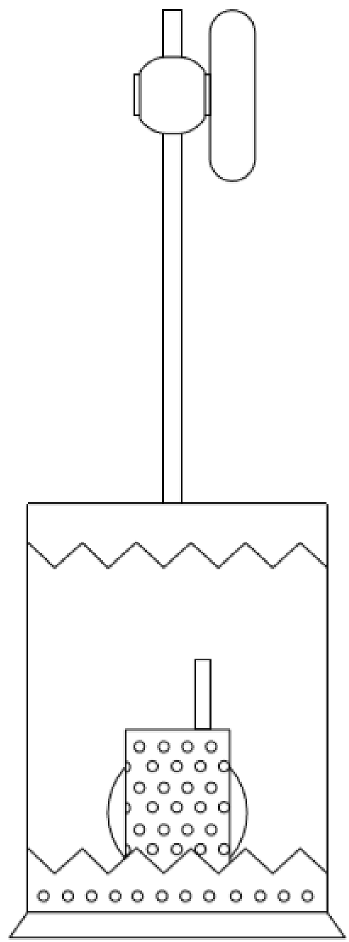
THOMPSON’S CALORIMETER



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EXPERIMENT

Thompson's Calorimeter.

OBJECTIVE

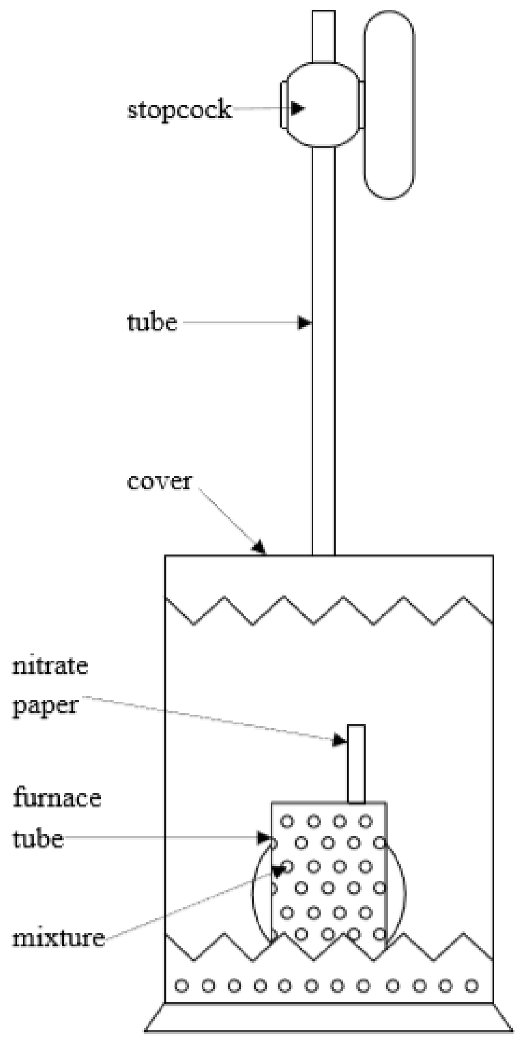
Determining the calorific value of a given solid fuel.

INTRODUCTION

The calorific value is the amount of energy produced by the complete combustion of a material or fuel. It is measured in units of energy per amount of material that is kJ/kg. It is important to know these values of materials for the application in thermodynamics such as in heat engines. In this practical we are going to find the calorific value of the coal

MATERIALS AND APPARATUS

- Coal powder 2 grams
- KNO3 6.5 grams
- KClO3 19.5 grams
- Nitrate paper
- Measuring cylinder with 2 litre of water
- Thompson's calorimeter Stopwatch
- Electric thermometer
- Mortar and pestle
- Digital balance
- Furnace tube
- Metal wire



Thompson's calorimeter

PROCEDURE

- Using digital balance measure and take 2g of coal, 19.5g of KCLO3, 6.5g of KNO3 and mix it and grind it for about 30 minutes to get a fine powder of the mixture using mortar and pestle which will ensure the proper burning process during practical.
- Pack the resulting compound into the furnace tube along with the nitrate paper.
- Take a 2litre of water in a measuring cylinder and take the initial temperature of the water using the thermometer.
- Ignite the nitrate paper, close it with the cover of calorimeter by using the stopcock and quickly lower it into the measuring cylinder with water as soon as possible without spilling the water and start the stop watch at the same time.
- Take the temperature readings of the thermometer for every 30 seconds.
- While recording the readings stir the water to evenly spread the heat throughout the measuring cylinder.
- The end of bubbling will indicate the maximum temperature of the water during the burning process of the mixture.
- Open the stopcock and clear the tube using the metal wire provided after all the readings up to thirty minute are taken.

THEORY

This practical involves basically three types of reactions. These belongs to endothermic and exothermic reactions.

$$C_{(s)} + O_{2\,(g)} \rightarrow CO_{2\,(g)} + Heat$$

$$2KNO_{3\,(s)} \rightarrow 2KNO_{2\,(s)} + O_{2\,(g)} + Heat \qquad \textbf{(1)(exothermic)}$$

$$2KClO_{3\,(s)} + Heat \rightarrow 2KClO_{2\,(s)} + O_{2\,(s)} \qquad \textbf{(2)(endothermic)}$$

Since we have to find the calorific value of the coal, we need complete combustion of coal. For that we need to supply adequate amount of oxygen. However, since this reaction takes place inside water we cannot supply oxygen directly. Hence we introduce the mixture of KNO3 and KClO3 to the system. According to the reactions 1 and 2, adequate amount of oxygen will be supplied to the system.

But according to reaction (1) heat will be released to the system and according to reaction (2) some heat will be absorbed from system. This heat

will disturb the calculation of calorific value as we are calculating it using the heat change in the system. If the amounts of KNO_3 and $KClO_3$ are taken such a way that the heat released by reaction (1) is completely absorbed by reaction (2), the net change in
heat energy would be purely associated with the combustion of coal. So we used 6.5g of KNO_3 and 19.5g of $KClO_3$ to achieve it. The amount of O_2 released in this combination is sufficient enough for the complete combustion of 2g of coal.

ASSUMPTIONS

The energy from the combustion of coal is completely absorbed by the water and the calorimeter. Further there is no impurity in the mixture and the coal is pure. Complete combustion (burning of coal) takes place.

The heat generated by the system is absorbed by the water surrounding the apparatus and the calorimeter.

$$\mathrm{H_{re}} = \mathrm{H_{ab}}$$
$$m_{coal}c_{coal} = \sum ms\Delta\theta$$
$$m_{coal}c_{coal} = (m_{water}s_{water} + m_{cu}s_{cu})\,\Delta\theta$$
$$\Delta\theta = T_{mean} - T_{initial}$$
$$T_{mean} = (T_{cal} + T_{max})/2$$

Here,

$H_{re} - Energy\ released\ (J)$
$\mathrm{H_{ab}} - Energy\ absorbed (J)$
$m_{coal} - mass\ of\ coal\ (kg)$
$c_{coal} - calorific\ value\ of\ a\ coal\ (J\ kg^{-1})$
$m_{water} - mass\ of\ water\ (kg)$
$s_{water} - specific\ heat\ capacity\ of\ water\ (J\ kg^{-1}\ K^{-1})$
$m_{Cu} - mass\ of\ calorimeter\ (kg)$
$s_{Cu} - specific\ heat\ capacity\ of\ calorimeter (copper)\ (J\ kg^{-1}\ K^{-1})$
$\Delta\theta - net\ temprature\ rise\ (K)$

c_{coal} is what we are trying to find, that is the calorific value of coal. Therefore,

$$c_{coal} = [(m_{water}s_{water} + m_{Cu}s_{Cu}) \times \Delta\theta] / m_{coal}$$

CALCULATIONS

- Mass of coal, $m_{coal} = \left(\frac{2}{28}\right) 24.29\ g = 0.001735 kg$
- Mass of water (assuming density of water as 1 g cm-3),
  $m_{water} = 1 \times 2000 \times 10^{-3}\ kg$
  $m_{water} = 2\ kg$
- Specific heat capacity of water, $s_{water} = 4200\ J\ kg^{-1}\ K^{-1}$
- Mass of calorimeter, $m_{Cu} = 442.24\ g = 0.44224 kg$
- Specific heat capacity of calorimeter(copper), $s_{Cu} = 386\ J\ kg^{-1}\ K^{-1}$
- $T_{initial} = 29.6℃ = 302.6\ \mathrm{K}$

From graph,

$T_{max} = 34.4\ ℃ = 307.4\ K$
$T_{cal} = 34.6\ ℃ = 307.6\ K$

✓ Calculation

$T_{mean} = (307.4 + 307.6)/\ 2\ K$
$T_{mean} = 307.5\ K$
$\Delta\theta = 307.5 - 302.6\ K$
$\Delta\theta = 4.9\ K$

$\boldsymbol{c_{coal} = (m_{water}s_{water} + m_{Cu}s_{Cu}) \times \Delta\theta\ m_{coal}}$

$c_{coal} = \frac{[(2 \times 4200) + (0.44224 \times 386)] \times 4.9}{1.735 \times 10^{-3}} J\ kg^{-1}$

$c_{coal} = 24205448.3\ J\ kg^{-1}$

$\boldsymbol{c_{coal} = 24.205\ MJ\ kg^{-1}}$

RESULT

The calorific value of the given sample of coal is, $\boldsymbol{ccoal = 24.205\ MJ\ kg^{-1}}$

DISCUSSION

- ✓ Describe briefly the method used in correcting for heat loss by radiation etc. indicating the assumptions made.

  Heat is released to the environment by the following ways,
  Radiation: Polishing the surface of the calorimeter.
  Convection: Covering the entire apparatus.
  Conduction: Cover the measuring cylinder with an insulation material.

  In order to correct the heat loss to environment, we initiate the experiment from a slightly lower temperature than that of the environment and end up the experiment with a slightly higher temperature than environment by the same amount. By doing this step we assume that the heat absorbed by the system during the initial stage of the experiment is equal to the heat released by the system at the end of the experiment.

- ✓ Describe the Dickinson method of correcting for radiation losses as prescribed by ASTM.

  Dickinson stated that the maximum temperature is not a temperature what we are getting in the practical, it is calculated by the following equation.
  $T_{mean} = (T_{cal} + T_{max})/2$

- ✓ How was the heat of reaction of Nitrate and Chlorate accounted for?

  It is corrected by the assumption that the heat released in the exothermic reaction of KNO3 is fully absorbed by the KCLO3 for the endothermic reaction to take place. This is attained by choosing the optimum ratio of KNO3 and KCLO3 so that net heat released is zero.

- ✓ What is the expected calorific value of coal? Indicate the reasons for any discrepancy between your observed values and expected values.

  The calorific value of coal is varying in different samples due to the impurities present in the samples in the range 15 MJ – 32 MJ. But 30MJ can be given as an average value. In practical we obtained as 24.663 $MJ\ kg{-}1$ Reasons for discrepancy between observed value & expected value; - Some amount of water spilled out due to bubbling. - Absence of complete combustion. - The heat absorbed by the measuring cylinder was ignored - Impurities in the ingredients. - There are heat losses during the practical in the modes of radiation, convection, and conduction - Measuring errors.

- ✓ What other important methods are used to obtain the calorific value of solid fuels?

  Isothermal Bomb Calorimeter, Market's Boiler, Separation & Throttling, Boy`s Calorimeter

- ✓ If you were asked to find the calorific value of a given sample of firewood, how would you do it?

  Take the dry firewood and grind it well with KNO3 and KCLO3. Same steps are followed except for firewood we use Bomb calorimeter instead of Thompson's calorimeter. Since there are more impurities and components in firewood the equations and amount of O2 needed may vary. So calculate and take suitable amount of KNO3 and KClO3 to follow the same procedure as above.