Experiment 30B

Midn

Energy Content of Fuels

Problem: Determine and compare the energy content of *n*-octane and 2-pentanol.

Pre-Laboratory Assignment

1. In this experiment a liquid fuel burner is used to heat water in an aluminum beverage can. Not all of the energy from the burner is transferred to the water, i.e., $q_{combustion} + q_{water} \neq 0$. Because of this, the efficiency of the energy transfer must be determined using the relationship

$$\text{efficiency} = \frac{-q_{water}}{q_{combustion}}$$

   a. In this experiment what will be the sign of q_{water}?

   b. What is the sign of $q_{combustion}$?

   c. Why is the negative sign included with the q_{water}?

2. a. Write a balanced chemical equation for the complete combustion of one mole of liquid ethanol, C_2H_5OH. (Assume the water produced is in the liquid state.)

   b. Using standard enthalpy of formation values found in Appendix J of your textbook, calculate ΔH for this reaction.

   c. The energy content of a substance is kilojoules of energy released per gram of fuel burned. Calculate the energy content for ethanol.

Experiment Procedures

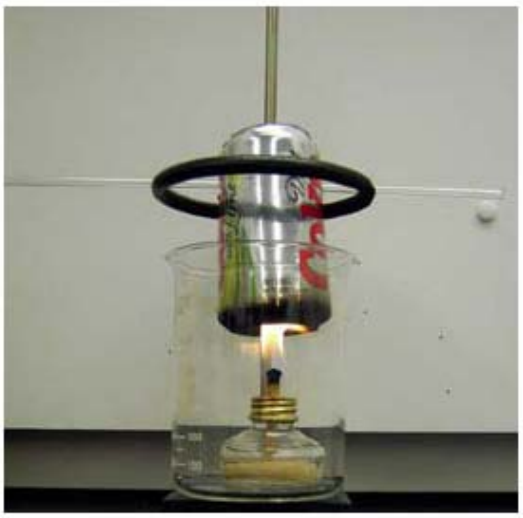
Caution: Ethanol, 2-pentanol, and *n*-octane are flammable.

1. Determining the Efficiency of Energy Transfer

a. Light the ethanol burner. If the flame is not an inch or less in height, extinguish the flame by replacing the burner cap. Adjust the height of the wick and recheck the flame. Once the wick is adjusted properly, extinguish the flame by recapping.

b. Weigh the ethanol burner with cap on a top-loading balance and record the mass. Place the capped burner in an 800 mL beaker.

c. Use steel wool to clean your aluminum can, if it is sooty. Gently push a glass rod through the pre-drilled holes in a clean, aluminum can. Set up an iron ring on a ring stand to suspend the can assembly as in the figure. Adjust the height such that the bottom of the can is approximately an inch above the burner. AFTER THIS ADJUSTMENT DO NOT CHANGE THE HEIGHT OF THE RING.



d. Using a graduated cylinder, place 100 mL of water into the aluminum can. Record the temperature of the water.

e. Lift out the can, remove the burner cap, and then light the burner and replace the can as quickly as possible. Stir the water with the thermometer. (Don't just leave the tip sitting on the bottom!)

f. When the water temperature is about 40°C above its initial temperature, remove the can and quickly cap the burner (use tongs). Re-suspend the can and keep stirring the water; record the <u>highest</u> temperature the water reaches.

g. Weigh and record the mass of the ethanol burner and cap.

h. Pour the water out of the can. If the can is sooty, clean it with steel wool. Readjust the wick if necessary.

i. Repeat the measurement. If the temperature change of the water divided by the mass change of the burner does not agree with the first measurement within 10%, repeat the measurement a third time.

2. Determining the Energy Content of *n*-octane and 2-pentanol

a. Repeat all of Part 1 using the *n*-octane burner.

b. Repeat all of Part 1 using the 2-pentanol burner.

Experiment Data and Observations

Ethanol Burner

	Trial 1	Trial 2	Trial 3
Final mass of burner and cap, g			
Initial mass of burner and cap, g			
Mass of ethanol combusted, g			
Final temperature of water, ^{o}C			
Initial temperature of water, ^{o}C			
ΔT, ^{o}C			

n-octane Burner

	Trial 1	Trial 2	Trial 3
Final mass of burner and cap, g			
Initial mass of burner and cap, g			
Mass of n-octane combusted, g			
Final temperature of water, ^{o}C			
Initial temperature of water, ^{o}C			
ΔT, ^{o}C			

2-pentanol Burner

	Trial 1	Trial 2	Trial 3
Final mass of burner and cap, g			
Initial mass of burner and cap, g			
Mass of 2-pentanol combusted, g			
Final temperature of water, ^{o}C			
Initial temperature of water, ^{o}C			
ΔT, ^{o}C			

Post-Laboratory Questions

1. Determining the Efficiency of Energy Transfer

   a. Using the relationship q_{water} = specific heat × mass × ΔT, show the calculation for q_{water} for Trial 1.

   b. Using the energy content for ethanol determined in Pre-Laboratory Assignment 2c and the mass of ethanol combusted, show the calculation for $q_{combustion}$ for Trial 1.

   c. Show the calculation for the efficiency of energy transferred for Trial 1.

   d. Calculate q_{water}, $q_{combustion}$, and efficiency for your other trial(s) and summarize the results in this table.

	Trial 1	Trial 2	Trial 3
q_{water}, kJ			
$q_{combustion}$, kJ			
efficiency			

   e. What is the average efficiency? Note that this number will be used to calculate the energy content of your two fuels.

2. Determining the Energy Content of *n*-octane

   a. Calculate the q_{water} for each *n* -octane trial and record in the table below.

   b. Use the average efficiency for the ethanol burned and q_{water} for each *n* -octane trial to calculate the $q_{combustion}$ for each *n* -octane trial. Record in the table.

   c. Use the $q_{combustion}$ and mass of *n* -octane combusted to calculate the energy content for each *n* -octane trial. Record in the table.

	Trial 1	Trial 2	Trial 3
q_{water}, kJ			
$q_{combustion}$, kJ			
energy content, kJ/g			

   d. What is the average energy content for *n* -octane ? _____

3. Determining the Energy Content of 2-pentanol

   a. Calculate the q_{water} for each 2-pentanol trial and record in the table below.

   b. Use the average efficiency for the ethanol burned and q_{water} for each 2-pentanol trial to calculate the $q_{combustion}$ for each 2-pentanol trial. Record in the table.

   c. Use the $q_{combustion}$ and mass of 2-pentanol combusted to calculate the energy content for each 2-pentanol trial. Record in the table.

	Trial 1	Trial 2	Trial 3
q_{water}, kJ			
$q_{combustion}$, kJ			
energy content, kJ/g			

   d. What is the average energy content for 2-pentanol? _____

4. a. Calculate the mass percent of oxygen in ethanol (C_2H_5OH), *n*-octane (C_8H_{18}), and 2-pentanol ($C_5H_{11}OH$).

   b. Oxygenated fuels (compounds containing C, H, and O) are used as motor vehicle fuels or fuel additives because they burn cleaner, thereby reducing air pollution. They also affect the miles per gallon for the motor vehicle. Do the energy content values you determined for ethanol, *n*-octane, and 2-pentanol suggest an increase or decrease in miles per gallon due to oxygenation? (Assume that the densities are the same). Explain why you think oxygenating fuels changes their energy content.

c. Use the energy content values to calculate the maximum kJ/gal you could get from ethanol (0.789 g/mL) and n-octane (0.703 g/mL).

d. Assuming that one's gas mileage is proportional to the total energy released upon combustion of fuel, how many gallons of ethanol would one need in order to drive the same distance as one could drive in with one gallon of n-octane? How much should a gallon of ethanol cost relative to a gallon of n-octane if the cost per mile driven is to be equivalent?