skin, ingested, or inhaled. Both petroleum jelly and ethanol are flammable, so care was taken to keep sources away from open flames. All materials were handled with caution for the duration of the lab.

Materials:

- 21 pieces of printer paper (2x3 inches)
- Aluminum Can
- 2 ring stands
- 2 ring clamps
- Thermometer
- Timer
- Burner
- Forceps
- Hairdryer
- Soda
- Hydrogen Peroxide
- Vaseline (petroleum jelly)
- Ethanol
- Water
- Energy Drink

Procedure:
27 pieces of paper, 2x3 inches each, were labeled in pencil with the trial number and the liquid used for soaking. Three paper pieces were each soaked in the same liquid, and the papers' masses were recorded before and after the soaking period. The liquids used included soda (Coke), hydrogen peroxide, petroleum jelly, ethanol, water, and energy drink (Monster). The papers were then with a hairdryer held three to five inches away. Three unaltered pieces of paper were used as the control.

A calorimeter was used to measure the heat produced from the burning paper. It was constructed by taking an aluminum can and filling it with 25 ml of water. A thermometer was suspended with a ring clamp inside of the can so that it did come in in contact with the water, but not the can. A ring stand and clamp were placed in the can, and the calorimeter was placed on top of the stand. The thermometer was allowed to equilibrate for two minutes before any recordings were taken.

Using forceps, a paper square was held and one corner of it was lighted while simultaneously starting the timer. The paper was immediately placed under the calorimeter. The thermometer was observed so that the highest temperature could be recorded and other observations noted. When the entire piece of paper had been burned, the total burn time was also recorded. The thermometer was allowed to return to its original temperature, and the water in the can was replaced after each trial, with a new initial temperature being recorded. This procedure was repeated for all of the paper squares.

RESULTS:

Table 1: Change in Mass for Trials 1-3

		Substance																				
		Control			Soda			Energy Drink			Hydrogen Peroxide			Petroleum Jelly			Water			Ethanol		
	Trial:	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Mass (g)	Before	0.26	0.26	0.27	0.28	0.27	0.27	0.28	0.27	0.27	0.29	0.26	0.27	0.28	0.25	0.28	0.28	0.28	0.27	0.29	0.26	0.28
	After	0.26	0.26	0.27	0.36	0.38	0.38	0.31	0.34	0.37	0.34	0.35	0.31	0.91	0.96	1.57	0.30	0.30	0.29	0.40	0.41	0.50
	Gained	0	0	0	0.08	0.11	0.11	0.03	0.07	0.1	0.05	0.09	0.04	0.63	0.71	1.29	0.02	0.02	0.02	0.11	0.15	0.22

Table 2: Burn Time for Trials 1-3

		Substance						
	Trial	Control	Soda	Energy Drink	Hydrogen Peroxide	Petroleum Jelly	Water	Ethanol
Burn Time (s)	1	20	9	31	34	35	35	5
	2	23	25	57	28	33	26	6
	3	20	35	30	15	50	33	7

Table 3: Change in Temperature for Trials 1-3

		Substance																				
		Control			Soda			Energy Drink			Hydrogen Peroxide			Petroleum Jelly			Water			Ethanol		
	Trial:	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Temp (°C)	Before	20	19	21	14	15	14	14	15	15	18	15	15	16	17	18	19	17	17	15	16	15
	After	24	25	25	21	24	25	21	22	22	30	25	22	28	28	35	25	25	24	25	22	21
	Produced	4	6	4	7	9	11	7	7	7	12	10	7	12	11	17	6	8	7	10	6	6

Table 4: Average Data

	Substance						
Averages	Control	Soda	Energy Drink	Hydrogen Peroxide	Petroleum Jelly	Water	Ethanol
Burn Time (s)	21	23	39	26	39	31	6
Mass Gained (g)	0	0.10	0.07	0.06	0.88	0.02	0.16
Change in Temperature w/ Paper (°C)	4.67	9.00	7.00	9.67	13.33	7.00	7.33
Change in Temperature w/o Paper (°C)	0.00	4.33	2.33	5.00	8.67	2.33	2.67

Table 5: Energy in Liquids

	Substance						
Energy	Control	Soda	Energy Drink	Hydrogen Peroxide	Petroleum Jelly	Water	Ethanol
Produced (J)	488.72	453.48	244.18	523.25	906.97	244.18	279.07
Density (J/g)	1879.68	4534.83	3662.75	8720.83	1034.56	12209.17	1744.17

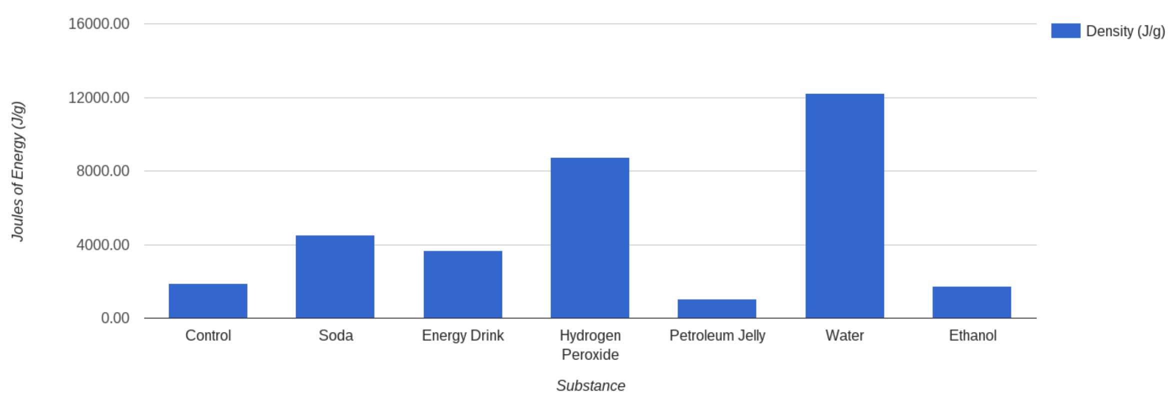

Figure 1: Energy Density of Substances

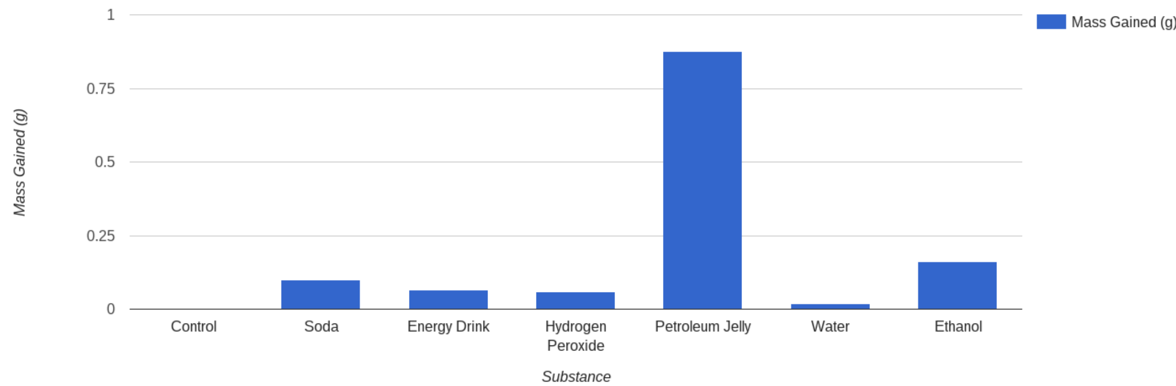

Figure 2: Average Mass Gained of Substances

The data displayed in Table 1 above was collected by weighing each piece of 2x3 inch paper both before and after it was submerged in a substance. The mass gained was calculated by subtracting the original mass from the mass of the substance post-submersion.

Table 2 data was collected by starting a stopwatch the moment the flame touched the paper and was stopped once the flame was no longer visible for each trial. Table 3 is the rise in recorded temperature both before and after the paper was burned under the calorimeter. Table 4 is the combination of the calculated averages for each of the trials.

All of the data in Table 5 was calculated using the trial averages found in Table 4. Energy Produced was found by multiplying the change in temperature by the specific heat capacity of water by the average change in temperature for each substance. (See Example Calculation 1.) Energy Density for each substance was computed by dividing the Heat Produced by the Mass Gained. (See Example Calculation 2.) The Change in Temperature of normal paper (that is, the control group) was subtracted from each of the other substances' recorded Change in Temperature to determine how much temperature each individual substance produced by itself without the paper.

Figure 1 displays the calculated Energy Densities of each substance, and Figure 2 depicts the calculated mass gain of each substance. It should be noted that the normal paper in the control group had a mass of 0.26 grams. There is no linear trend, systematic variance, or pattern within the collected data.

Example Calculation 1 for Soda:

$\Delta T = 4.33\ °C$ $\qquad$ $E = C * \Delta T * M$

$M = 25\ g$ $\qquad$ $E = 25\ g * 4.33\ °C * 4.186\ J/g*°C$

C = 4.186 J/g*°C   E = 453.48 J = Energy Produced

Example Calculation 2 for Soda:

Energy Density = Energy Produced / Mass Gained

Energy Density = 453.48 J / 0.10 g

Energy Density = 4534.83 J/g

DISCUSSION:

The purpose of this experiment was to determine the energy density of specific household liquids. Knowing the heat produced from the combustion of different liquids is helpful for society because knowing how much energy is stored in different substances can yield better choices when it comes to deciding which fuels are the most efficient. Pieces of paper were soaked in different liquids and then burned. By calculating the mass of the substances absorbed by the paper and the amount of heat produced by the burning of said paper, the energy density was calculated. It was hypothesized that either ethanol or hydrogen peroxide would have the highest energy density due to their flammable nature. The collected results did not correlate with the prediction, and many diverse sources of error and uncertainty exist.

As displayed by Figure 1, water was calculated to have the highest energy density, followed by hydrogen peroxide, soda, energy drink, and ethanol. Figure 2 shows that the paper soaked in petroleum jelly gained the most mass, followed by ethanol, soda, energy drink, hydrogen peroxide, and last, water.

Contrary to expectation, water had the highest energy density and lowest mass gained. It can be confirmed that this value is inaccurate due to water's non-combustive nature. This result means that a laboratory inaccuracy is at fault. Due to a lack of bowls during preparation, each substance was placed in the same bowl, meaning that the container could have been contaminated with other substances as a result of improper cleaning. It should also be noted that after the paper was dried, there shouldn't have been a change of mass. The water that the paper was soaked in was from the tap, so additional minerals could have been present post-evaporation.

When water is removed from the data set as an outlier, hydrogen peroxide had the highest energy density. This finding is peculiar because hydrogen peroxide (H_2O_2) shouldn't be flammable. It is a highly reactive substance and used as an oxidizing agent, but doesn't possess a carbon fuel source to make it naturally flammable. However, the decomposition of the substance on the paper could have released oxygen, which would have accelerated the flame.

It was predicted that ethanol would have the second highest energy density. Although results did not support this conjecture, it may still be true. After the paper was soaked in substances, they were allowed to dry before the experiment was conducted. The ethanol could have evaporated off of the paper, which would result in the low energy density.

It is illogical that the energy drink or soda would have relatively high energy densities due to the fact that they're mostly comprised of water. After all of the water evaporated out of the paper, an unknown substance could have been left over. Future investigation is suggested to determine what the substance could be.

The result of petroleum jelly having a low energy density is expected. Although petroleum is flammable due to its high hydrocarbon count, the addition of other substances may dilute its ability to burn constantly. The paper was soaked in a viscous petroleum jelly solution, not pure petroleum. Also, as the calorimeter gets hotter, it loses heat more quickly and as a result the additional energy from the petroleum jelly might all be retained and the contribution from the paper for the other substances could be more significant in the other substance's trials.

Although these results of this specific experiment are not of paramount real-world importance, the procedure followed can be applied elsewhere. Using these concepts, one would be able to determine the energy density of different energy sources, such as wood, butane, ethanol, coal, natural gas, petroleum, and biodiesel. The energy resource with the highest energy density will be the most efficient in the power production process, possibly eliminating unnecessary resource development.

The calculations performed within this experiment were accurate. However, some procedural errors probably existed. As previously stated, soaking the paper repeatedly in the same container despite proper cleaning could have led to cross contamination, possibly leading to the recording of an increased energy density.

Some uncertainty also exists in this experiment. Each piece of paper absorbed a varying random amount of substance. Since each paper contained differing amounts of substance, the energy density would be drastically affected accordingly. A systematic discrepancy also existed. The smaller the mass gain by the paper, the larger the calculated energy density was. Respectively, if the paper gained a large amount of mass, the calculated energy density was very small. This uncertainty resulted from how the change in mass values sits in the denominator of a division calculation, resulting in an inflated quotient value. This uncertainty, combined with the random uncertainty of how much mass each paper gained, makes these results, at minimum, inconsistent.

The inconsistency of these results can be seen when the calculated energy density of ethanol is compared to its known energy density. Ethanol's potential energy is approximately 28217.93 J/g. The calculated potential energy for ethanol is 1744.17 J/g. There is a percent error of -93.82%, meaning that the experimental value is way below what it should have been. All of the results have similar inaccuracies as discussed above.

To improve this experiment, it is suggested to use different containers for the soaking of each paper as well as a uniform way to ensure that each paper absorbs the same amount of substance. This approach could be possible with the utilization of a pipette dropper. If this exact procedure is replicated, pure liquid petroleum should be used as well as distilled water for test liquids. The additional omission of the paper, instead burning the individual liquids for a uniform amount of time, would increase the accuracy of the results.

Further investigation is suggested into what substance remains after the evaporation of the soda and energy drink.