Module – 6: Fuels and Combustion

- Calorific value - Definition of LCV, HCV. Measurement of calorific value using bomb calorimeter and Boy's calorimeter including numerical problems.
- Controlled combustion of fuels - Air fuel ratio - minimum quantity of air by volume and by weight - Numerical problems
- Three way catalytic converter - selective catalytic reduction of NO_X
- Knocking in IC engines - Octane and Cetane number - Anti-knocking agents.

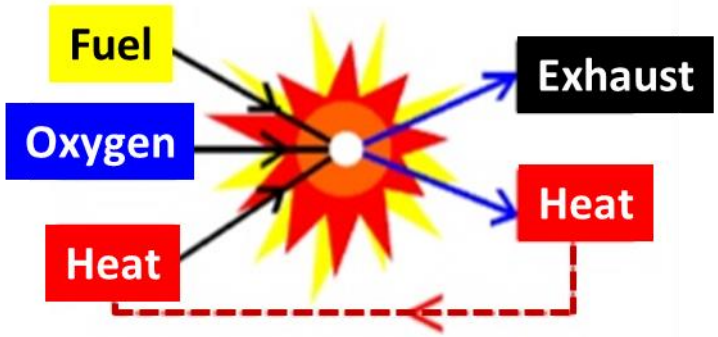
Fuel

- **Fuel:** Anything which burn to give heat in presence of oxygen

$$\text{Fuel} + O_2 \rightarrow \text{Product} + \text{Heat}$$

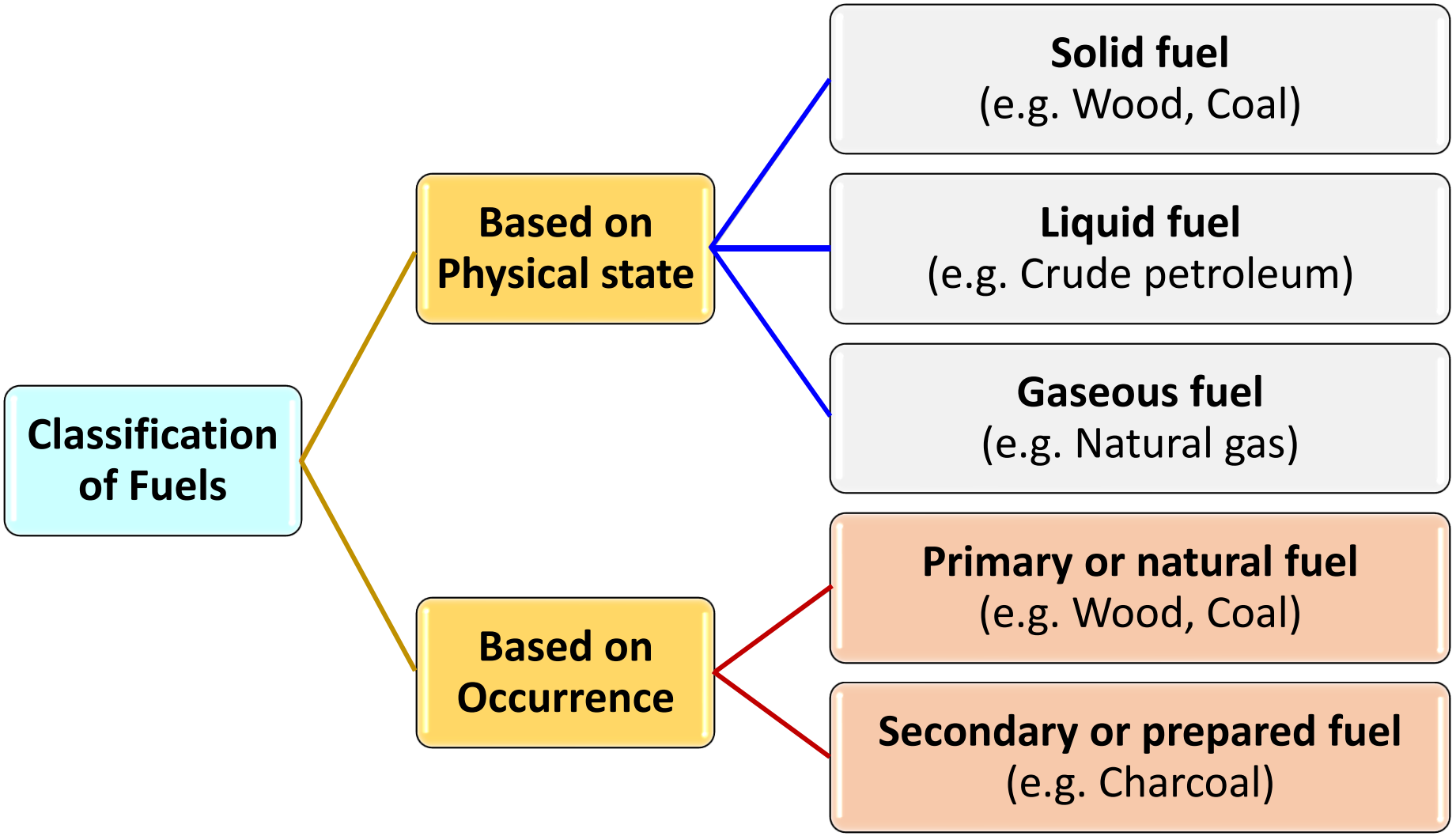
- **Combustion:** The process of burning fuel. In other words, combustion involves oxidation of fuels to CO_2 and H_2O.

$$H_2 + O_2 \rightarrow H_2O + \text{Heat}$$
$$C + O_2 \rightarrow CO_2 + \text{Heat}$$
$$CH_4 + O_2 \rightarrow CO_2 + H_2O + \text{Heat}$$



- During this fuel combustion process large amount of heat energy is liberated which can be utilized.

Classification of Fuel



Characteristic of good fuel

1. It should **ignite easily**
2. It should give out a **lot of heat (High calorific value)**
3. It should have **low smoke** and **low combustible matter** such as ash
4. It should be **inexpensive** and **readily available**
5. It should be **easy to store and transport**
6. It should have **low ash content**

Calorific value of fuels

- **Calorific value:** The total quantity of heat liberated when a unit mass or volume of the fuel is burnt completely **(capacity to supply heat)**.

- **Units:** cal/g (or) kJ/kg.

- **Calorie:** The amount of heat required to raise the temperature of one gram of water through one degree centigrade.

Fuel	Calorific Value (kJ/kg)
Cow dung cake	6000-8000
Wood	17000-22000
Coal	25000-33000
Petrol	45000
Kerosene	45000
Diesel	45000
Methane	50000
CNG	50000
LPG	55000
Biogas	35000-40000
Hydrogen	150000

Calorific Value = Heat produced on burning of 1 kg of fuel

Types of calorific value

Calorific value

- **Higher or Gross Calorific Value**
  - HCV or GCV
- **Lower or Net Calorific Value**
  - LCV or NCV

Determination of Calorific Value

Bomb Calorimeter

- HCV (or) GCV

Boy's Calorimeter

- Gaseous (or) Liquid fuels

Higher or Gross Calorific Value (HCV or GCV)

It is defined as

The total amount of heat liberated, when a unit mass of fuel is burnt completely and the products of the combustion are cooled down to room temperature

- Usually, all fuels contain some hydrogen
- When the calorific value of hydrogen containing fuel is determined experimentally, the hydrogen is converted to steam.
- If the products of combustion are condensed to room temperature (25°C), the steam gets condensed into water and latent heat is evolved.
- The latent heat of condensation of steam also gets included in the measured heat.
- A good fuel posses HCV

Lower or Net Calorific Value

It is defined as

The net heat produced when unit mass / volume of the fuel is burnt completely and the products are permitted to escape

- In actual use of fuel, the water vapour and moisture *etc*. are not condensed and escapes as such along with hot combustion gases. Hence a lesser amount of heat is available.
- Net or lower calorific value can be found from GCV value

NCV = GCV - Latent heat of water vapour formed

= GCV - Mass of hydrogen x 9 x latent heat of steam

- 1 part by mass of hydrogen produces 9 parts by mass of water. The latent heat of steam is 587 kcal/kg formed at room temperature. (i.e. 25°C).

Latent heat of water vapour formed

Latent heat of water vapours is 587 kcal/kg

Hydrogen in the fuel reacts with oxygen to give water

$$H_2 + 1/2\,O_2 \rightarrow H_2O$$

$$2H = 1/2O_2 = H_2O$$

$$2\text{parts} = 16\text{parts} = 18\text{parts}$$

$$1\text{parts} = 8\text{parts} = 9\text{parts}$$

Thus,

$$\mathbf{NCV=GCV-0.09H*587}$$

Note:

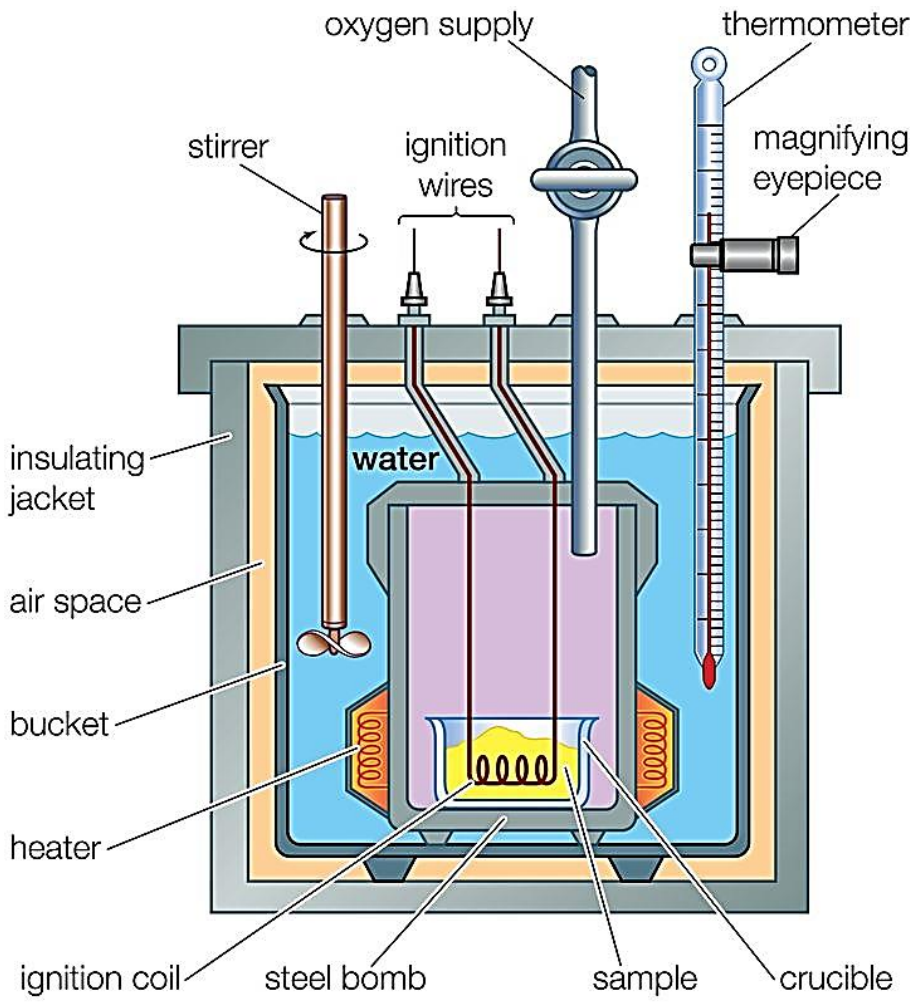
If H is the percentage of hydrogen in fuel,

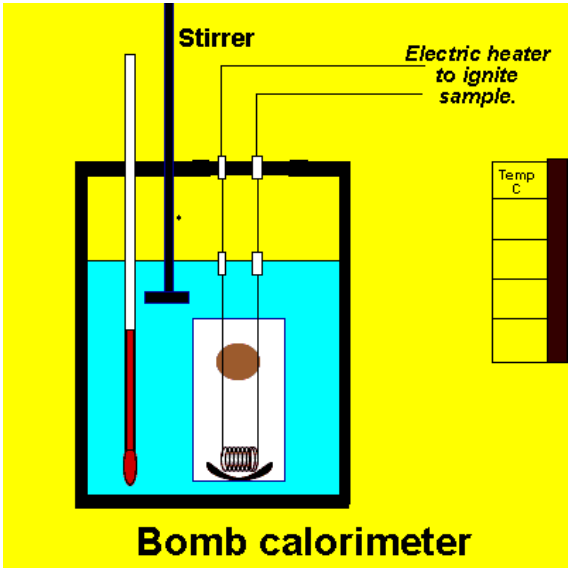
the mass of water produced from 1 g of fuel = (9/100)×H

= 0.09 H

Determination of Calorific Value

Bomb calorimeter





Calculation for HCV

$$HCV = \frac{(W+w)(t_2-t_1) \times \text{Specific heat of water}}{m} \text{ cal/g}$$

m	=	mass of fuel pellet (g)
W	=	mass of water in the calorimeter (g)
w	=	water equivalent of calorimeter (g)
t_1	=	initial temperature of calorimeter
t_2	=	final temperature of calorimeter
HCV	=	Higher/gross calorific value of fuel

Specific heat of water = 1 cal/g °C

$$HCV = \frac{(W+w)(t_2-t_1)}{m} \text{ cal/g}$$

Numerical

0.72 g of a fuel containing 80% carbon, when burnt in a bomb calorimeter, increased the temperature of water from 27.3 °C to 29.1 °C. If the calorimeter contains 250 g of water and its water equivalents is 150 g, calculate the HCV of the fuel. Give your answer in kJ/kg.

Solution:

Here, m = 0.72 g; W = 250 g; w = 150 g; t_1 = 27.3 °C and t_2 = 29.1 °C.

HCV of fuel (L) = $\frac{(W+w)(t_2-t_1)}{m}$ cal/g

1 cal/g = 4.2 kJ/kg

$= \frac{(250+150)(29.1-27.3)}{0.72} = 1000\ cal/g$

= 1000 x 4.2 = **4,200 kJ/kg**

Calculation for LCV

Water Equivalent of the calorimeter

- It is determined by burning a fuel of known calorific value Benzoic acid (HCV = 6,325 kcal/kg) and naphthalene (HCV = 9,688 kcal/kg)

If H is the percentage of hydrogen in fuel,
the mass of water produced from 1 g of fuel = (9/100)×H
= 0.09 H

Heat taken by water in forming steam = 0.09 H× 587 cal

(latent heat of steam = 587 cal/kg)

LCV = HCV – Latent heat of water formed

LCV = [HCV – (0.09 H x 587)] kcal/kg

Numerical - Problem

On burning 0.83 g of a solid fuel in a bomb calorimeter, the temperature of 3,500 g of water increased from 26.5 °C to 29.2 °C. Water equivalent of calorimeter and latent heat of steam are 385.0 g of and 587.0 cal/g, respectively. If the fuel contains 0.7% hydrogen, calculate its gross and net calorific value.

Weight of fuel	=	m	=	?	0.83 g
Weight of water	=	W	=	?	3,500 g
Water equivalent of calorimeter	=	w	=	?	385 g
Final temperature	=	t_2	=	?	29.2 °C
Initial temperature	=	t_1	=	?	26.5 °C
Percentage of hydrogen	=	H	=	?	0.7%
Latent heat of steam	=		=	?	587 cal/g

Numerical

$$\text{HCV of fuel (L)} = \frac{(W+w)(t_2-t_1)}{m} \text{ cal/g}$$

$$= \frac{(3500+385)(29.2-26.5)}{0.83}$$

$$= 12,638 \text{ cal/g}$$

NCV = [GCV – 0.09 H × 587]

= (12,63 8 – 0.09 × 0.7 × 587) cal/g

= (12,638 – 37) cal/g

= 12,601 cal/g