Fuels

- They are combustible substance ~~used~~ which produce useful amount of energy either by combustion or by nuclear react.
- Fuel is combustible substance which has carbon as main constituent.

chemical fuels :- jab react karvane ke baad product mein heat bhi mile

Classification of fuel :- 1. on basis of occurance :- → [Inko primary fuel se bhi bana skte hai]

- **Primary fuel / Natural fuel**
  - fuel jo humne environment se milrha hai jisko hum bina kisi processing ke ya halki si processing krke use kar skte hai.
- **Secondary / derived fuel**
  - aise fuel jisko hum chemical processing ya bohot zyada processing ke baad use kr rhe h.

2. on basis of physical state :- → [koi bhi natural ya secondary fuel ko woh 3 type ke hote hai is basis pr]

- **Solid fuel**
  - eg. wood, peat → Natural solid fuel ka example
  - coal, charcoal, coke → derived solid fuel ka eg.
- **liquid fuel**
  - eg. crude oil, petrol, tar, diesel
- **gaseous fuel**
  - eg. natural gas, coal gas, oil gas

*** Properties of fuel :-**

1. It should have high calorific value. [Jo amount of heat fuel liberate krta hai.]
2. Should have moderate ignition temperature.
3. Should have high amount of fixed carbon.
4. Should have less amount of moisture. → [non-combustable subs ↑ then calorific value ↓ ; " " " ↓ then " " ↑]
5. Should have less amount of non-combustible subs.
6. Should be easily available and ecofriendly.
7. Should have low ash component. → [ash component ↑ then calorific value ↓]

*** classification of coal on basis of %age of carbon / Ranking of coal :-** → [calorific value ↑ then Rank ↑]

S.no / Rank	fuel / coal	C %	calorific value (kcal/kg)
1	wood	50	4000 - 4500
2	Peat	57	4125 - 5400
3	lignite	67	6500 - 7100
4	Sub-Bituminous	77	7000 - 7500
5	Bituminous	83	8000 - 8500
6	Semi-Bituminous	90	8350 - 8500
7	Anthracite	93	8650 - 8700

* Flash point :-

- Jab fuel ke vapor initially flash ke. form mein ayegi for some time.

flash point is a temperature at which vapour of fuel will ignite in form of flash when it come in ~~correct~~ contact with fire (it may last long for 5 sec)

* Fire point :-

fire point is temp. at which vapor of fuel will ignite for long time when it come in contact with fire.

* calorific value and its types :-

- the ~~total~~ amount of heat liberated when unit mass/vol. of fuel burned completely.

amount of heat

- Types :- → Jab fuel ko puri tarah jalaye aur uske products ko room temp. pr thanda kre.

1. Higher / Gross calorific value (HCV or GCV)
2. lower / Net calorific value (LCV or NCV)

→ amount of heat jab sum fuel ko puri tarah jalaye pr uske products to include na kre.

1. Higher / Gross calorific value :-

- the amount of heat liberated when unit mass / vol. of fuel burnt completely and products of combustion having been cooled at Room temp.

eg. fuel mein hydrogen ho to woh oxygen se combustion hone ke baad steam banayega then usko room temp. pe cool krenge then woh water ban jaye to H.C.V calculate krte time hum uss water ki latent heat of water bhi lenge.

2. lower / ~~Gross~~ Net calorific value :-

- the amount of heat liberated when unit mass / vol. of fuel burnt completely and product of combustion are allowed to escape.

⇒ Relation b/w HCV & LCV

$$LCV = HCV - \text{latent heat of water vapour form}$$

generally latent heat of steam = 587 cal/gm

or $\left[L.C.V = H.C.V - \text{weight of Hydrogen in fuel} \times 9 \left(\text{latent heat of steam} \right) \right]$

* Unit of calorific value :-

1. Calorie :- The amount of heat required to raise temperature of 1gm of water by 1°C.

2. kilocalorie :- Defined as ~~heat~~ amount of heat required to raise temp. of 1kg of water by 1°C

3. British thermal unit (BTU) :- amount of heat req. to raise the temp. of 1 pound of water by 1° Fahrenheit.

4. centigrade heat unit (CHU) :- amount of heat req. to raise the temp. of 1 pound of water by 1°C.

Note :- [1 kcal = 1000 cal = 3.9688 BTU = 22 CHU] Units ke beech ka relation.

* Determination / calculation of calorific value :-

2 type ke calorific value hote hai

- Net calorific value (L.C.V) → [L.C.V = HCV − 9 × mass of H × latent heat of steam] → L.C.V ko determine karne ka ek hi tareeka hai
- Gross calorific value (G.C.V) → Isko nikalne ke 2 ways hai
  - 1. Determination (practically) → By bomb calorimeter
  - 2. Calculation (theoritically) → By dulong's method

* Dulong's Method :-

- Isne bataya ki kisi bhi fuel mein jo calorific value mil rhi hai, wooh mil rhi hai due combustion of Carbon, Hydrogen, Sulphur.

C ki C.V → 8080 kcal/kg
H ki C.V → 34500 kcal/kg
S ki C.V → 2240 kcal/kg

agar humre pas ko' namare fuel mein kitna C, H, S hai toh hum calculate krke C.V nikal skte hai fuel ka

→ So hydrogen → oxygen ke saath react krega usko fixed hydrogen bolte hai. • Ques. mein Oxygen pehle se diya hoga warna hum total composition ko 100 mein se minus krke check kr skte hai fuel mein oxygen tha ya nhi?

agar humare fuel mein oxygen hai to wooh Hydrogen ke saath react krke H_2O banayega aur yeh H_2O calorific value mein contribute nhi krega.

So, dulong's formula :- → Isme C, H, S ki value % age mein hogi.

Aur L.C.V ka formula to wohi purane wala h.

$$HCV = \frac{1}{100}\left[8080\,C + 34500\left(H - \frac{O}{8}\right) + 2240\,S\right] \text{ kCal/kg}$$

Q) Calculate gross and net calorific value of coal having following composition :
Carbon = 85%, hydrogen = 8%, sulphur = 1%, nitrogen = 2%, ash = 4%.
latent heat of steam = 587 cal/gm.

Sol) Given :- C = 85% (acc to dulong yeh none zaruri that), H = 8%, S = 1%, N = 2%, ash = 4% (yeh bss batayenge ki fuel mein oxygen hai ya nhi ... How?)

Oxygen = 100 − [85 + 8 + 1 + 2 + 4] ⇒ O = 0 (oxygen ke liye 100 mein se given composition ko minus krenge. → zero aya matlb oxygen nhi hai.)

Dulong's formula :-

$$H.C.V = \frac{1}{100}\left[8080 \times 85 + 34500\left(8 - \frac{0}{8}\right) + 2240 \times 1\right] \text{ kcal/kg}$$

$$= \frac{1}{100}\left[686,800 + 276,000 + 2240\right]$$

G.C.V / H.C.V = 9650.40 kcal/kg.

$LCV = HCV - 9 \times \text{mass of H} \times \text{Latent heat of steam}$ (Steam ki latent heat hamesha 587 hoti hai to agar ques. mein given nhi hai to 587 lena hamesh)

$= 9650.4 - 9 \times 8/100 \times 587 = 9650.4 - 0.09 \times 8 \times 587$

L.C.V = 9227.76 kcal/kg

* **Bomb Calorimeter :-** (gaseous fuel ki calorific value calculate krne ke liye junker's calorimeter use krte hai.)

- used to determine calorific value of solid & non-volatile liq. fuel.

• **Principles-**

Bomb calorimeter iss principle pe work krega ~~jab ko~~ kisi bhi known mass of fuel ka complete combustion karaya jayega toh usse jo bhi heat liberate hone wali hai usko hum known mass of water mein absorb kra denge.

Jis known mass of water mein liberate krayenge jitni bhi heat liberate hui hai, hum usko calculate kr skte hai by noting the rise in temperature.

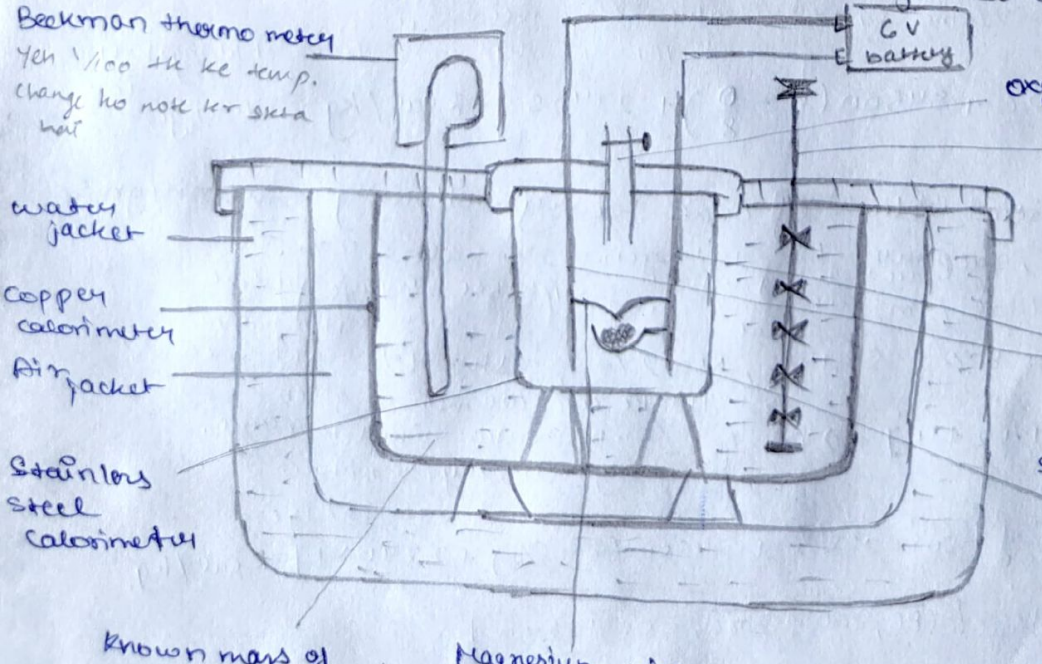
Hamare paani ka temp. kitna rise hua isko note kr ke jo heat absorb hui hai hamare fuel ne liberate kri aur jo water ne absorb kri usko calculate kr payenge.

• **Heat liberated by the fuel = Heat absorbed by water and Calorimeter**

* **construction of calorimeter :-**

• Yeh 3 parts se milke bana hota hai

1. ~~Stainless~~ Stainless steel calorimeter → isko hum copper calorimeter mein rkhenge aur isme hum fuel ka combustion krenge, jo heat liberate hoke copper calorimeter mein paani haga usme absorb hogi.
2. Copper calorimeter →
3. Air and water jacket. → radiation ke through heat loss na ho uske liye jackets use krenge.



• working :-

Jo bhi hamara fuel crusible mein present hai us ka complete combustion hoga aur usse jo bhi heat liberate hogi woh uss known mass of water ke through absorb hogi. yaha pr hum water ka initial aur final temp. note kr lenge with help of Bekmen thermometer. Stirrer, jo bhi heat liberate hogi usko uniformly circulate krega known mass of water mein. Jab humne combustion krvaana hoga to hum electrodes to 6V ki battery se connect kra denge. Tab fuel rkhenge crusible pe ton apne magnesium wire stretch honge jise lid air tight hogi aur usme bss oxygen hoga. 25 atmospheric pressure pr oxygen fill hogi then combustion start hoga fir heat liberate hoke paani mein jayegi. cooling and heating dono simultaneously process hai ton heat ka loss naa ho uske liye air jacket aur water jacket use kiya.

• calculation :-

let → jo humne crusible mein rkha hai

weight of fuel = x gm

weight of water = h gm → jo copper calorimeter mein liya

water equivalent of calorimeter = w → small 'w'

initial temp. = t_1 °C → fuel burn hone se pehle ka

final temp. = t_2 °C

HCV / GCV = H cal/gm → apne product jo condense hote hai unko bhi include krte hai. Jo bhi heat liberate krte hai usko calculate krte hai :. HCV aayegi.

we know that

Heat liberated by fuel = Heat absorbed by water + Heat absorbed by calorimeter.

mass of fuel ← x × H = W (ΔT) + w (ΔT)

water ka mass, → temp change, → calorimeter mein water ka mass

$x \times H = W(t_2 - t_1) + w(t_2 - t_1)$

$$H = \frac{(W + w)(t_2 - t_1)}{x}$$

→ formula to calculate CV with help of Bomb calorimeter

• corrections :- Zyada accuracy ke liye kuch corrections apply krne pdte hai

1. Fuse wire correction (C_F) :- Jab humne nickel crusible mein fuel ka combustion kiya ton magnesium fuse wire ka bhi combustion hua jisse heat produce hui. aur yeh heat hamari calorific value mein aagyi. ton isko hataan padega.

2. Acid correction (C_A) :- Agar hamare fuel mein nitrogen aur sulphur present hai to woh oxygen ke saath react krke oxides banenge aur Hydrogen ton hota hai hi hai to hydrogen oxygen se react krke water banayegi. Now oxides aur water react krke H_2SO_4 aur HNO_3 banenge

Nitric acid aur sulphuric acid ka banna exothermic react hai matlb heat liberate hogi ∴ yeh bhi calorific value mein aa jayega ∴ isko bhi nikalna padega.

3. Cooling correction (C_c) :- Heating & cooling simultaneous process hai toh agar water ka temp. upar jaa rha hai toh radiation loss ki wajah se uski heat ka higher temp. note nhi ho payega usse kam hi note hoga ∴ cooling correction add hoga.

4. Cotton thread correction (C_{CT}) :- Jo apni crucible hoti hai usme kuch cotton threads daal dete hai taaki wood easily fire ko catch kr ske. ∴ cotton thread ka combustion bhi exclude krna hoga.

same corrections ko apply ↑ krne ke baad jo HCV hoga — yeh add hogg ↑ — baaki subtract hoge

Now, $$HCV = \frac{(W+w)(t_2 - t_1 + C_c) - (C_f + C_A + C_{CT})}{x}$$ → isse more accurate result aayega.

Q) 0.72g of solid fuel containing 80% carbon, when burnt in bomb calorimeter, increased the temp. of water from 27.3°C to 29.1°C. If the calorimeter contains 250g of water and its water equivalent is 150g, Calculate the HCV of fuel. Give answer in kJ/kg.

80% carbon dekh ke lgta hai ki dulong's method use krna chahiye par aage likha hua hai bomb calorimeter ∴ hum 80% carbon ko kahi bhi include nhi krenge just ignore it.

Answer) $x = 0.72$ gm
$t_1 = 27.3°C$
$t_2 = 29.1°C$
$W = 250$ gm
$w = 150$ gm
HCV = ?

So, $HCV = \frac{(W+w)(t_2 - t_1)}{x}$
$= \frac{(250+150)(29.1-27.3)}{0.72}$
$= 1000$ cal/gm

Now, we know 1 cal = 4.18 Joules
1000 cal = $1000 \times 4.18 = 4180$ J/gm
or HCV = 4180 kJ/kg

Q) A coal sample contains : C = 92% ; H = 5% and ash = 3%. When this coal sample was tested in lab for calorific value in bomb calorimeter. the data obtained :-

%age composition de rkha hai matlb hum dulong's method use kr skte thae but next line mein likha hai "bomb calorimeter" ∴ dulong's method use nhi krenge.

(i) wt. of coal burnt = 0.095g → (x)
(ii) wt. of water taken = 200g → (W)
(iii) water equivalent of bomb calorimeter = 2000g (w)
(iv) Rise in temp. = 2.48°C (ΔT)
(v) fuse wire correction = 10 cal (C_f)
(vi) Acid correction = 60.0 cal (C_A)
(vii) Cooling correction = 0.02°C (C_c)

Calculate gross and net calorific value of coal sample in cal/gm. Assume heat of condensation of steam as 580 cal/g.

Isko 580 de rkha hai. agar yeh nhi hota to generally 587 lete.

C_c hamesha add hota hai ← → Ques mein 3 hi° correction diye hai to wahi lenge

Ans) $$HCV = \frac{(W+w)(\Delta t + C_c) - (C_f + C_A)}{w}$$

$$= \frac{(700+2000)(2.48+0.02) - (10+60)}{0.95} \text{ cal/gm}$$

$$= \frac{6750-70}{0.95} \text{ cal/gm}$$

So, $\boxed{H.CV = 7031.57 \text{ cal/gm}}$

Now, $L.C.V = HCV - 9 \times \text{mass of } H \times \text{latent heat of steam}$

$= 7031.57 - 9 \times 5/100 \times 580$ cal/gm

So, $\boxed{L.C.V = 6770.57 \text{ cal/gm}}$

* Analysis of coal :-

- Composition of coal varies widely so it is necessary to analyze a coal for particular utilization.
- There are 2 types of analysis of coal :-

1. proximate analysis 2. Ultimate analysis.

1. Proximate analysis of coal :-

- Proximate analysis ka data proximate hota hai aur is pe depend krta hai ki hum kya procedure apply krte hai. It gives us 4 types of analysis.

1.) Moisture content
2.) Volatile matter
3.) Ash
4.) fixed carbon

- **Moisture content :-** Jis bhi coal ka yeh krna hai uska hum known mass lete hai fir usko hot air oven mein at 105-110°C for 1 hr ke liye rkhte fir usko nikal ke desicator mein cool krte hai. Is procedure mein moisture kam hua hoga jisse weight kam hua hoga ussi ko note krte hai aur pta lgate hai

So, % of moisture content $= \frac{\text{loss in weight}}{\text{wt. of coal sample taken}} \times 100$

i.e. $\boxed{\% \text{ of moisture content} = \frac{w - w_1}{w} \times 100}$

w_1 = oven mein se nikalne ke badd jo wt. aayega.

w = oven mein dalne se pehle jo wt. tha

- **Volatile matter (w)**:- Isme hum w_1 sample lenge i.e oven se bahar nikla hua sample w/o moisture wala. toh isko hum silica crucible mein, muffle furnace mein $927 \pm 20^\circ C$ pr ek cover lid ke saath 7min ke liye rkhenge jiski wajah se isme jo bhi volatile matter hoga woh itne high temp. pr udd jayega aur fir se iska weight km hoga.

So, % of volatile matter = $\frac{\text{loss in wt.}}{\text{wt. of coal sample}} \times 100$

w_1 → furnace mein daalne se pehle wala weight

w_2 → furnace se nikalne ke baad wala weight

$$\boxed{\% \text{ of V.M} = \frac{w_1 - w_2}{w_1} \times 100} //$$

- **Ash**:- Isme w_2 sample lenge usko muffle furnace mein rkhenge at $700 \pm 50^\circ C$ for 30 min w/o cover lid. Then usko nikal ke desiccator mein cool krenge & weigh lenge. (let w_3) -ab isme loss in weight nhi dekhna hai because sab kuch toh upar humne dry kr diya, evaporate kr diya ab jo bhi bachega woh residue hai.

So, % of ash = $\frac{\text{wt. of residue}}{\text{wt. of coal sample taken}} \times 100$

$$\boxed{\% \text{ of Ash} = \frac{w_3}{w_2} \times 100}$$

- **Fixed carbon**:- Jo bhi analysis hai woh %age mein hai toh hum inko 100 mein se subtract kr de toh fixed carbon mil jayega.

So, $$\boxed{\%\text{age of fixed carbon} = 100 - \%\text{age of (moisture + V.M + ash)}} //$$

w —(In hot air oven for 1 hr at 105 -110°C)→ w_1 —(in muffle furnace (with lid) for 7 min at $927 \pm 20^\circ C$)→ w_2 —(in muffle furnace (w/o lid) for 30 min at $700 \pm 50^\circ C$)→ w_3

So, % of moisture = $\frac{(w - w_1)}{w} \times 100$

So, % age of VM = $\frac{w_1 - w_2}{w} \times 100$

So, % age of ash = $\frac{w_3}{w} \times 100$

* Significance of proximate analysis :-

1. Moisture content :- Agar humare coal/fuel mein moisture content zyada hai to calorific value kam ho jayegi.
   ↳ low hona chahiye
2. Volatile matter :- Volatile matter ki moderate hona chahiye because agar
   ↓
   low hona bohot zyada hoga to C.V kam ho jayegi agar bohot kam hoga toh
   chahiye fuel easily fire ko catch nhi krega.
3. Ash :- coal mein ash kam nikalna chahiye because yeh residue hamare
   ↓
   low hona fuel aur coal ka weight to badha rha hai pr C.V mein contribute nhi
   chahiye krta. Ash ki amount jitna zyada hogi coal ki C.V utni kam hogi. therefore ash amount kam hona chahiye.
4. fixed carbon :- yehi hai coal mein jo C.V deta hai. iski amount
   ↓
   high hona chahiye. ~~first~~ jitni badhegi coal ki C.V aur rank utni zyada ayegi.
   So fixed carbon high hona chahiye.

2. Ultimate Analysis / elementary analysis :-

- Ultimate analysis mein hum elements ka analysis krte hai.

1. Carbon & hydrogen
2. Nitrogen
3. Sulphur
4. Oxygen

- Carbon & hydrogen :- Jis coal ka ultimate analysis krna hai usko known weight lenge usko oxygen ke saath combustion krayenge.

toh carbon aur hydrogen

$C + O_2 \rightarrow CO_2$ banayega

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

ab agar hum weight wise pta krte ki kitni CO_2 aur H_2O bana to hum nikal skte hai ki sample mein Carbon aur hydrogen kitna hai

So, for carbon

$C + O_2 \rightarrow CO_2$ → Isko hum isme daal denge

known vol of KOH

$KOH + CO_2 \rightarrow K_2CO_3$

↳ So, pehle se wt. badh jayega

iss increase in wt. ko nikal le toh pta chal jayega kitna CO_2 tha.

for hydrogen

$H_2 + 1/2\,O_2 \rightarrow H_2O$ → Isko $CaCl_2$ mein daaldenge

anhy. $CaCl_2 + 7H_2O \rightarrow CaCl_2 \cdot 7H_2O$

↳ So, pehle se wt. badh jayega

agar yeh pta krte kitna weight badha hai toh kitna water hai pta ker skte hai

humne water aur ~~carbon~~ CO_2 pta chal jayega ki kitna hai but humko Carbon aur Hydrogen pta krna hai

So, w.k.t.

$C \longrightarrow CO_2$

12 part 44 part

$H_2 \longrightarrow H_2O$

2 part 18 part

$\therefore$ % of carbon $= \frac{12}{44} \times \frac{\text{Increase in wt. of KOH tube}}{\text{wt. of coal taken}} \times 100$

$\therefore$ % of Hydrogen $= \frac{2}{18} \times \frac{\text{Increase in wt of } CaCl_2 \text{ tube}}{\text{wt. of coal taken}} \times 100$

- **Nitrogen :-** Nitrogen ka analysis hum Kjeldahl's method se krte hai, isme jo bhi nitrogen hai coal sample mein usko hum ammonia tak convert krenge fir ammonia ko H_2SO_4 mein absorb krayenge fir kitne equivalent ammonia ne kitne equivalent H_2SO_4 ke saath absorb hui hai usse nitrogen calculate krenge.

$$N + \underset{\text{conc.}}{H_2SO_4} \xrightarrow{K_2SO_4} (NH_4)_2SO_4$$

$$(NH_4)_2SO_4 + \underset{NaOH}{\text{excess}} \longrightarrow 2NH_3 + Na_2SO_4 + 2H_2O$$

$$NH_3 + H_2SO_4 \longrightarrow (NH_4)_2SO_4$$

Let weight of coal sample taken = x

Normality of H_2SO_4 = N_1

Vol. of H_2SO_4 = V_1

% of N = $\frac{1.4 \times \text{normality of Acid used} \times \text{vol. of acid used}}{\text{wt. of coal sample taken}}$

So, $\boxed{\% \text{ of } N = \frac{1.4 \times N_1 \times V_1}{x}}$

- **Sulphur :-** For sulphur ultimate analysis, given / known coal ko bomb calorimeter mein combustion krvate hai. Isse jitna bhi sulphur hoga woh sulphate mein convert ho chuka hoga. Yaha se jo bhi ash milegi usko extract krte hai HCl ke through. fir extracted acid ki reaction krvate hai Barium chloride ke through. Jisse barium sulphate milega fir usko titrate krenge, dry krenge aur weight krenge.

$\underset{32 \text{ parts}}{S} \longrightarrow SO_4^{--} + BaCl_2 \longrightarrow \underset{233 \text{ parts}}{BaSO_4}$

So, $\left[\% \text{ of sulphur} = \frac{32}{233} \times \frac{\text{wt. of } BaSO_4}{\text{wt. of sample taken}} \times 100\right]$ =

- Oxygen :-

Oxygen analysis ke liye humne jitne bhi analysis kiye hai i.e carbon, Hydrogen, Nitrogen, Sulphur aur Ash bhi lenge inn sbko add krke 100 mein se subtract krdo. → Iski % age proximate analysis se milegi

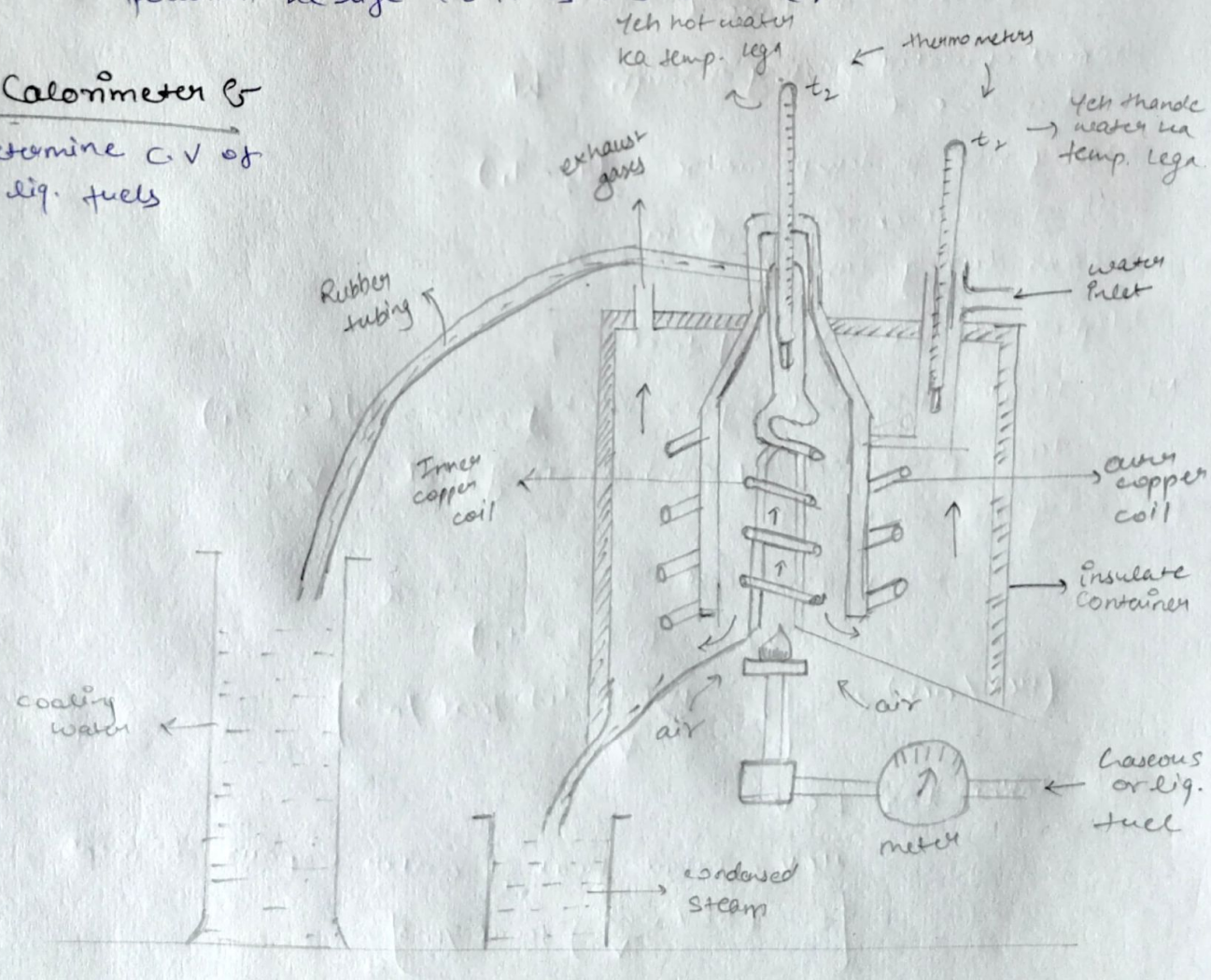
$\left[\% \text{ of oxygen} = 100 - \%(C + H + Ni + S + Ash)\right]$ =

* Significance of ultimate analysis :-

1. Carbon & hydrogen :- % jitni zyada, fuel utna achha.
2. Nitrogen :- % jitna zyada, fuel utna bekar.
3. Sulphur :- Yeh C.V mein contribute ton krta hai but yeh SO_2 se SO_3 mein oxidise hota hai jo responsible hai pollution ke liye ∴ it is undesirable.

* Boy's Calorimeter :-

- use to determine C.V of gaseous & liq. fuels



Principle :- work on law of conservation of energy.

A known amount of fuel burnt in excess oxygen and heat liberated by combustion of fuel is transferred to known quantity of water

So, Heat liberated by fuel = Heat absorbed by water. =

working :- gaseous / liq.

- pehle hum fuel ka combustion karayenge aur gas / liq. fuel ko meter ki help se measure kar lenge fir water inlet karenge jo combustion chamber ke outerside ke copper coils mein jayega fir uske baad chamber ke inside copper coils mein jayega aur fuels se hui ke liberated heat ko absorb karega, temp. rise hoga aur upar thermometer uska temp. note karega aur hot water outlet ki taraf water jayega. Initial state mein ~~heat~~ cooling water ko collect nhi karenge.

System ke steady hone par hum stop watch use karke uss water ko particular time 't' par collect karenge. Uss time mein combustion camber mein jitni bhi steam ~~collect~~ hogi usko bhi collect karenge.

fir hum t_1 and t_2 temp. measure karenge.

- calculation :-

vol. of gas burnt at const. temp. and pressure in time t $= V$

amount of water passing through coil in time t $= W$

Steady rise in temperature $= (T_2 - T_1)$

mass of water condensed from Steam during time t $= m$

Higher calorific value of fuel $= L$

Now, Heat absorbed by circulating water $= W(T_2 - T_1)$

Heat produced by combustion of fuel $= V \times L$

Assuming no heat loss,

Heat produced = Heat absorbed

$$VL = W(T_2 - T_1)$$

(HCV / GCV) $\leftarrow$ $$\boxed{L = \frac{W(T_2 - T_1)}{V} \text{ kcal/m}^3}$$

calculation for LCV

= HCV - latent heat of water vapour formed

= $$\boxed{L - \left(587 \times \frac{m}{V}\right) \text{ kcal/m}^3}$$