SUBJECT: - ENERGY & ENVIRONMENT

SEMESTER -1 QUESTION BANK – UNIT 1

UNIT I BASICS OF ENERGY AND SOLID FUELS

QUE.1). Define Specific Heat and Heat Capacity. (2M)

Ans: Specific heat and heat capacity are both measures of the amount of heat energy required to change the temperature of a substance.

Specific heat is defined as the amount of heat energy required to raise the temperature of one unit mass of a substance by one degree Celsius (or one Kelvin). The units of specific heat are J/(kg·K) or J/(kg·C), where J is the unit of energy, kg is the unit of mass, and K (or C) is the unit of temperature. Specific heat is a characteristic property of a substance and varies depending on the material.

Heat capacity, on the other hand, is the amount of heat energy required to raise the temperature of an entire object or system by one degree Celsius (or one Kelvin). It is the product of the specific heat and the mass of the object. The units of heat capacity are J/K or J/C, where J is the unit of energy and K (or C) is the unit of temperature. Heat capacity is a measure of the ability of an object or system to store heat energy.

QUE.2). Numerical on Specific heat / Heat capacity. (2M)

1. **What is the heat energy required to raise the temperature of 2 kg of water from 20°C to 40°C, given that the specific heat of water is 4184 J/(kg·K)?**

Solution: The change in temperature: $\Delta T = (40°C - 20°C) = 20°C$

Formula: $Q = mc\Delta T$

Where, Q = the heat energy required,

m = the mass of water,

c = the specific heat of water,

ΔT = the change in temperature.

$Q = (2\ kg) \times (4184\ J/(kg·K)) \times (20°C)$

$Q = 167,360\ J$

Therefore, the heat energy required to raise the temperature of 2 kg of water from 20°C to 40°C is 167,360 J.

2. **What is the heat capacity of a metal object that requires 250 J of heat energy to raise its temperature by 10°C, given that the mass of the object is 0.5 kg?**

Solution: **Formula**: $C = Q/\Delta T$

Where, C = the heat capacity of the object,

Q = the heat energy required,

ΔT = the change in temperature.

$C = (250\ J) / (10°C)$

$C = 25\ J/°C$

The heat capacity per unit mass (specific heat) by dividing by the mass of the object:

$c = C/m$

$c = (25 \text{ J/°C}) / (0.5 \text{ kg})$

$c = 50 \text{ J/(kg·°C)}$

Therefore, the specific heat of the metal object is 50 J/(kg·°C).

QUE.3). Define Sensible and Latent Heat. (2M)

Ans: Sensible heat and latent heat are both forms of heat energy that can be transferred during a thermal process.

Sensible heat is the heat energy that is transferred to or from a substance resulting in a change in its temperature, but without any change in its phase. In other words, it is the heat energy that can be sensed or measured using a thermometer. Examples of processes that involve sensible heat include heating a pot of water on a stove or cooling a room with an air conditioner.

Latent heat, on the other hand, is the heat energy that is transferred to or from a substance during a change in its phase, such as from solid to liquid or liquid to gas, without a change in temperature. This heat energy is used to either break or form intermolecular bonds between the molecules of the substance. Examples of processes that involve latent heat include melting of ice, boiling of water, and condensation of water vapor.

The amount of heat energy required to change the phase of a substance is typically much greater than the amount required to change its temperature, due to the energy needed to break or form intermolecular bonds. As a result, latent heat plays a significant role in many natural and industrial processes, such as weather patterns and refrigeration systems.

QUE.4). Differentiate between Sensible heat and Latent heat. (3M)

Ans: The differences between sensible heat and latent heat:

Sensible Heat	Latent Heat
1. Sensible heat is the heat energy that is transferred to or from a substance resulting in a change in its temperature, but without any change in its phase.	1. Latent heat is the heat energy that is transferred to or from a substance during a change in its phase, such as from solid to liquid or liquid to gas, without a change in temperature.
2. Sensible heat is easily measurable using a thermometer, as it results in a change in temperature that can be sensed.	2. Latent heat cannot be sensed directly as it does not result in a change in temperature, but it is responsible for the phase change of the substance.
3. The amount of sensible heat required to change the temperature of a substance depends on the specific heat of the material, as well as the mass of the substance being heated or cooled.	3. The amount of latent heat required to change the phase of a substance depends on the substance's heat of fusion or heat of vaporization, as well as the mass of the substance undergoing the phase change.
4. Sensible heat can be calculated using the formula $Q = mc\Delta T$, where Q is the heat energy transferred, m is the mass of the substance, c is the specific heat of the material, and ΔT is the change in temperature.	4. Latent heat can be calculated using the formula $Q = mL$, where Q is the heat energy transferred, m is the mass of the substance undergoing the phase change, and L is the specific latent heat of fusion or vaporization for the material.

QUE.5). What is evaporation? Mention its applications. (2M)

Ans: Evaporation is a process in which a liquid turns into a gas or vapor by gaining energy from its surroundings, typically by heating or exposure to air currents. During evaporation, the more energetic molecules of the liquid escape into the surrounding air, leaving behind the less energetic molecules, which results in a decrease in the temperature of the liquid.

Applications of evaporation include:

1. Drying: Evaporation is commonly used to remove moisture from various substances, such as clothes, foods, and industrial materials. This is achieved by exposing the substance to air currents or heat, which causes the moisture to evaporate and escape into the surrounding air.
2. Cooling: Evaporative cooling is a process in which the evaporation of a liquid, such as water, results in a decrease in the temperature of the surrounding air or surface. This effect is commonly used in air conditioning systems, cooling towers, and refrigeration units.
3. Distillation: Evaporation is a key step in the process of distillation, which is used to separate a mixture of liquids with different boiling points. By heating the mixture, the liquid with the lower boiling point evaporates first and is collected separately, leaving behind the liquid with the higher boiling point.
4. Salt production: Evaporation is used in the production of salt, where seawater or brine is evaporated to remove the water and leave behind the salt crystals.

QUE.6). What is Condensation? State its applications. (2M)

Ans: Condensation is the process in which a gas or vapor turns into a liquid by losing energy to its surroundings, typically by cooling or compression. During condensation, the less energetic molecules of the gas or vapor lose energy and come together to form a liquid droplet.

Applications of condensation include:

1. Water harvesting: Condensation can be used to collect water from the atmosphere in areas where water is scarce. This is achieved by cooling the air to a temperature below its dew point, which causes the water vapor in the air to condense into liquid droplets that can be collected.
2. Heat exchangers: Condensation is used in heat exchangers, which are devices that transfer heat from one fluid to another. By condensing a hot vapor, such as steam, on the surface of a cooler fluid, heat can be transferred from the vapor to the fluid.
3. Refrigeration: Condensation is a key step in the process of refrigeration, where a refrigerant gas is compressed and cooled to cause it to condense into a liquid, releasing heat in the process. The liquid refrigerant is then evaporated to absorb heat, providing cooling.
4. Distillation: Condensation is used in the process of distillation, where a vapor is cooled and condensed to separate it from other substances. By condensing the vapor, it is converted back into a liquid, which can be collected separately.

QUE.7). What is Humidity? Mention the different measurements can be employed for humidity? (2M)

Ans: Humidity refers to the amount of water vapor present in the air or atmosphere. It is a key factor in weather forecasting, indoor air quality, and many industrial processes.

There are different measurements that can be employed to measure humidity, including:

1. Relative humidity: This is the most commonly used measure of humidity and is expressed as a percentage of the maximum amount of moisture that the air can hold at a given temperature. It is measured using a device called a hygrometer, which compares the amount of moisture in the air to the maximum amount of moisture that the air can hold at that temperature.

2. Absolute humidity: This is the measure of the total amount of water vapor present in the air, expressed as the mass of water vapor per unit volume of air. It is commonly used in industrial processes, such as drying and dehydration.
3. Specific humidity: This is the measure of the mass of water vapor present in the air per unit mass of air. It is commonly used in meteorology and weather forecasting.
4. Mixing ratio: This is the ratio of the mass of water vapor present in the air to the mass of dry air, expressed in grams of water vapor per kilogram of dry air. It is commonly used in meteorology and weather forecasting.

QUE.8). Define Renewable and Non-renewable sources of energy. Give their examples. (3M)

Ans: Renewable sources of energy are those that are replenished naturally and can be continuously used without the risk of depletion. These sources of energy are also called sustainable sources of energy as they do not produce harmful emissions that pollute the environment. Examples of renewable sources of energy include:

1. Solar energy: The energy obtained from the sun using solar panels and other devices is a renewable source of energy.
2. Wind energy: The energy obtained from the wind through the use of wind turbines is a renewable source of energy.
3. Hydro energy: The energy obtained from the flow of water in rivers, waterfalls, and dams through the use of hydroelectric power plants is a renewable source of energy.
4. Geothermal energy: The energy obtained from the heat generated by the Earth's core through the use of geothermal power plants is a renewable source of energy.

Non-renewable sources of energy are those that are finite in quantity and cannot be replenished naturally. These sources of energy are also called unsustainable sources of energy as they produce harmful emissions that pollute the environment and contribute to global warming. Examples of non-renewable sources of energy include:

1. Fossil fuels: Coal, oil, and natural gas are examples of fossil fuels that are non-renewable sources of energy.
2. Nuclear energy: The energy obtained from nuclear reactions using nuclear power plants is a non-renewable source of energy.
3. Biomass: The energy obtained from burning organic matter such as wood, crops, and animal waste is also considered a non-renewable source of energy as it is not sustainable and can contribute to deforestation and other environmental problems.

QUE.9). Differentiate between Conventional and Non-conventional sources of energy. (3M)

Ans: Conventional sources of energy are those that have been in use for a long time and are widely used for power generation. These sources of energy are based on traditional technologies and include fossil fuels such as coal, oil, and natural gas, as well as hydroelectric power and nuclear power. They are called conventional sources of energy because they are the most common and widely used sources of energy in the world.

Non-conventional sources of energy are those that have been developed more recently and are based on modern technologies. These sources of energy are also called alternative or renewable sources of energy, and they include solar, wind, geothermal, and tidal power. They are called non-conventional sources of energy because they are not as widely used as conventional sources of energy and are still in the process of being developed and deployed on a large scale.

The main differences between conventional and non-conventional sources of energy are:

1. Availability: Conventional sources of energy are finite and will eventually run out, while non-conventional sources of energy are renewable and will not run out.

2. Cost: Conventional sources of energy are cheaper than non-conventional sources of energy, but the cost of non-conventional sources of energy is decreasing as technology improves and economies of scale are achieved.

3. Environmental impact: Conventional sources of energy are associated with environmental problems such as air and water pollution, climate change, and ecosystem destruction, while non-conventional sources of energy have lower environmental impacts and are generally considered more sustainable.

4. Efficiency: Conventional sources of energy are often more efficient in terms of power generation, but non-conventional sources of energy are improving in efficiency as technology advances.

QUE.10). Write an informative note on non-conventional energy sources (3M)

Ans: Non-conventional energy sources are alternative energy sources that do not rely on traditional fossil fuels and nuclear power. These sources of energy are renewable, meaning they are replenished naturally and can be used indefinitely without running out. Non-conventional energy sources have been gaining in popularity in recent years due to concerns about climate change, energy security, and the finite nature of traditional energy sources.

Here are some examples of non-conventional energy sources:

1. Solar energy: The energy obtained from the sun using solar panels is a renewable source of energy that is becoming increasingly popular. Solar panels are becoming more efficient and affordable, and they can be used to power homes, businesses, and even entire communities.

2. Wind energy: The energy obtained from wind turbines is another renewable source of energy that is gaining in popularity. Wind turbines can be used to generate electricity on a small or large scale, and they can be installed on land or offshore.

3. Hydro energy: The energy obtained from the flow of water in rivers, waterfalls, and dams through the use of hydroelectric power plants is a renewable source of energy that has been in use for many years. Hydroelectric power plants can generate large amounts of electricity and can be used to provide power to entire cities.

4. Tidal energy: The energy obtained from the rise and fall of tides through the use of tidal power plants is a renewable source of energy that is still in the early stages of development. Tidal power plants can generate electricity on a small or large scale, and they have the potential to provide a significant amount of power to coastal communities.

QUE.11). Define Calorific value. Mention its types. (2M)

Ans: Calorific value is the amount of heat energy released per unit of mass of a fuel when it is burnt completely. It is also known as the heating value of the fuel and is typically measured in units of joules per kilogram (J/kg) or British Thermal Units per pound (BTU/lb).

There are two main types of calorific value:

1. Gross calorific value (GCV): This is the total amount of heat released when a fuel is burnt completely and includes the heat released by the fuel's combustion products. GCV is also known as the higher heating value (HHV) or the gross heat of combustion.

2. Net calorific value (NCV): This is the amount of heat released when a fuel is burnt completely, but it does not include the heat released by the fuel's combustion products that are subsequently condensed. NCV is also known as the lower heating value (LHV) or the net heat of combustion.

The difference between the GCV and NCV is because the water vapor produced by combustion is not always condensed and may be present in the combustion products. GCV assumes that all water vapor is condensed and the heat released is included, while NCV assumes that the water vapor is not condensed and the heat released is not included. The choice between GCV and NCV depends on the specific application and the assumptions made about the combustion process.

QUE.12). Differentiate between GCV and NCV. (2M)

Ans: The main difference between GCV (Gross Calorific Value) and NCV (Net Calorific Value) is that GCV includes the heat released by the fuel's combustion products that are subsequently condensed, while NCV does not include this heat.

In other words, GCV is the total amount of heat released when a fuel is burnt completely, while NCV is the amount of heat released when a fuel is burnt completely but does not include the heat released by the fuel's combustion products that are subsequently condensed.

GCV is also known as the higher heating value (HHV) and NCV is known as the lower heating value (LHV). The difference between the two values depends on the specific application and the assumptions made about the combustion process.

QUE.13). Give reason: Net calorific value is less than Gross calorific value. (2M)

Ans: The reason why the net calorific value (NCV) is less than the gross calorific value (GCV) is due to the fact that NCV does not include the heat released by the combustion products that are subsequently condensed.

When a fuel is burnt, the combustion products include water vapor, which can be condensed to release additional heat. The GCV includes this additional heat, while the NCV does not. Therefore, the NCV is always lower than the GCV.

The choice between GCV and NCV depends on the specific application and the assumptions made about the combustion process. For example, if the combustion products are assumed to be condensed and the released heat is to be recovered, then GCV may be used. On the other hand, if the combustion products are not expected to be condensed, then NCV may be more appropriate.

QUE.14). Explain the determination of calorific value of solid and non-volatile liquid fuels by using Bomb Calorimeter. (5M)

Ans: Bomb calorimetry is a commonly used method for determining the calorific value of solid and non-volatile liquid fuels. The basic principle of this method is to burn a known mass of the fuel in a closed container (bomb calorimeter) and measure the heat released by the combustion process.

The setup for bomb calorimetry consists of a small metal bomb (typically made of stainless steel) that is filled with a known amount of the fuel sample and oxygen. The bomb is then placed in a water-filled jacket (calorimeter) and immersed in a known amount of water. A small electric spark is used to ignite the fuel and initiate the combustion process, which leads to the release of heat.

The heat released by the combustion process is absorbed by the water surrounding the bomb and causes a temperature rise in the water. The amount of heat released is calculated by measuring the temperature rise of the water and the heat capacity of the calorimeter system. The calorific value of the fuel is then calculated by dividing the heat released by the mass of the fuel sample.

The determination of calorific value using bomb calorimetry is an accurate and precise method that can be used for a wide range of solid and non-volatile liquid fuels, including coal, biomass, and petroleum products. However, this method has some limitations, such as the inability to measure the energy released by volatile fuels and the difficulty of obtaining a representative sample of heterogeneous fuels.

In summary, bomb calorimetry is a useful method for determining the calorific value of solid and non-volatile liquid fuels, and it involves burning a known mass of the fuel in a closed container and measuring the heat released by the combustion process.

QUE.15). Discuss the various corrections applied during determination of calorific value of solid fuel by Bomb Calorimeter. (3M)

Ans: During the determination of the calorific value of solid fuel by bomb calorimeter, several corrections need to be applied to obtain an accurate result. These corrections include:

1. Water equivalent correction: The water equivalent correction takes into account the heat capacity of the calorimeter system, including the bomb, stirrer, and other parts. The water equivalent is determined by burning a known mass of a standard substance (such as benzoic acid) in the calorimeter and measuring the temperature rise.
2. Heat of formation correction: The heat of formation correction is applied to account for the heat released or absorbed during the combustion process due to the formation or destruction of chemical bonds in the fuel. This correction can be calculated from the chemical composition of the fuel and the combustion products.
3. Nitrogen correction: The nitrogen correction is applied to account for the heat released during the oxidation of nitrogen compounds in the fuel, such as inorganic salts or organic nitrogen compounds. This correction can be calculated from the nitrogen content of the fuel and the stoichiometry of the combustion reaction.
4. Ash correction: The ash correction is applied to account for the heat released by the combustion of the non-combustible components in the fuel, such as mineral matter or inorganic compounds. This correction can be calculated from the ash content of the fuel and the heat of combustion of the ash components.

Overall, these corrections are necessary to account for several factors that can affect the accuracy of the calorific value determination, and their application ensures a more reliable measurement of the fuel's energy content.

QUE.16). Numerical on Bomb Calorimeter experiment (4M)

A 0.5-gram sample of coal was burned in a bomb calorimeter. The temperature of 2000 grams of water in the calorimeter rose from 25°C to 28.5°C. The water equivalent of the calorimeter was 150 grams. Calculate the calorific value of the coal sample, given that the heat capacity of water is 4.18 J/g°C.

Solution: Mass of coal sample = 0.5 g

Temperature rises of water,

ΔT = 28.5°C - 25°C = 3.5°C

Mass of water,

m = 2000 g

Water equivalent of calorimeter = 150 g

Heat absorbed by water = $mC\Delta T$ = 2000 g x 4.18 J/g°C x 3.5°C = 29,330 J

Heat released by the combustion of coal = heat absorbed by water + heat equivalent of calorimeter

= 29,330 J + (150 g x 4.18 J/g°C x 3.5°C)

= 29,936 J

Calorific value of coal sample = Heat released / Mass of coal sample = 29,936 J / 0.5 g = 59,872 J/g

Therefore, the calorific value of the coal sample is 59,872 J/g.

QUE.17). Explain how the calorific value of a gaseous fuel is determined by using Boy's calorimeter. (4M)

Ans: The Boy's calorimeter is a device used for the determination of the calorific value of gaseous fuels. It works on the principle of the adiabatic expansion of the gas, which results in a decrease in its temperature. The calorific value of the gas can be calculated from the change in temperature and the volume of the gas.

The steps involved in the determination of calorific value of a gaseous fuel using Boy's calorimeter are as follows:

1. The gas is passed through a throttling valve, which reduces its pressure and causes it to expand adiabatically. As the gas expands, it undergoes a decrease in temperature, which is measured by a thermometer placed in the expansion chamber.
2. The volume of the gas is measured before and after the expansion using a gas meter. The gas meter should be calibrated before use to ensure accurate volume measurements.
3. The pressure of the gas is also measured before and after the expansion using a pressure gauge.
4. The calorific value of the gas can then be calculated from the change in temperature, volume, and pressure using the following formula:

Calorific value = $[V/(V1-V2)] \times [P1-P2]/t$

where V is the volume of the gas, V1 and V2 are the initial and final volumes of the gas, P1 and P2 are the initial and final pressures of the gas, and t is the temperature change.

5. Obtain accurate results, several corrections must be applied, including the correction for the heat of vaporization of any moisture present in the gas and the correction for the heat of compression or expansion of the gas.

By following these steps and applying the necessary corrections, the Boy's calorimeter can be used to determine the calorific value of a gaseous fuel.

QUE.18). Numerical on Boy's Calorimeter experiment (4M)

A sample of methane gas at a pressure of 10 bar and a temperature of 25°C is passed through a Boy's calorimeter. The initial volume of the gas is 2 L, and after expansion, it occupies a volume of 4 L. The temperature of the gas after expansion is 10°C. Determine the calorific value of methane gas.

Solution: Given data:

Initial pressure of methane gas (P1) = 10 bar

Initial temperature of methane gas (T1) = 25°C = 298 K

Initial volume of methane gas (V1) = 2 L

Final volume of methane gas (V2) = 4 L

Final temperature of methane gas (T2) = 10°C = 283 K

Calorific value = $[V/(V1-V2)] \times [P1-P2]/t$

where V is the volume of gas burned, P1 and P2 are the initial and final pressures of the gas, V1 and V2 are the initial and final volumes of the gas, and t is the temperature change.

$P1V1/T1 = P2V2/T2$

$10 \times 2 / 298 = P2 \times 4 / 283$

$P2 = 11.06$ bar

Calorific value = $[V/(V1-V2)] \times [P1-P2]/t$

If 1 mole of methane gas is burned, its volume at standard temperature and pressure (STP) is 22.4 L.

$V = 22.4 \times (273/298) = 20.47$ L

$t = T1 - T2 = 298 - 283 = 15$ K

Calorific value = $[20.47/(2-4)] \times [10-11.06]/15$

Calorific value = 51.2 MJ/m^3

Therefore, the calorific value of methane gas is 51.2 MJ/m^3.

QUE.19). Discuss the significance of Proximate analysis of coal. (3M)

Ans: Proximate analysis is a standard method for determining the different components present in coal. The significance of proximate analysis of coal can be summarized as follows:

1. Coal Quality Evaluation: Proximate analysis is important for determining the quality of coal, as it provides information about the moisture, ash, volatile matter, and fixed carbon content of the coal. This information is useful for determining the suitability of the coal for various industrial processes.
2. Predicting Combustion Characteristics: Proximate analysis provides information about the combustibility of coal, as the fixed carbon and volatile matter content are the two primary factors that determine the combustion characteristics of coal. The higher the fixed carbon content, the greater the potential energy content of the coal. The higher the volatile matter content, the easier it is to ignite and burn the coal.
3. Control of Coal Quality: Proximate analysis is essential for maintaining the quality of coal used in industrial processes. By monitoring the proximate analysis of coal, it is possible to ensure that the coal being used meets the necessary quality standards for the specific application.
4. Price Determination: Proximate analysis is also used for determining the price of coal, as it provides information about the different components of coal that affect its quality and energy content. This information is important for determining the value of coal in the market.

In conclusion, proximate analysis of coal is a valuable tool for evaluating the quality, combustibility, energy yield, and price of coal. It is an essential step in the process of selecting and using coal for various industrial applications.

Que.20). Discuss the significance of Ultimate analysis of coal. (3M)

Ans: The ultimate analysis of coal refers to the determination of the chemical composition of coal by analyzing its elemental composition. This analysis involves determining the percentage of carbon, hydrogen, nitrogen, oxygen, sulphur, and other elements present in the coal. The significance of ultimate analysis of coal can be summarized as follows:

1. Fuel Quality Evaluation: Ultimate analysis provides an accurate determination of the chemical composition of coal, which is important for evaluating the quality of the fuel. This analysis can help in selecting the coal with the desired characteristics for specific industrial applications.
2. Estimation of Energy Content: Ultimate analysis provides the elemental composition of coal, which is used to estimate its energy content. The higher the carbon and hydrogen content, the greater the energy content of coal.

3. Price Determination: Ultimate analysis is also used for determining the price of coal, as it provides information about the elemental composition of coal that affects its quality and energy content. This information is important for determining the value of coal in the market.
4. Research and Development: Ultimate analysis of coal is essential in the research and development of new coal technologies. Understanding the elemental composition of coal can help in developing new techniques for improving the efficiency and reducing the emissions of coal-based technologies.

In conclusion, ultimate analysis of coal is a valuable tool for evaluating the quality, energy content, emissions, and price of coal. It is an essential step in the process of selecting and using coal for various industrial applications and in the research and development of new coal technologies.

QUE.21). Numerical on Dulong' s formula for calculation of theoretical calorific value of solid fuel. (3M)

Calculate the theoretical calorific value of a solid fuel with the following ultimate analysis: C = 75%, H = 5%, S = 1%, O = 19%.

Solution:

Calorific value = (C x 32.8) + (H x 142.7) + (S x 9.3) - (O x 28.0)

Calorific value = (75 x 32.8) + (5 x 142.7) + (1 x 9.3) - (19 x 28.0)

Calorific value = 2460 + 713.5 + 9.3 - 532

Calorific value = 2650.8 kcal/kg (approx.)

Therefore, the theoretical calorific value of the given solid fuel is approximately 2650.8 kcal/kg, as per Dulong's formula.

QUE.22). Numerical on Goutal's formula for calculation of theoretical calorific value of solid fuel. (3M)

Calculate the theoretical calorific value of a solid fuel with the following proximate analysis: Q = 30%, C = 50%, H = 3%, O = 17%.

Solution:

Calorific value = 80Q + 330C + 1200H - 20O

Calorific value = 80(30) + 330(50) + 1200(3) - 20(17)

Calorific value = 2400 + 16500 + 3600 - 340

Calorific value = 22160 kcal/kg (approx.)

Therefore, the theoretical calorific value of the given solid fuel is approximately 22160 kcal/kg, as per Goutal's formula.