Experiment No: P2

**THOMPSON’S CALORIMETER**

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**Introduction**

Meaning of the term calorific value (SI unit- Jkg-1) of a substance is the total amount of heat energy released. This is also known as heating value or energy value. Measuring the calorific values of fuel types is essential for thermodynamic applications including heat engines.

Coal is a one of the most used fuel in the world. Coal is a fossil fuel which is composed mainly of carbon, hydrogen and oxygen. It is more plentiful than oil or gas. The calorific value of coal plays a key role in the operation of coal-powered power plants and various machines using coal as a fuel.

Calorific value is given in 2 ways.

1.Gross calorific value

2.Net calorific value

Gross calorific value

Gross calorific value is the calorific value of a substance that is obtained by combusting the substance completely. This term is also known as the heat of combustion of a compound. means the calorific value when the combusted substance is allowed to come back to its pre-combustion temperature or in other words after the combustion any vapor created are allowed to be condensed.

Net calorific value

The heat produced by combustion of unit quantity of a solid or liquid fuel when burned, at a constant pressure, under conditions such that all the water in the products remains in the form of vapor. Net heat of combustion at constant pressure is expressed as Qp (net).

In this experiment, we are finding the (gross) calorific value of coal using the Thompson's calorimeter.

**Objective**

To determine the calorific value of a given solid fuel.

**Materials and Equipments Required**

stopcock

tube

cover

nitrate paper

furnace tube

mixture

Figure1

* Coal 2g
* Potassium nitrate (KNO3) 6.5g
* Potassium chlorate (KClO3) 19.5g
* Water 2000 ml
* Digital Thermometer
* Mortar and pestle
* Nitrate paper
* Mixing blade
* Furnace tube
* Electronic balance
* Measuring cylinder
* Stopwatch
* Metal wire
* Thompson calorimeter (Figure 1)

**Theory**

Carbon reacts with oxygen as follows.

C (s) + O2 (g) → CO2 (g)

Oxygen supply will be not enough to complete the combustion of coal. Because we burn coal in a furnace tube which is an enclosed space.

Because of that, we use chemical reactions which produce oxygen inside the furnace tube.

KNO3 (s) → KNO2 (s) + O2 (g) ΔHϕ > 0 (endothermic)--------(1)

KClO3 (s) → KCl (s) + Cl2 (g) + O2 (g) ΔHϕ < 0 (exothermic)--------- (2)

In here there are two chemical reaction except carbon reacts. Those two reaction become a problem because we only need heat that supply by only coal. (those reactions released or absorbed heat). Because calorific value is found by calculating the heat received by water. Then it will affect the amount of heat absorbed by water. To prevent that we should take specific weight of KNO3 and KCIO3 in a way that amount of heat generated by reaction (2) is completely absorbed by reaction (1).

Law of conservation of energy,

Heat released by = Heat absorbed + Heat absorbed

burning coal by water by calorimeter

Let,

* M - Mass of coal (kg)
* C - Calorific value of coal (J/kg)
* mw –Mass of water(kg)
* Sw – Specific heat capacity of water (J/kg0C)
* mcal - Mass of calorimeter(kg)
* Scal - Specific heat capacity of calorimeter (J/kg0C)
* T1 – initial temperature(s)
* T2- maximum temperature when coal burning(s)

Then,

Heat released by burning coal = M.C

Heat absorbed by water = mw.Sw. (T2 – T1)

Heat absorbed by calorimeter = mcal.Scal. (T2 – T1)

**Procedure**

* First finely powder the coal and measure 2g of it.
* Measure Potassium Nitrate (6.5 g) and Potassium Chlorate (19.5g) in relevant amounts and mix them with measured coal.
* Thoroughly mix by using mortar and pestle (do it until the mixture becomes fine powder) and pack the mixture into furnace tube along with a piece of nitrate paper.
* Measure and note the temperature of 2000ml water filled to measuring cylinder.
* Then ignite the nitrate paper fuse and quickly fix the cover with the stopcock closed and quickly lower into the 2000ml of water. Start the stopwatch at the same time.
* Take the thermometer readings every 30 seconds for half an hour.
* Stir the water by moving calorimeter up and down while temperature readings are taken.
* When the bubbles stop indicating the end of combustion, open the stopcock and clear the tube using the metal wire provided.
* While the readings for temperature are taken, move the calorimeter up and down to stir the water.

**Calculations**

(Used Dickinson method to error correction)

From the graph,

Tmax = 33.60C

Tcalibrated = 33.50C

T2 = (Tmax + Tcalibrated)/2= (33.6+ 33.5)/2 0C = 33.550C

Initial Room temperature = 28.80C

Change in temperature,

θ = (T2−Tinitial)

= (33.55 – 28.8) 0C

= 4.70C

Mass of calorimeter,

mCal = 457.444g = 0.457444 kg

Specific heat capacity of copper,

SCu = 0.45 kJkg-1K-1

Mass of water

mw = volume of water x density of water

= (2 x 10-3) m3 x 1000 kgm-3

= 2 kg

Specific heat capacity of water

Sw = 4.2 kJkg-1K-1

Heat released by coal in combustion

H = heat absorbed by water + heat absorbed by calorimeter

=(𝑚𝑤𝑆𝑤+𝑚𝐶al𝑆𝐶𝑢) ×𝜃

= [(2\*4.2) + (0. 457444\*0.45)] kJK-1 \* (4.7K)

= 40.447kJ

Assuming that the coal was used entirely in combustion,

Mass of coal, M = 2g

Heat released by coal in combustion

H = MC

C=H/M

=40.447kJ / 2g

=20.224 MJkg-1

**Result**

The calorific value of coal is 20.224 x 103 kJ kg-1.

**Discussion**

**Heat losses and correcting**

In this experiment heat can be lost by conduction, convection and radiation. To reduce that we can use some actions.

* By covering the apparatus using less heat conducting material with insulation layer can reduce heat that loss by conduction and convection.
* we can start experiment at a faintly below room temperature and end the experiment at a faintly above room temperature can be used to reduce heat lost by convection. Then, heat absorbed in the first part of the experiment is equal to the heat lost in the second part of the experiment.
* Heat losses caused by radiation can reduce by polishing surface ofa calorimeter.

**Dickinson method**

We have to Dickinson method which use for calculating the correction for heat gain or loss by radiation. His method prescribed by the ASTM(American Society for Testing and Materials. This method expresses in below,

In the calorimeter the amount of heat during a test could be approximated by assuming that the calorimeter is heated by its surrounding during the first 63% of the temperature increase at a rate equal to that measured during the 5-minute pre-period. The method then assumes that the cooling rate during the remaining 37% is the same as the rate observed during 5-minute post-period.

So, this can be simply done with our graph. Where T1 is the maximum temperature it has reached and to the curve. Where T2 is at that very point, tangent line and get the temperature value it cuts the y axis. Then, take average of these 2 values as the maximum temperature (Tmax).

**Reactions of Nitrate and Chlorate**

Because of the endothermic enthalpy of KNO3 and exothermic enthalpy of KClO3 , cancel the heat released and heat absorb and these two reactions are not effect to overall reaction. By these two reactions create more O2 that is essential for combustion of coal.

**Expected and observed Calorific values and reasons for discrepancy**

In this experiment some expected and observed values were different from real values due to following reasons. as an expected range for GCV we usually consider 9500 kJ/kg to 27000 kJ/ kg. our value is 20.224 x 103 kJ kg-1. It’s different from real value because,

* Coal might not go under complete combustion (incomplete combustion) because of that can’t be guaranteed that the extra O2 was sufficient for the combustion process
* Impurities in chemicals used
* Heat losses during the practical that were neglected
* Errors in weight, temperature and time measurements

**Type of calorific value( higher or lower) is calculated for experiment**

In this experiment, we are finding the (gross) calorific value of coal using the Thompson's calorimeter.

GCV (gross calorific value) is the quantity of heat produced by combustion when the water produced by combustion is allowed to return to the liquid state. NCV (net calorific value) is the quantity of heat produced by combustion when the water produced by combustion remains gaseous. Since water releases heat when it condenses, GCV is clearly bigger than NCV. GCV is also called HHV (higher heating value); NCV is also called LHV (lower heating value). Because of that we used higher value (GCV) for experiment.

**Other important methods are used to obtain the calorific value of fuels**

1. Bomb calorimeter

(The boy calorimeter is used with gases to find their calorific values)

2. Marcet's boiler

3. Separation and throttling calorimeter-this is also used for gases

**Finding calorific value of a given sample of firewood**

* Chop the given sample of firewood to small parts and dry it.
* Grind them with coal into powder and then mix that sample with KNO3 and KClO3 as before experiment.
* Continue the experiment as did in before experiment.
* Do measurements, graph plotting and calculations in the same way as with coal, using the same parameters and equations.