AKTU

GATEWAY CLASSES

B.Tech I-Year

Engg.Chemistry

Unit-4

ONE SHOT Revision

All Topics Unit-4

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Hard water

The water which does not give lather with soap is called hard water. The hard water contains dissolved calcium & magnesium salts.

Hardness

The amount of dissolved salts in water is known as its hardness.

Hardness of water is expressed in terms of $CaCO_3$ because of the following reasons:

1. Molecular weight of $\boxed{CaCO_3}$ is 100 (Equivalent wt. is 50) which makes the calculation easy.
2. $CaCO_3$ is most insoluble salt that can be precipitated in water treatment.

40
12
48
100

$\frac{m.w}{n}$

Ca^{2+}

Units of hardness

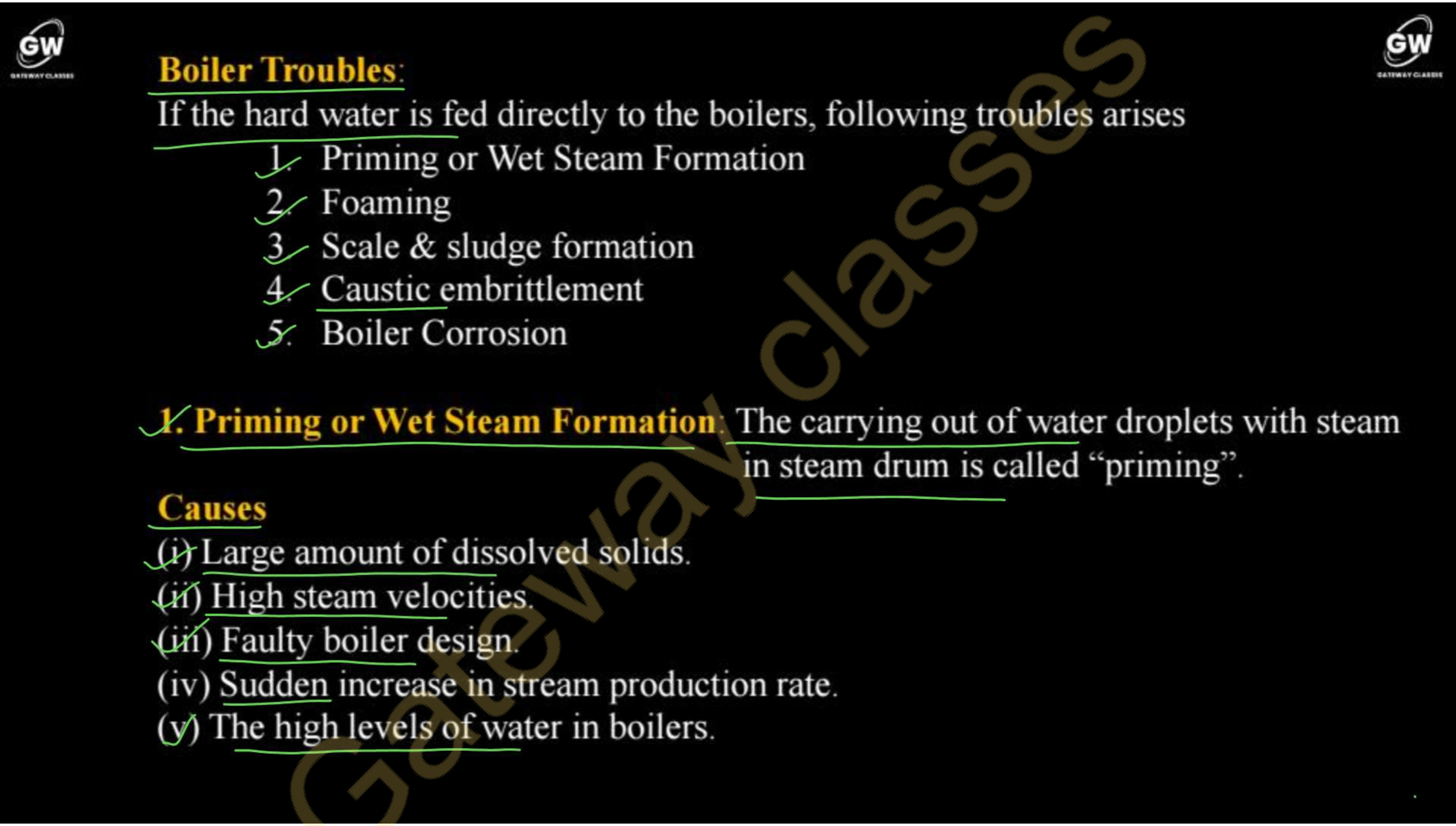
(1) Parts per million (ppm)
(2) Milligrams per liter (mg/l)
(3) Degree Clarke (°Cl)
(4) Degree French (°Fr)

1ppm = 1mg/L = 0.1°F = 0.07°Cl

TYPES OF HARDNESS

(1) Temporary hardness
(2) Permanent hardness

	Ca^{2+}	Mg^{2+}	
(Temp)	Bicarbonates	Bicarbonates	(Temp)
	$Ca(HCO_3)_2$	$Mg(HCO_3)_2$	
	Chlorides	Chlorides	
	$CaCl_2$	$MgCl_2$	
	Sulphates	Sulphates	
	$CaSO_4$	$MgSO_4$	



Boiler Troubles:

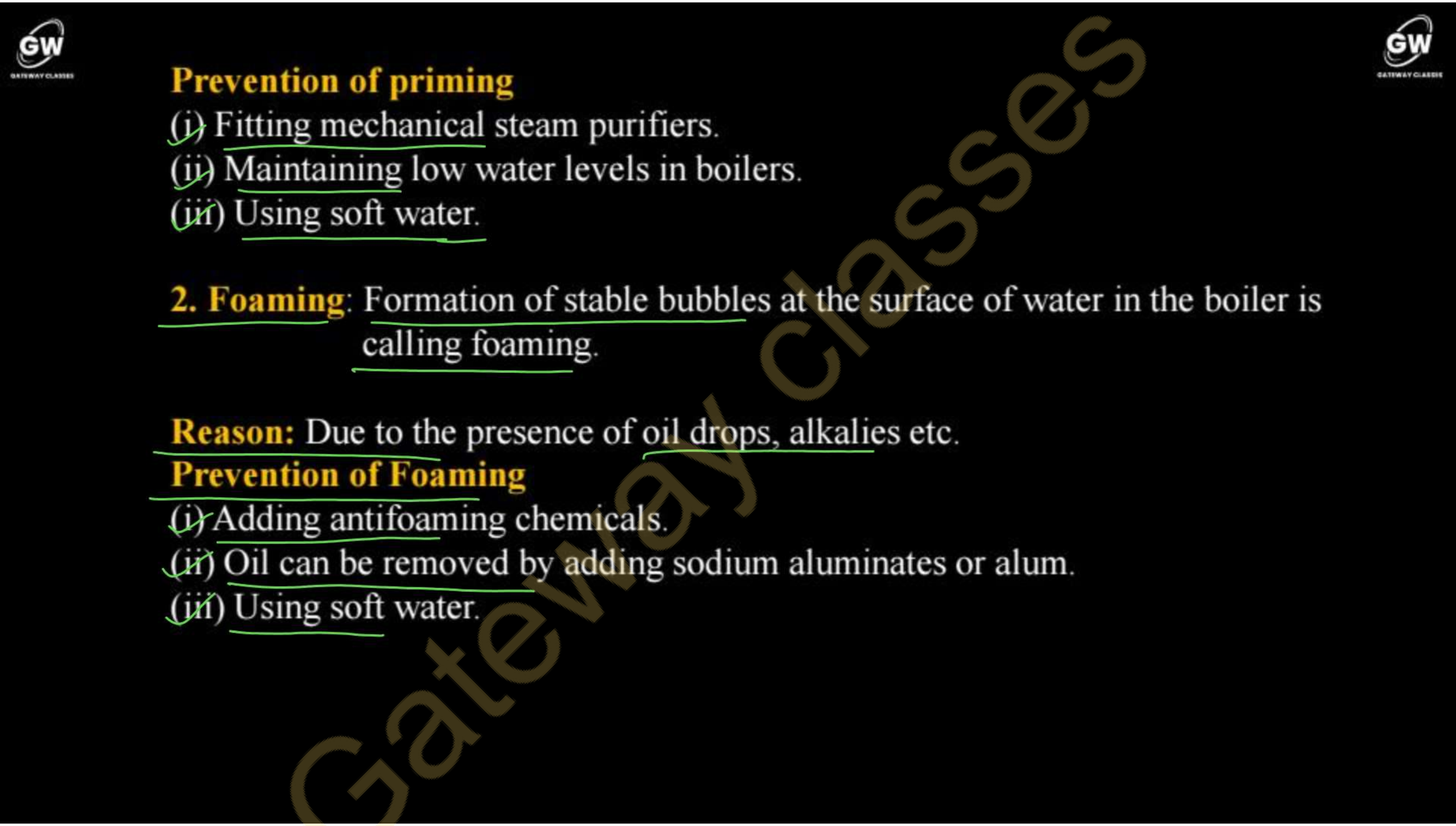
If the hard water is fed directly to the boilers, following troubles arises

1. Priming or Wet Steam Formation
2. Foaming
3. Scale & sludge formation
4. Caustic embrittlement
5. Boiler Corrosion

1. Priming or Wet Steam Formation: The carrying out of water droplets with steam in steam drum is called "priming".

Causes

(i) Large amount of dissolved solids.
(ii) High steam velocities.
(iii) Faulty boiler design.
(iv) Sudden increase in stream production rate.
(v) The high levels of water in boilers.



Prevention of priming

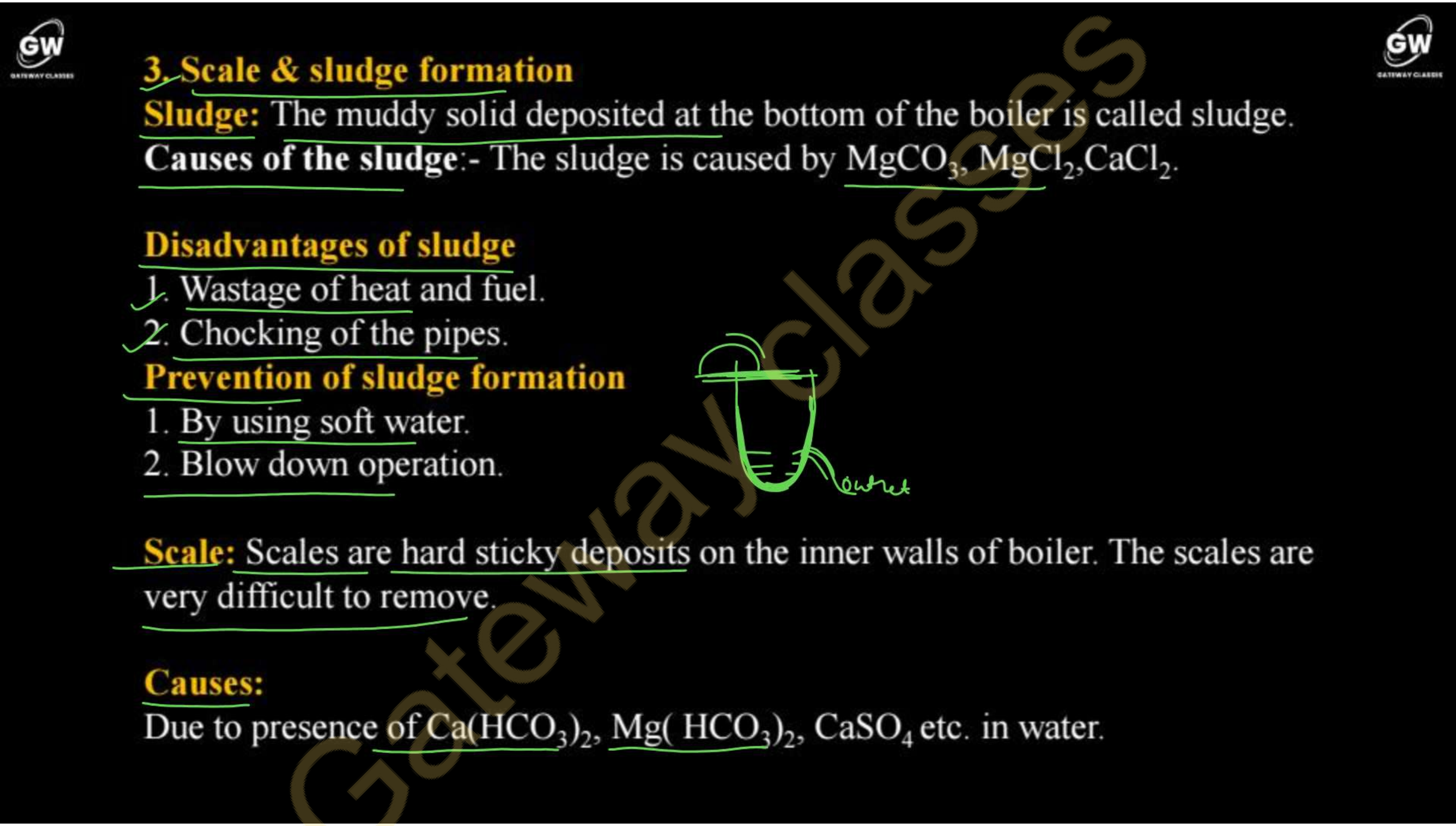
(i) Fitting mechanical steam purifiers.
(ii) Maintaining low water levels in boilers.
(iii) Using soft water.

2. Foaming: Formation of stable bubbles at the surface of water in the boiler is calling foaming.

Reason: Due to the presence of oil drops, alkalies etc.

Prevention of Foaming

(i) Adding antifoaming chemicals.
(ii) Oil can be removed by adding sodium aluminates or alum.
(iii) Using soft water.



3. Scale & sludge formation

Sludge: The muddy solid deposited at the bottom of the boiler is called sludge.

Causes of the sludge:- The sludge is caused by $MgCO_3$, $MgCl_2$,$CaCl_2$.

Disadvantages of sludge

1. Wastage of heat and fuel.
2. Chocking of the pipes.

Prevention of sludge formation

1. By using soft water.
2. Blow down operation.

Scale: Scales are hard sticky deposits on the inner walls of boiler. The scales are very difficult to remove.

Causes:

Due to presence of $Ca(HCO_3)_2$, $Mg(\ HCO_3)_2$, $CaSO_4$ etc. in water.

Disadvantages of Scale

1. Loss of heat and fuel.
2. Weakening of boiler material.
3. May result in explosion of boiler.

Removal of Scales

1. Soft scales can be removed by scrapper.
2. By giving thermal shocks.
3. Using 5-10% HCl Solution.

Sludge	**Scale**
It is soft, loose and slimy precipitate.	It forms hard deposits.
They form non-adherent deposits and can be easily removed.	They stick firmly to the inner surface of the boiler and are very difficult to remove.
✓ Formed by $CaCl_2$, $MgCl_2$, $MgSO_4$, $MgCO_3$ etc.	Formed by substances like $CaSO_4$, $Mg(OH)_2$ etc.
Less dangerous.	Chances of explosion are there.
Can be removed by blow down operation.	Can-not be removed by blow down operation.
Formed at colder portions of the boiler.	Formed at heated portions of the boiler.

4. Caustic embrittlement

The formation of cracks in boilers due to NaOH is called caustic embrittlement.

Prevention of caustic embrittlement

a) By using sodium phosphate or sodium sulphate for softening instead of Na_2CO_3.
b) By adding tannin or lignin to boiler water.

5. Boiler Corrosion

It is the decay of the boiler body material due to environmental factors.

Disadvantages

a) Reduced life of boiler.
b) Increased cost of repairs and maintenance.
c) Leakage of joints.

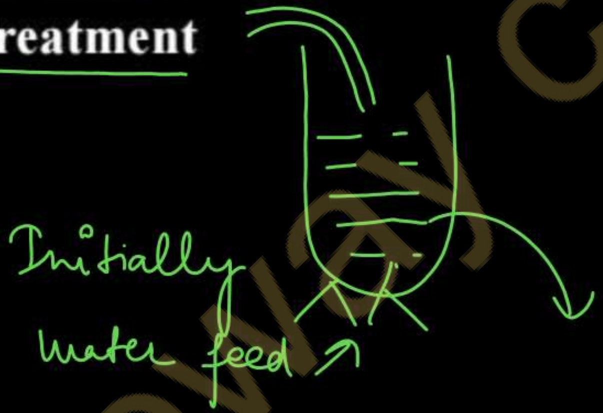
Prevention

1. By removal of oxygen using hydrazine, sodium sulphate etc.
2. By removal of CO_2: By adding ammonia.

Treatment of Boiler feed water is of two types:

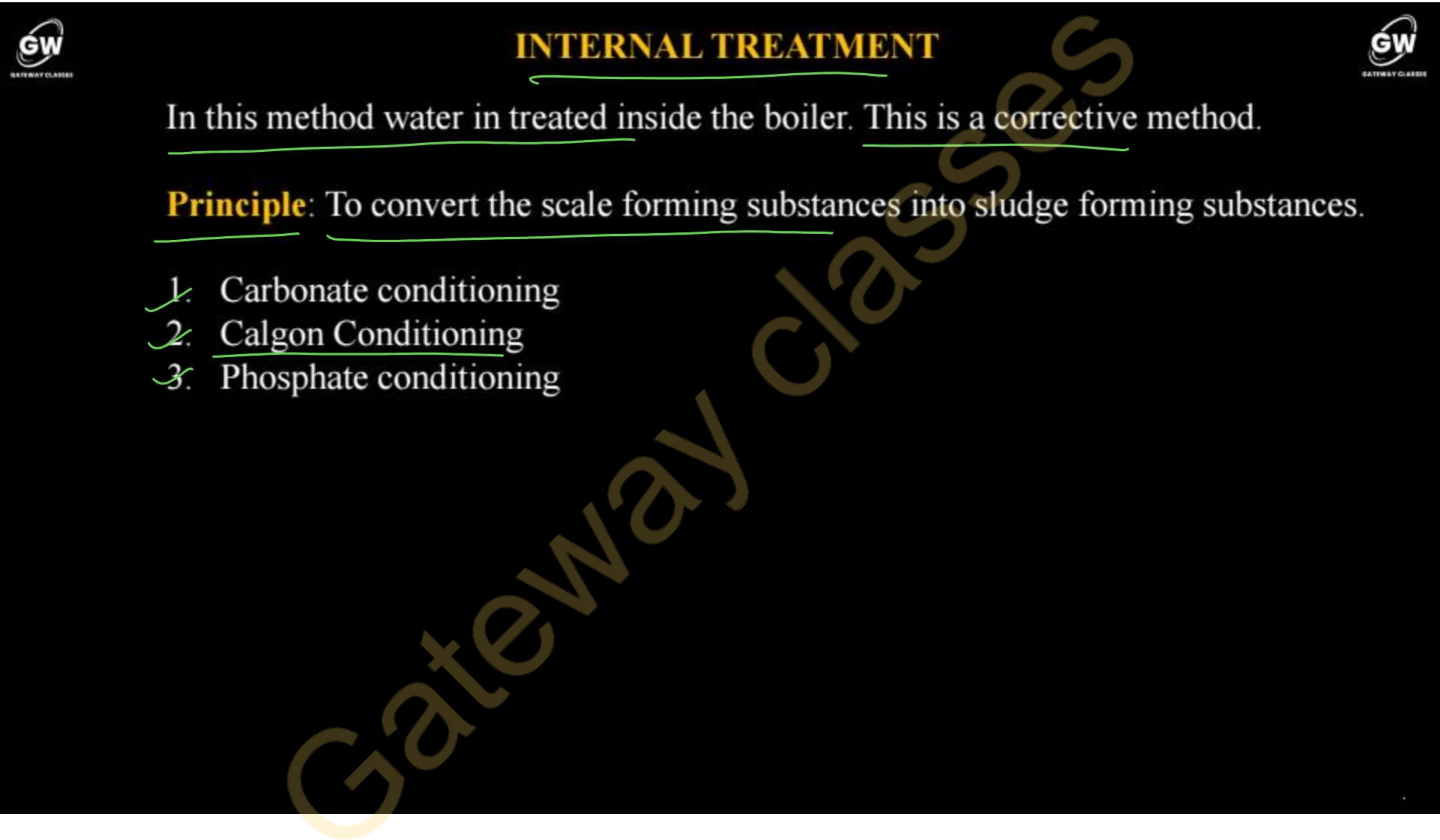
Internal Treatment

External Treatment



Initially water treat

feed Boiler

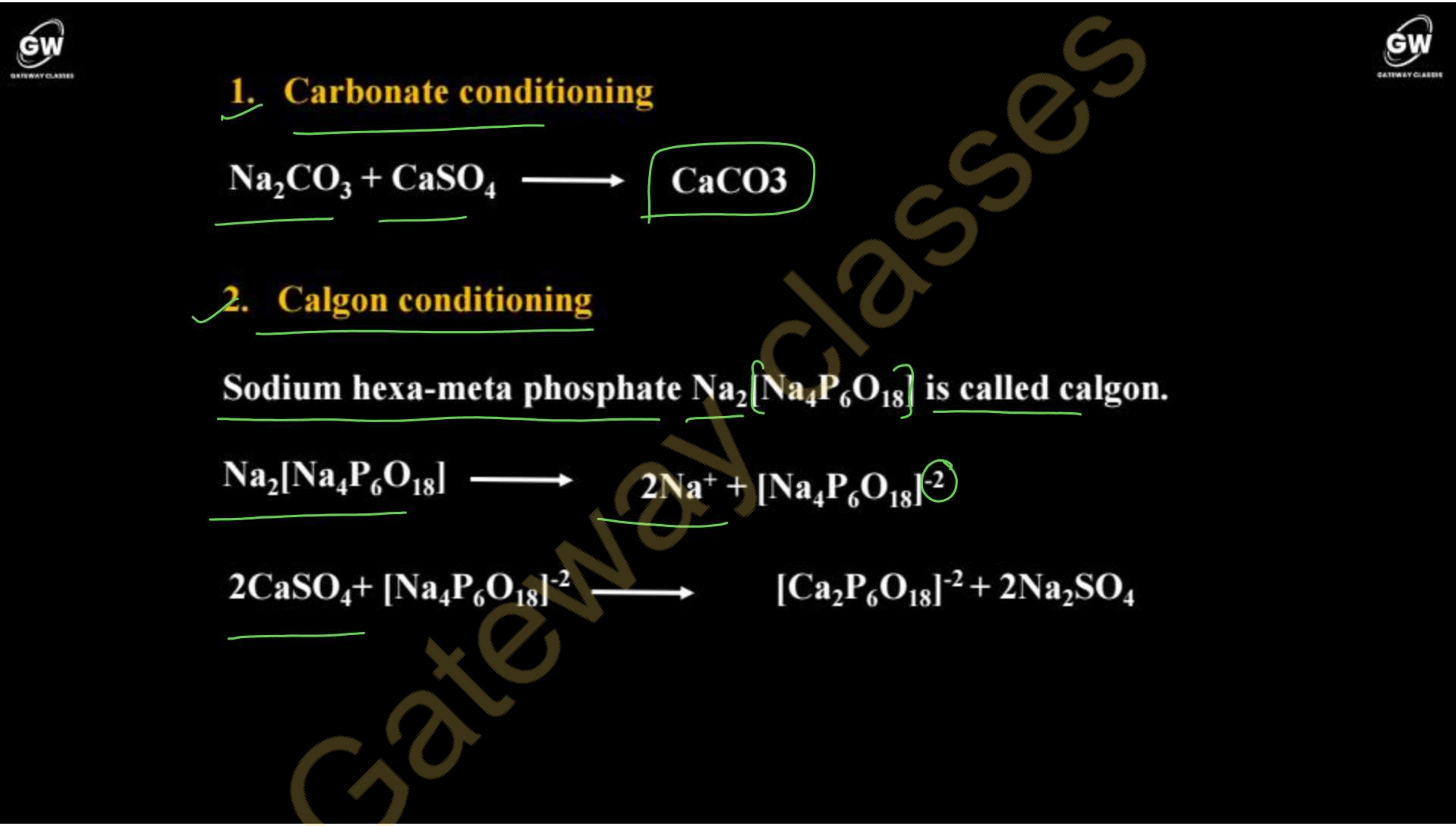


INTERNAL TREATMENT

In this method water in treated inside the boiler. This is a corrective method.

Principle: To convert the scale forming substances into sludge forming substances.

1. Carbonate conditioning
2. Calgon Conditioning
3. Phosphate conditioning



1. Carbonate conditioning

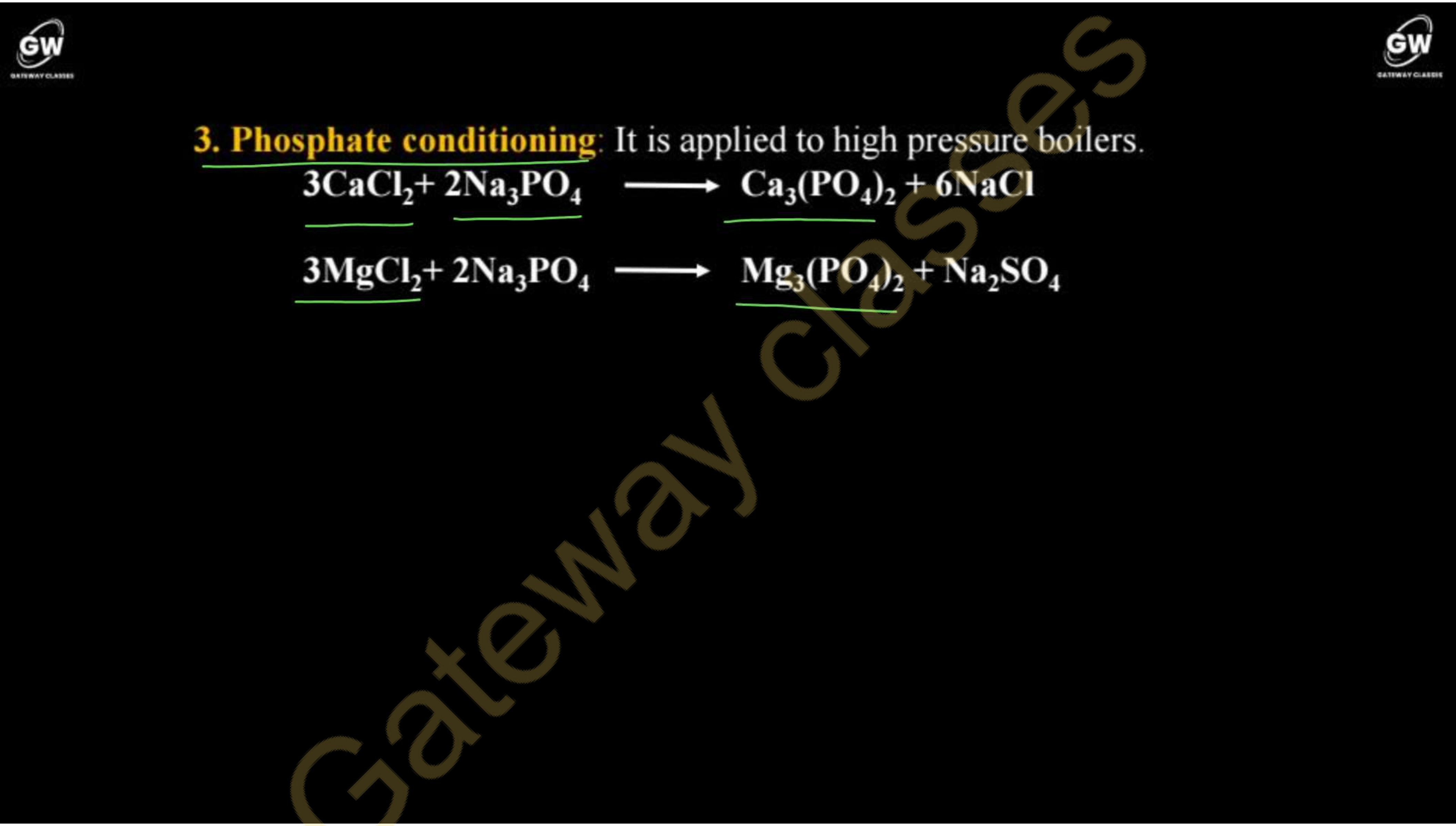
$$Na_2CO_3 + CaSO_4 \longrightarrow \boxed{\text{CaCO3}}$$

2. Calgon conditioning

Sodium hexa-meta phosphate $Na_2[Na_4P_6O_{18}]$ is called calgon.

$$Na_2[Na_4P_6O_{18}] \longrightarrow 2Na^+ + [Na_4P_6O_{18}]^{-2}$$

$$2CaSO_4 + [Na_4P_6O_{18}]^{-2} \longrightarrow [Ca_2P_6O_{18}]^{-2} + 2Na_2SO_4$$



3. Phosphate conditioning: It is applied to high pressure boilers.

$$\underline{3CaCl_2} + \underline{2Na_3PO_4} \longrightarrow \underline{Ca_3(PO_4)_2} + 6NaCl$$

$$\underline{3MgCl_2} + 2Na_3PO_4 \longrightarrow \underline{Mg_3(PO_4)_2} + Na_2SO_4$$

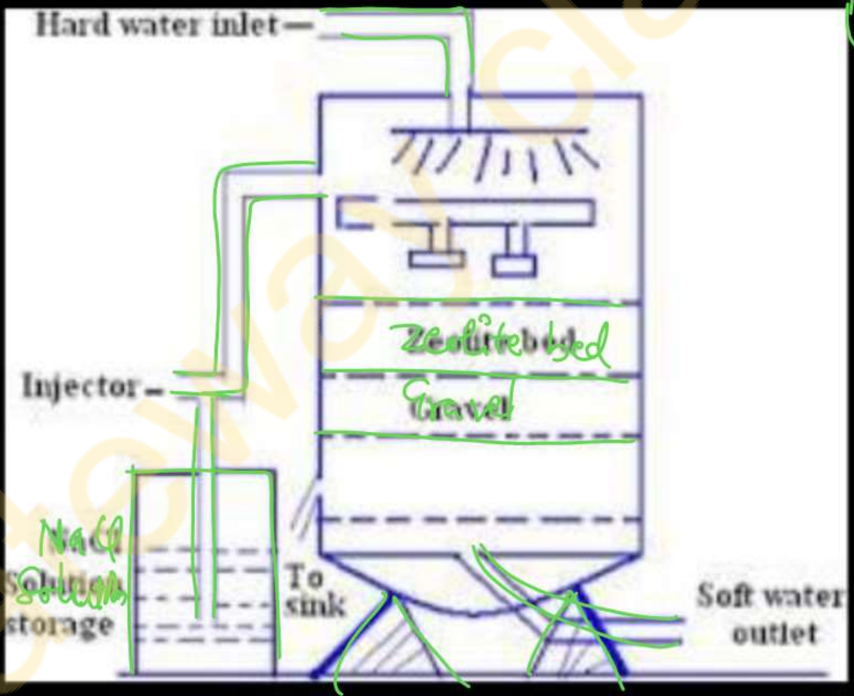
EXTERNAL TREATMENT

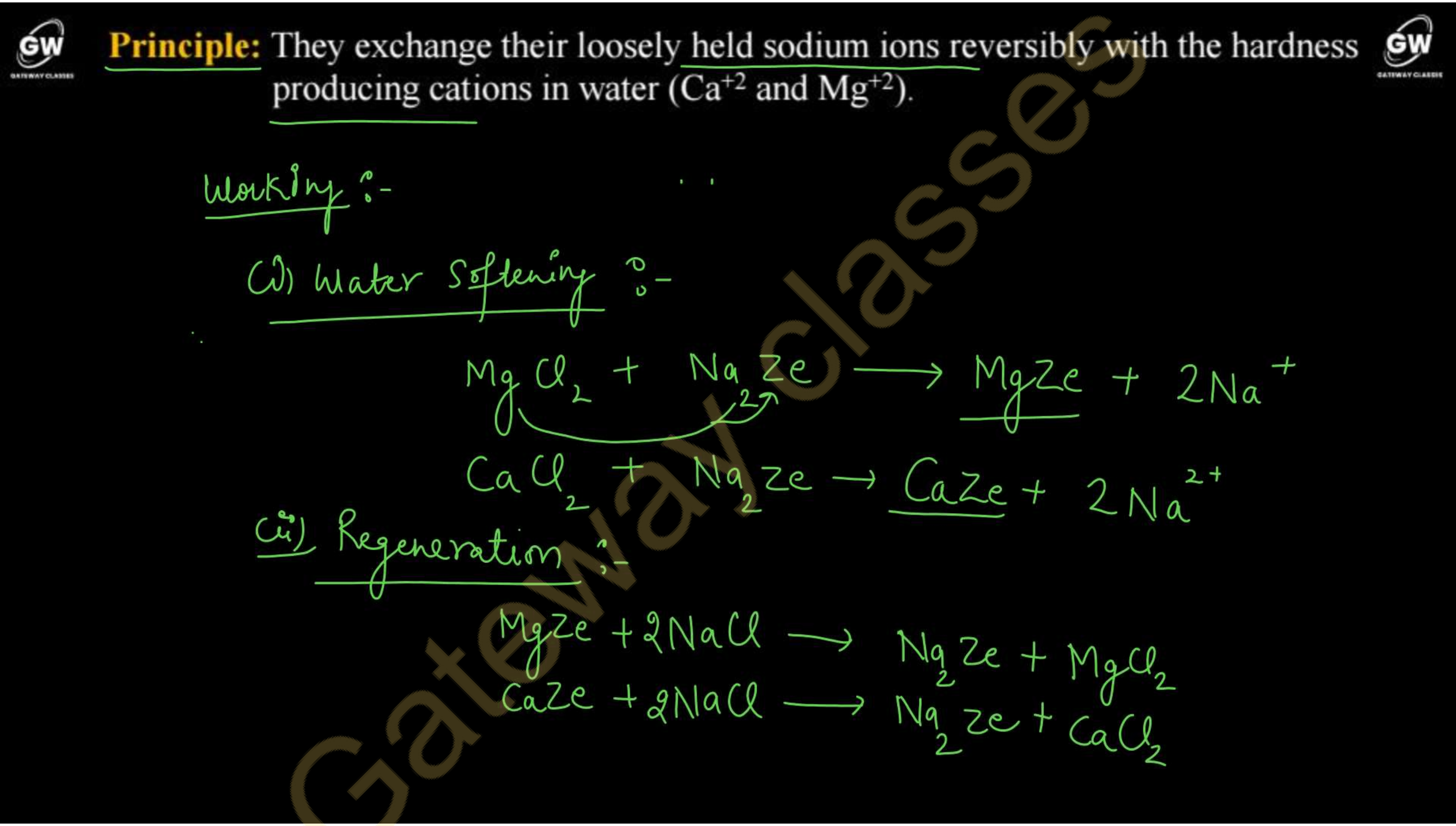
1. Zeolite method of water treatment/ Permutit process
2. Ion Exchange Process
3. Lime soda Process.

ZEOLITE METHOD OF WATER TREATMENT/ PERMUTIT PROCESS

Zeolites are **hydrated sodium alumina silicates**.
They have porous structure with molecular formula **$Na_2O.Al_2O_3.xSiO2.yH2O$** **(x=2 to 10 & y=2 to 6)**. They are **represented as Na_2Ze**

$\boxed{Na_2Ze}$





Principle: They exchange their loosely held sodium ions reversibly with the hardness producing cations in water (Ca^{+2} and Mg^{+2}).

Working :-

(i) Water Softening :-

$$MgCl_2 + Na_2Ze \longrightarrow \underline{MgZe} + 2Na^+$$

$$CaCl_2 + Na_2Ze \longrightarrow \underline{CaZe} + 2Na^{2+}$$

(ii) Regeneration :-

$$MgZe + 2NaCl \longrightarrow Na_2Ze + MgCl_2$$

$$CaZe + 2NaCl \longrightarrow Na_2Ze + CaCl_2$$

Advantages

1. Only 10 ppm hardness is left behind.
2. No sludge formation.
3. Requires less time and operation is clean.
4. Automatically adjusts itself according to the hardness of water.
5. Equipment is compact, maintenance and operation is easy.

Disadvantages

1. Removes cationic impurities; anions are left behind in water.
2. Treated water contains more sodium salts.

Limitations

1. Turbid water cannot be feeded.
2. Acidic water cannot be feeded.
3. Hot water cannot be used.
4. If used for heavy metal ions like Fe^{+3} or Al^{+3} etc., zeolites cannot be regenerated.

ION EXCHANGE RESINS FOR WATER SOFTENING

These are high molecular weight, insoluble, cross linked, organic polymers having porous structure. There are two types of ion exchangers.

$MgSO_4$, $MgCl_2$ Mg^{2+}, SO_4^- Cl_2^-

a) Cation Exchange resins:

Have loosely held H^+ ions which are reversibly exchanged by hardness producing cations (Ca^{2+} and Mg^{+2}) in water.

b) Anion Exchange resins:

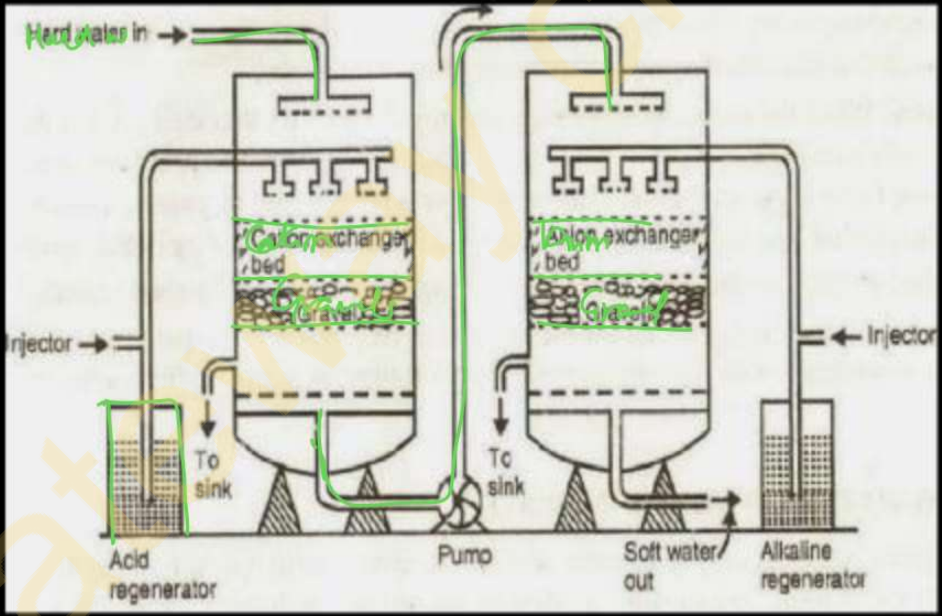
Have loosely held OH^- ions which are reversibly exchanged by hardness producing anions (Cl^- and $SO4^{-2}$) in water.

Principle:

These are capable of exchanging hardness producing ions (cations as well as anions) in water with their H^+ and OH^- ions.

Working:

Ion exchange process consists of two columns- Cation exchanger column and anion exchanger column.



Working :-

(i) Water softening

Cation exchanger resin :-

$$2R-H + Ca^{2+} \longrightarrow R_2Ca + \boxed{2H^+}$$

$$2R-H + Mg^{2+} \longrightarrow R_2Mg + \boxed{2H^+}$$

Anion exchanger resins

$$R-OH + Cl^- \longrightarrow RCl + \boxed{OH^-}$$

$$2R-OH + SO_4^{2-} \longrightarrow R_2SO_4 + \boxed{2OH^-}$$

Regeneration

Cation Regeneration

$$R_2Mg + 2H^+ \longrightarrow 2R-H + Mg^{2+}$$

Anion Regeneration

$$R-Cl + OH^- \longrightarrow R-OH + Cl^-$$

Advantages:

1. Gives water of zero hardness and no ionic impurities.
2. Occupies less space.
3. Easy to operate.
4. Negligible running cost.

Limitations:

1. Initial cost is high.
2. Used for small scale treatment of water.

LIME SODA PROCESS FOR WATER SOFTENING

Principle: By adding calculated amounts of lime $Ca(OH)_2$ and soda Na_2CO_3.

- All the calcium salts are precipitated out as calcium carbonate $CaCO_3$.
- All the magnesium salts are precipitated as magnesium hydroxide Mg(OH)2 Which can be easily filtered off .

1. Lime removes all the temporary hardness.

$$Ca(HCO_3)_2 + Ca(OH)_2 \longrightarrow \underline{2CaCO_3} + 2H_2O$$

$$Mg(HCO_3)_2 + Ca(OH)_2 \longrightarrow \underline{MgCO_3} + CaCO_3 + 2H_2O$$

$$MgCO_3 + Ca(OH)_2 \longrightarrow Mg(OH)_2 + CaCO_3$$

2. Lime removes all the permanent hardness of magnesium salts.

$$MgSO_4 + Ca(OH)_2 \longrightarrow Mg(OH)_2 + CaSO_4$$

$$MgCl_2 + Ca(OH)_2 \longrightarrow Mg(OH)_2 + CaCl_2$$

3. Lime removes the dissolved gases.

$$CO_2 + Ca(OH)_2 \longrightarrow CaCO_3 + H_2O$$

$$H_2S + Ca(OH)_2 \longrightarrow CaS + 2H_2O$$

4. Lime removes free mineral acids.

$$\underline{Ca}(OH)_2 + 2H\underline{Cl} \longrightarrow CaCl_2 + 2H_2O$$

$$\underline{Ca}(OH)_2 + \underline{H_2SO_4} \longrightarrow CaSO_4 + 2H_2O$$

5. Lime removes dissolved iron and aluminum salts.

$$FeSO_4 + Ca(OH)_2 \longrightarrow \underline{Fe(OH)_2} + CaSO_4$$

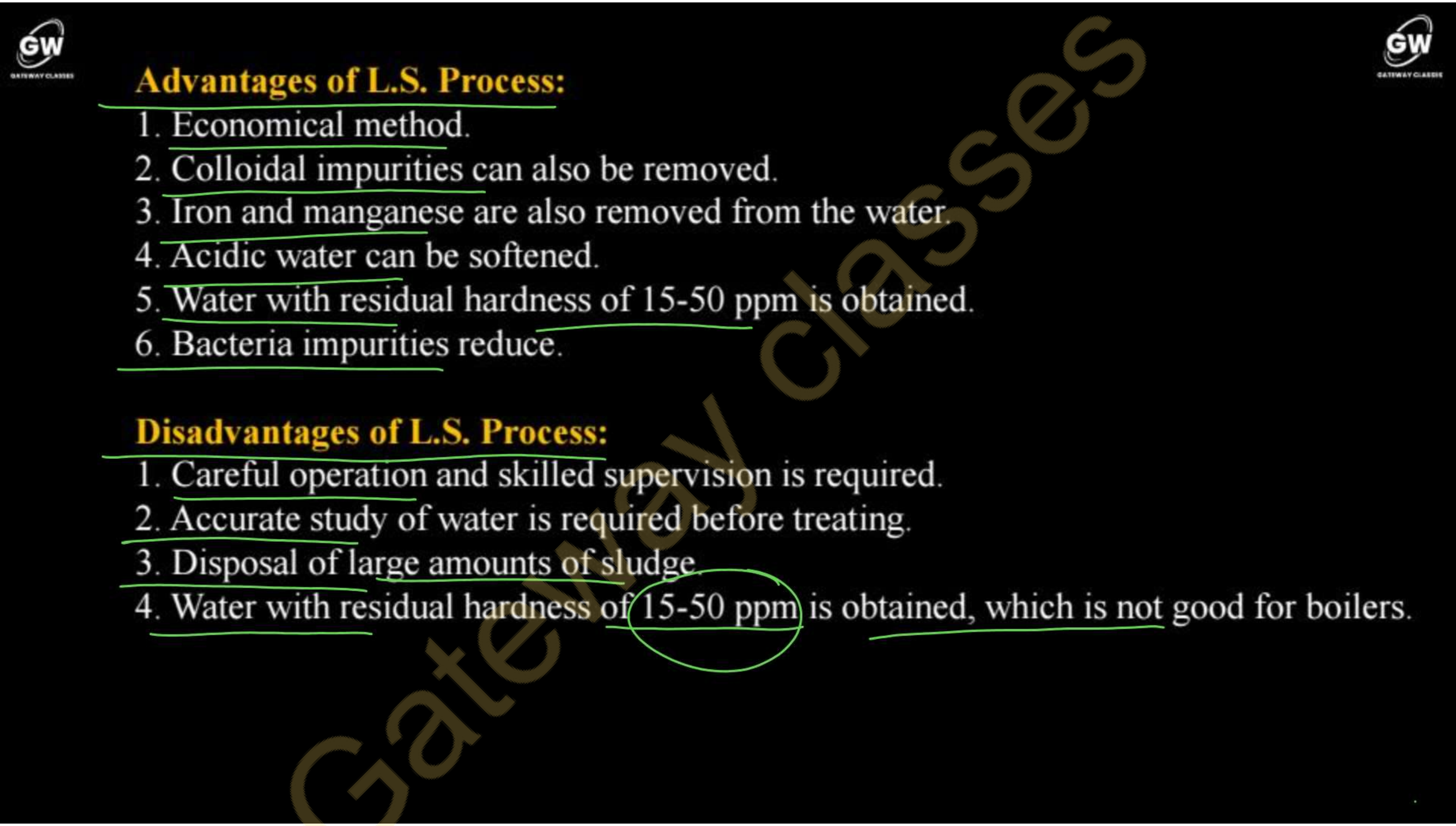
$$2Fe(OH)_2 + H_2O + \frac{1}{2}O_2 \longrightarrow 2Fe(OH)_3$$

$$Al_2(SO_4)_3 + 3Ca(OH)_2 \longrightarrow 2\underline{Al}(OH)_3 + 3Ca(SO_4)$$

6. Soda removes all soluble calcium permanent hardness.

$$CaSO_4 + Na_2CO_3 \longrightarrow CaCO_3 + Na_2SO_4$$

$$CaCl_2 + Na_2CO_3 \longrightarrow CaCO_3 + 2NaCl$$

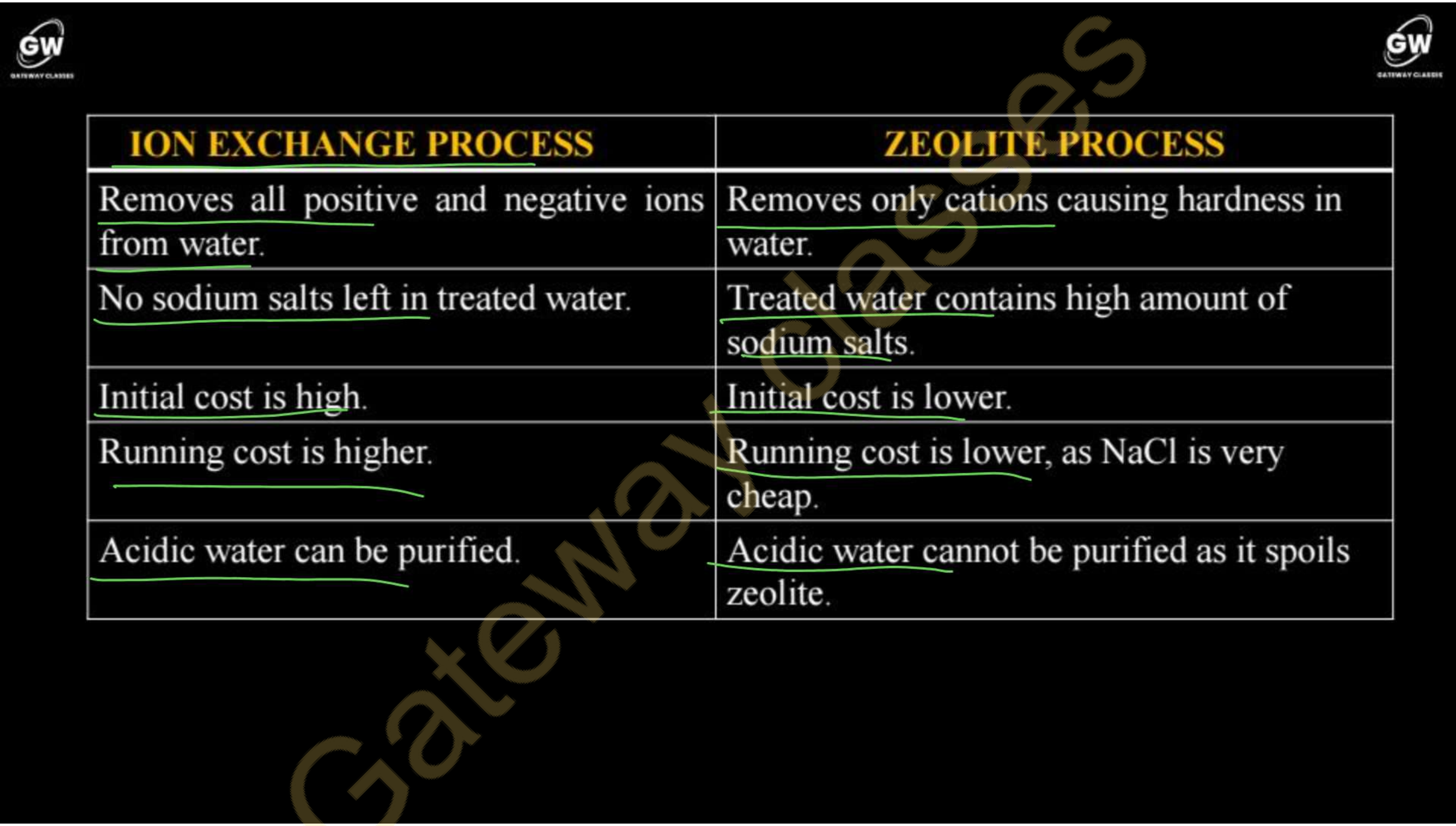


Advantages of L.S. Process:

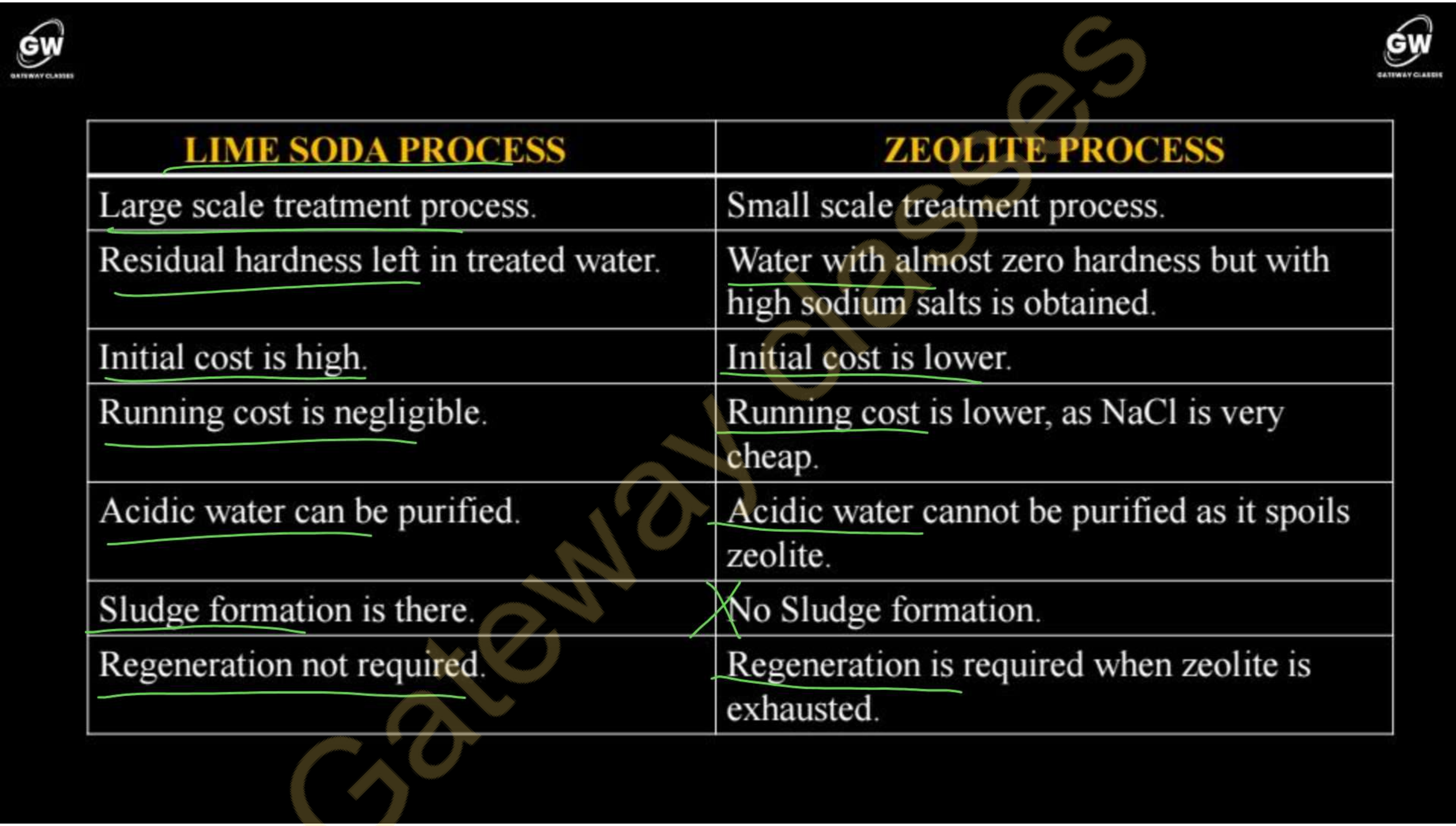
1. Economical method.
2. Colloidal impurities can also be removed.
3. Iron and manganese are also removed from the water.
4. Acidic water can be softened.
5. Water with residual hardness of 15-50 ppm is obtained.
6. Bacteria impurities reduce.

Disadvantages of L.S. Process:

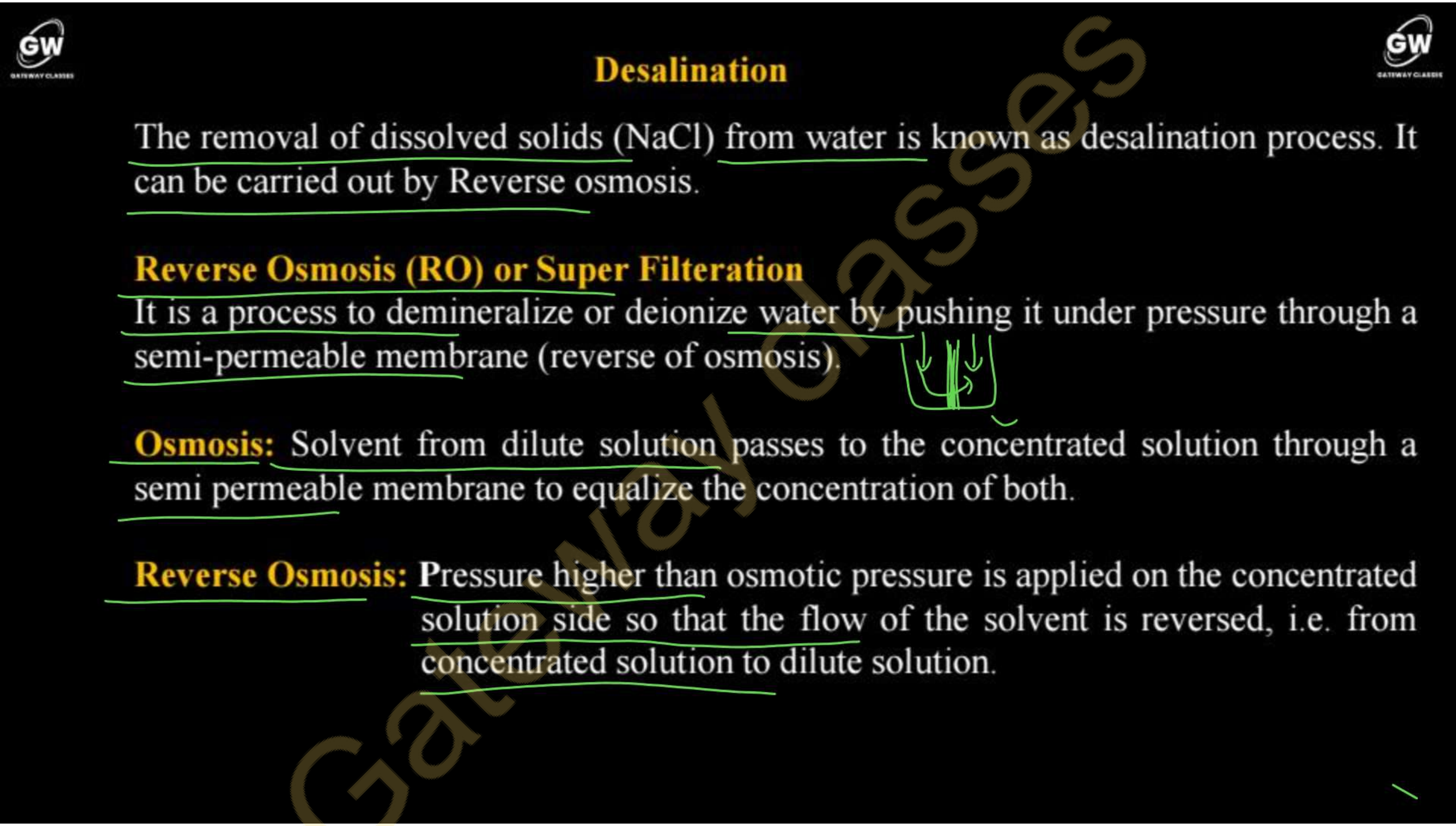
1. Careful operation and skilled supervision is required.
2. Accurate study of water is required before treating.
3. Disposal of large amounts of sludge.
4. Water with residual hardness of 15-50 ppm is obtained, which is not good for boilers.



ION EXCHANGE PROCESS	ZEOLITE PROCESS
Removes all positive and negative ions from water.	Removes only cations causing hardness in water.
No sodium salts left in treated water.	Treated water contains high amount of sodium salts.
Initial cost is high.	Initial cost is lower.
Running cost is higher.	Running cost is lower, as NaCl is very cheap.
Acidic water can be purified.	Acidic water cannot be purified as it spoils zeolite.



LIME SODA PROCESS	ZEOLITE PROCESS
Large scale treatment process.	Small scale treatment process.
Residual hardness left in treated water.	Water with almost zero hardness but with high sodium salts is obtained.
Initial cost is high.	Initial cost is lower.
Running cost is negligible.	Running cost is lower, as NaCl is very cheap.
Acidic water can be purified.	Acidic water cannot be purified as it spoils zeolite.
Sludge formation is there.	No Sludge formation.
Regeneration not required.	Regeneration is required when zeolite is exhausted.



Desalination

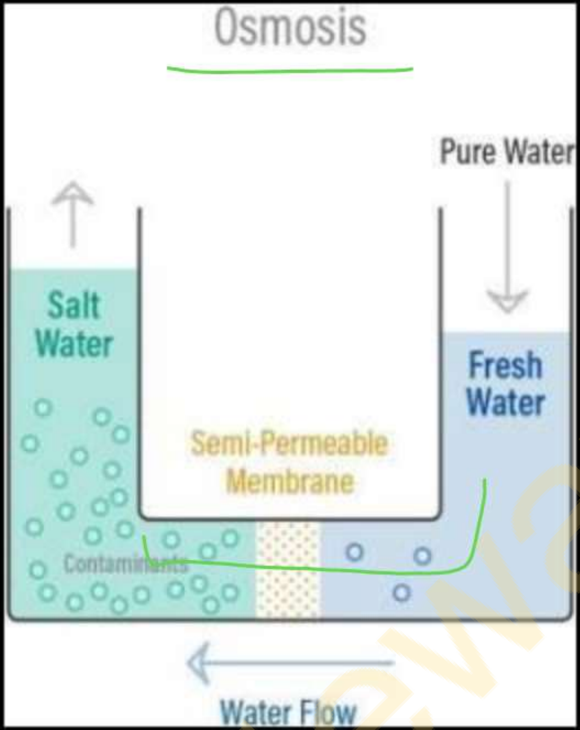
The removal of dissolved solids (NaCl) from water is known as desalination process. It can be carried out by Reverse osmosis.

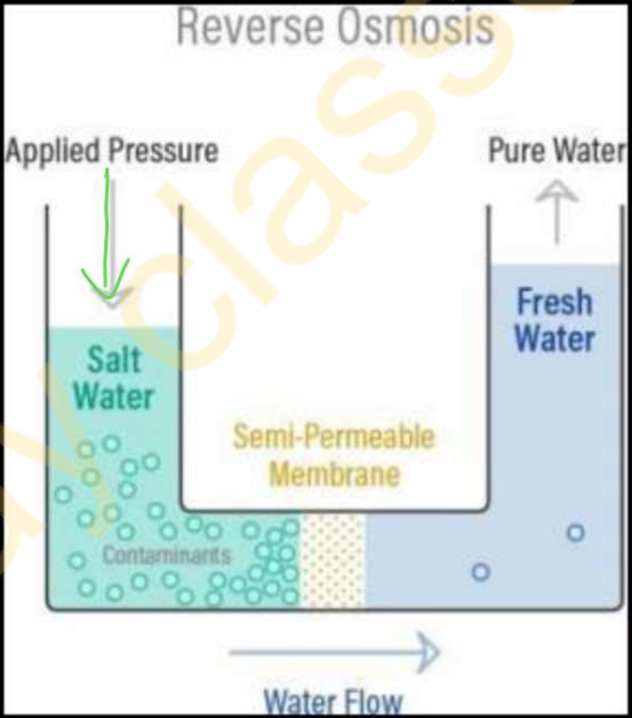
Reverse Osmosis (RO) or Super Filteration

It is a process to demineralize or deionize water by pushing it under pressure through a semi-permeable membrane (reverse of osmosis).

Osmosis: Solvent from dilute solution passes to the concentrated solution through a semi permeable membrane to equalize the concentration of both.

Reverse Osmosis: Pressure higher than osmotic pressure is applied on the concentrated solution side so that the flow of the solvent is reversed, i.e. from concentrated solution to dilute solution.


Osmosis


Reverse Osmosis

Advantages:

1. Removes up to 99% of the dissolved salts (ions), particles, colloids, organics, bacteria and pathogens from water.
2. Removes both ionic and non-ionic impurities.
3. Requires extremely low energy.
4. Low cost process.
5. Simple to operate.
6. Pure water for high pressure boilers can be obtained.

Applications or Uses for Demineralized Water:

1. Industrial uses.
2. Lab application.
3. In lead acid batteries and cooling systems.
4. Cosmetics.
5. Aquariums.
6. Fire extinguishers.

AKTU B.Tech First Year

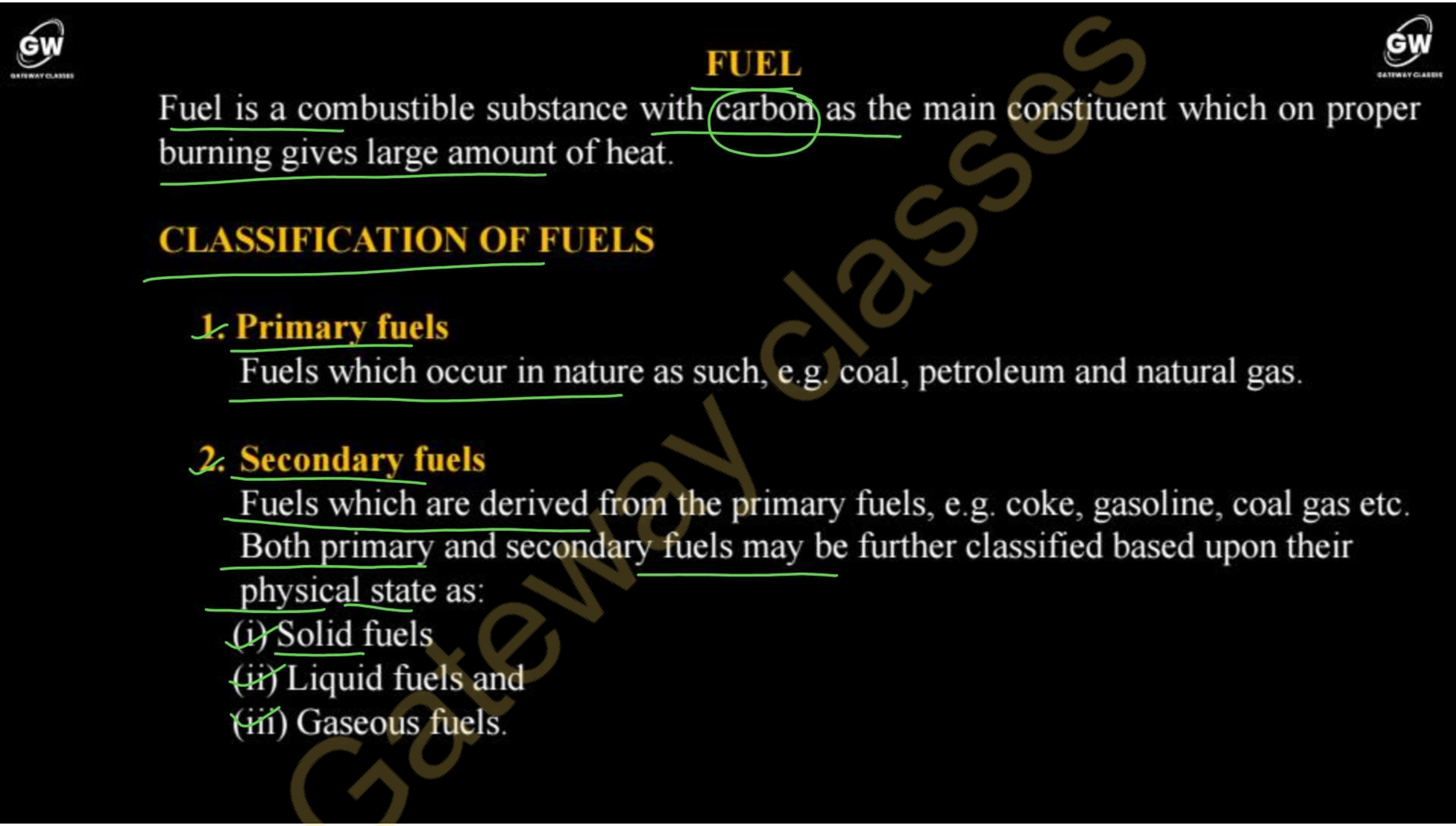
ENGINEERING CHEMISTRY (BAS102 / BAS202)

ONE SHOT REVISION
Unit-4

As per New Syllabus
2022-2023

Today's Target

- ✓ All topics of Unit-4 Part-II
- ✓ Numericals



FUEL

Fuel is a combustible substance with carbon as the main constituent which on proper burning gives large amount of heat.

CLASSIFICATION OF FUELS

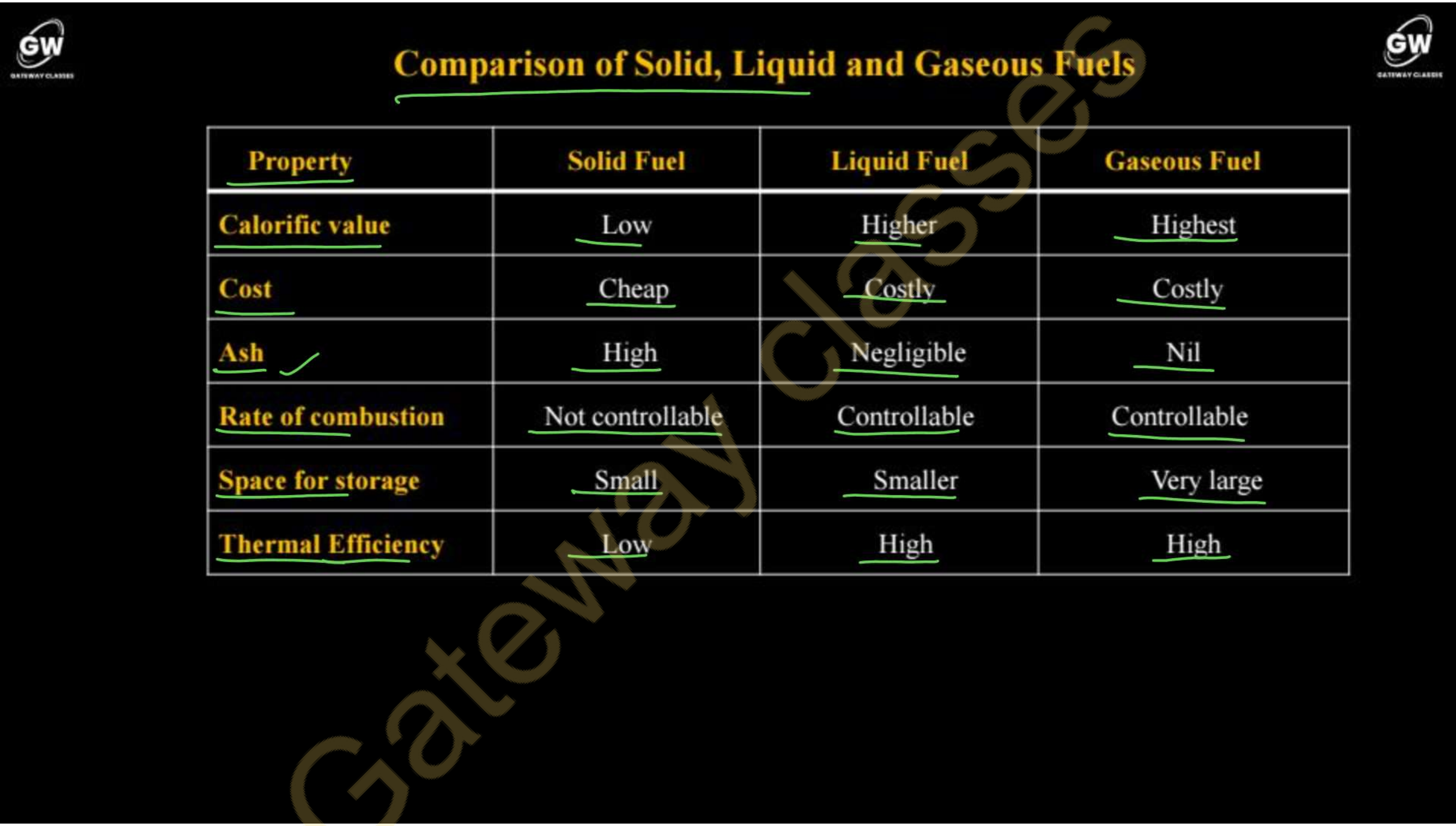
1. **Primary fuels**

   Fuels which occur in nature as such, e.g. coal, petroleum and natural gas.

2. **Secondary fuels**

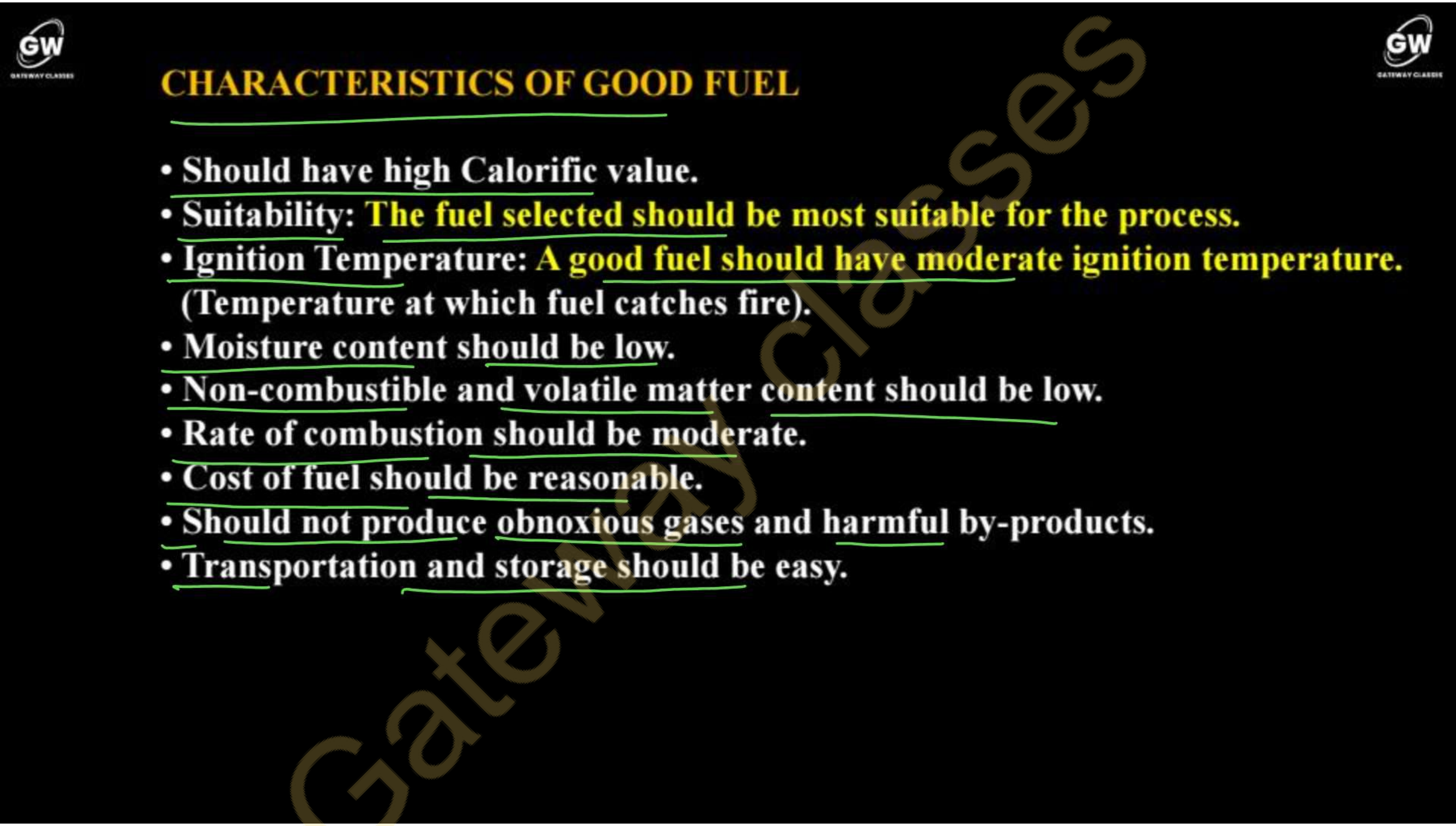
   Fuels which are derived from the primary fuels, e.g. coke, gasoline, coal gas etc. Both primary and secondary fuels may be further classified based upon their physical state as:

   (i) Solid fuels
   (ii) Liquid fuels and
   (iii) Gaseous fuels.



Comparison of Solid, Liquid and Gaseous Fuels

Property	Solid Fuel	Liquid Fuel	Gaseous Fuel
Calorific value	Low	Higher	Highest
Cost	Cheap	Costly	Costly
Ash ✓	High	Negligible	Nil
Rate of combustion	Not controllable	Controllable	Controllable
Space for storage	Small	Smaller	Very large
Thermal Efficiency	Low	High	High



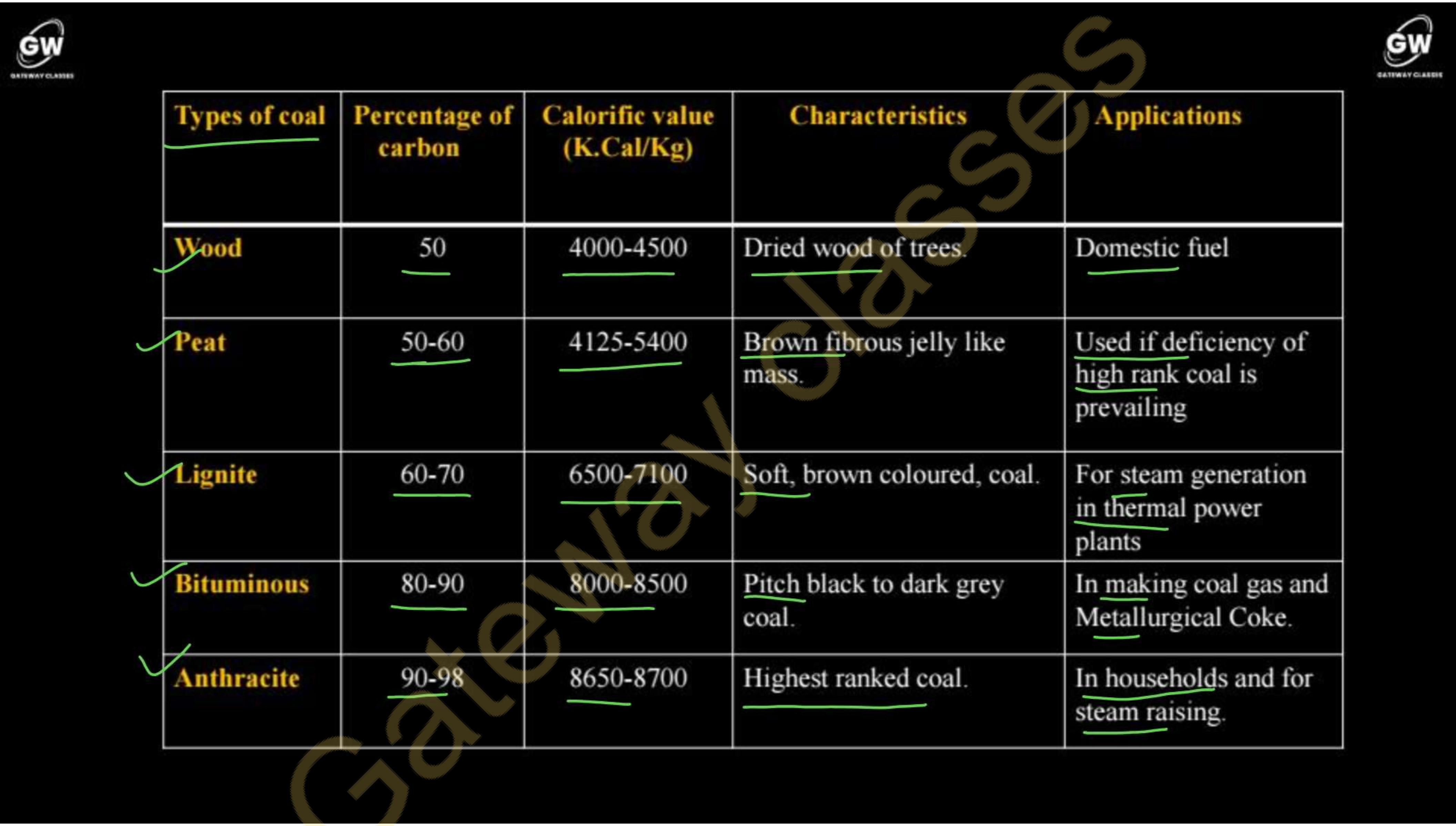
CHARACTERISTICS OF GOOD FUEL

- Should have high Calorific value.
- Suitability: The fuel selected should be most suitable for the process.
- Ignition Temperature: A good fuel should have moderate ignition temperature. (Temperature at which fuel catches fire).
- Moisture content should be low.
- Non-combustible and volatile matter content should be low.
- Rate of combustion should be moderate.
- Cost of fuel should be reasonable.
- Should not produce obnoxious gases and harmful by-products.
- Transportation and storage should be easy.

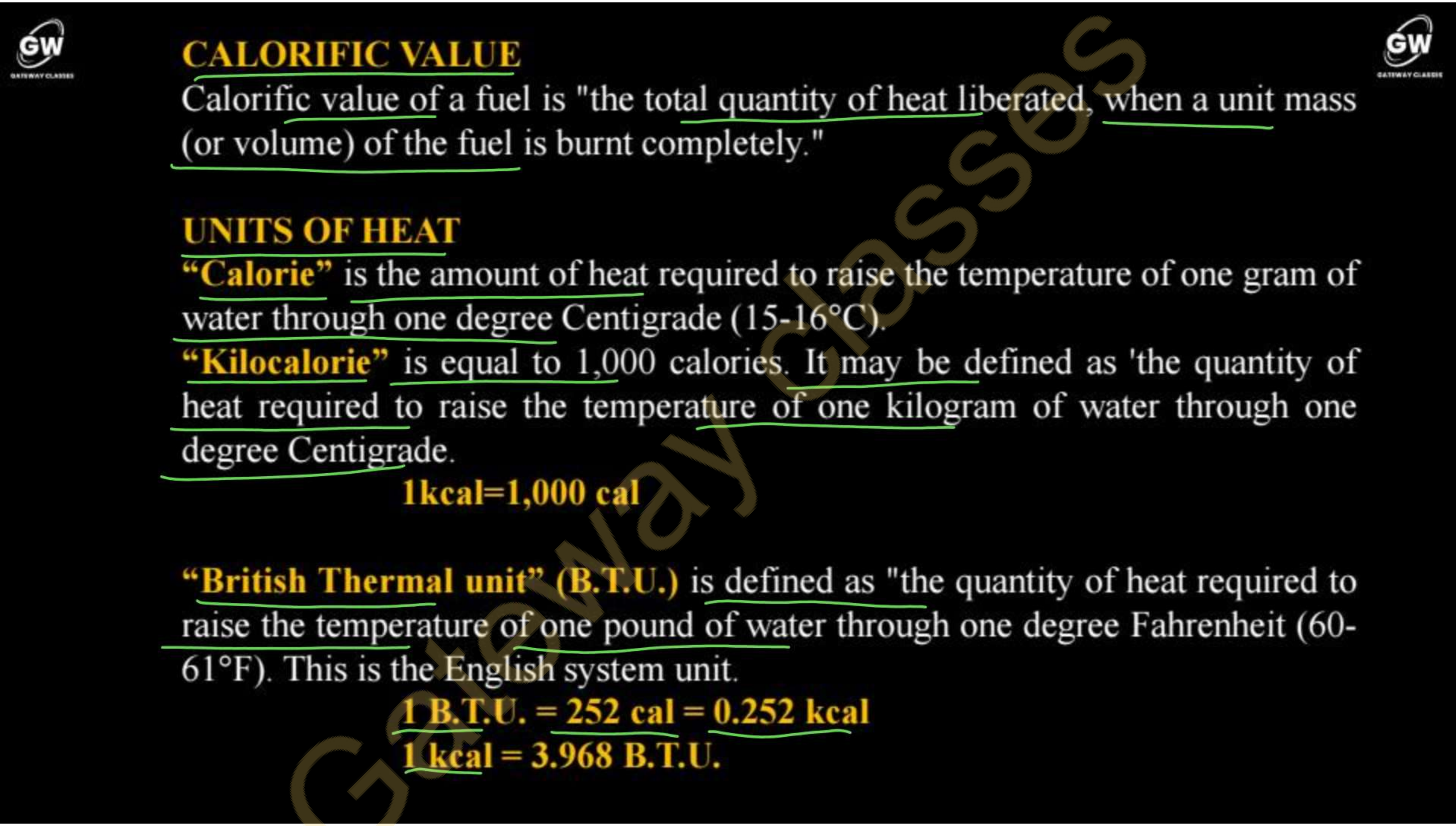
COAL

Coal is regarded as a fossil fuel produced from the vegetable buried under conditions of high temperature and pressure over millions of years.

Classification of Coal: Coal is given a ranking depending upon the carbon content of the coal from wood to anthracite.



Types of coal	Percentage of carbon	Calorific value (K.Cal/Kg)	Characteristics	Applications
Wood	50	4000-4500	Dried wood of trees.	Domestic fuel
Peat	50-60	4125-5400	Brown fibrous jelly like mass.	Used if deficiency of high rank coal is prevailing
Lignite	60-70	6500-7100	Soft, brown coloured, coal.	For steam generation in thermal power plants
Bituminous	80-90	8000-8500	Pitch black to dark grey coal.	In making coal gas and Metallurgical Coke.
Anthracite	90-98	8650-8700	Highest ranked coal.	In households and for steam raising.



CALORIFIC VALUE

Calorific value of a fuel is "the total quantity of heat liberated, when a unit mass (or volume) of the fuel is burnt completely."

UNITS OF HEAT

"Calorie" is the amount of heat required to raise the temperature of one gram of water through one degree Centigrade (15-16°C).

"Kilocalorie" is equal to 1,000 calories. It may be defined as 'the quantity of heat required to raise the temperature of one kilogram of water through one degree Centigrade.

1kcal=1,000 cal

"British Thermal unit" (B.T.U.) is defined as "the quantity of heat required to raise the temperature of one pound of water through one degree Fahrenheit (60-61°F). This is the English system unit.

1 B.T.U. = 252 cal = 0.252 kcal

1 kcal = 3.968 B.T.U.

Higher or gross calorific value

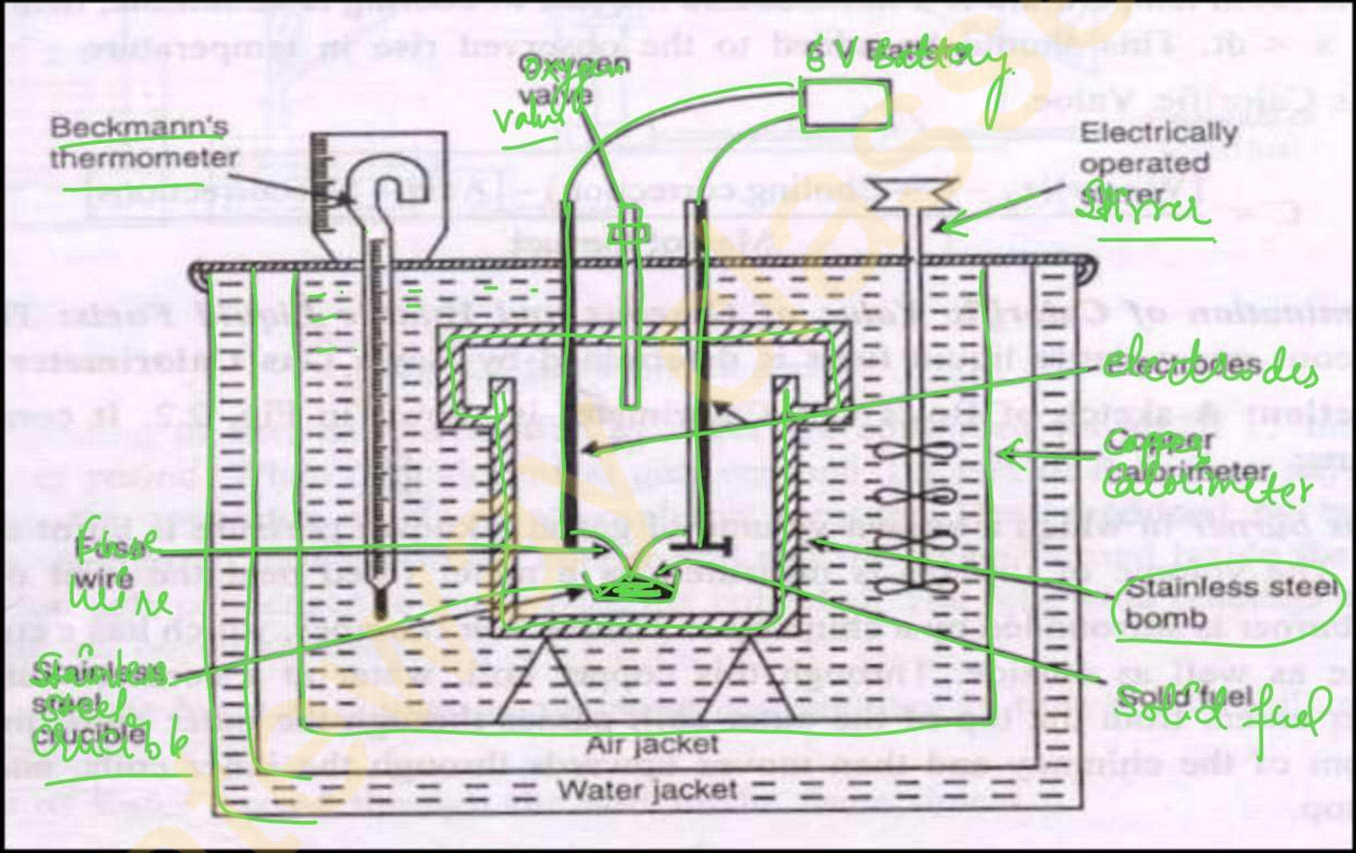
HCV is "the total amount of heat produced, when unit mass/volume of the fuel has been burnt completely and the products of combustion have been cooled to room temperature"(i.e., 15°C or 60°F). GCV

Lower or net calorific Value (NCV)

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

✓ NCV = GCV - % H x 0.09 x Latent heat of steam

BOMB CALORIMETER



Construction:

1. A strong stainless steel pot fitted with a lid.
2. Two electrodes.
3. One oxygen inlet.
4. One of the electrodes is attached to the crucible having fuel.
5. Fuel sample is weighed and burnt in high pressure oxygen (25-30 atm).
6. Stainless steel or copper calorimeter.
7. Stirrer for uniform circulation of water.
8. Beckmann thermometer (0.01°C changes in temperature can be easily noted)
9. Water and air jackets to avoid heat losses.
10. 6 V battery to start combustion of fuel.

PRINCIPLE

A known amount of the fuel is burnt in excess of oxygen and heat liberated is transferred to a known amount of water. The calorific value of the fuel is then determined by applying the principle of calorimeter **i.e. Heat gained = Heat lost**

WORKING OF BOMB CALORIMETER

1. Weigh fuel sample and keep it in crucible.
2. Fix the lid tightly of bomb pot.
3. Fill the bomb with oxygen (25-30 atm pressure).
4. Place the bomb in calorimeter.
5. Add known volume of water in the calorimeter.
6. Keep the thermometer and stirrer in the water.
7. Place the calorimeter in the water jacket.
8. Put the plastic cover on top and make electrical connections.
9. Stir for 5 minutes and note the initial temperature of water.
10. Pass the current to heat the wire so that the fuel catches fire.
11. Note the maximum temperature reached.

Calculations

Let weight of the fuel sample taken = x g

Weight of water in the Calorimeter = W g

Water equivalent of the Calorimeter, stirrer, bomb, thermometer = w g

Initial temperature of water = t_1 °C

Final temperature of water = t_2 °C

✓ GCV = $(\underset{x}{W}+w)(t_2-t_1)/x$

Net Calorific value or Lower calorific value = GCV- 0.09%H×587 cal/gm

Corrections: For accurate results the following corrections are also incorporated

- Acid corrections (C_A)
- Cooling correction (C_c) ✓
- Fuse wire (C_f)
- Cotton thread correction (C_{CT})

Therefore, Gross calorific value

GCV=(W+w)(t_2-t_1+ Cooling correction)-(Acid+ fuse+ Cotton thread)/Mass of the fuel.

OR

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

$$GCV = \frac{[(W+w)(t_2-t_1+C_C)] - (C_A+C_F+C_{CT})}{x}$$

Theoretical calculation of Calorific Value

The calorific value of a fuel can be calculated by Dulong's Formula if the percentages of the constituent elements are known.

Substrate	Calorific value
Carbon	8080
Hydrogen	34500
Sulphur	2240

Dulong's formula

GCV or HCV = 1/100 [8080 x %C + 34500 (%H – % O/8)+ 2240 %S]

NCV = GCV − 0.09 × %H × 587 cal/gm

ANALYSIS OF COAL

In order to assess the quality of coal the following two types of analysis are made: Proximate analysis and Ultimate analysis.

(1) Proximate Analysis

It includes the determination of moisture, volatile matter, ash and fixed carbon.

$$\overset{\text{known}}{\text{Coal amount}} \xrightarrow[\text{1 hour}]{110^\circ C} \underset{\text{(cool down)}}{\text{fuel}} \longrightarrow \text{weigh}$$

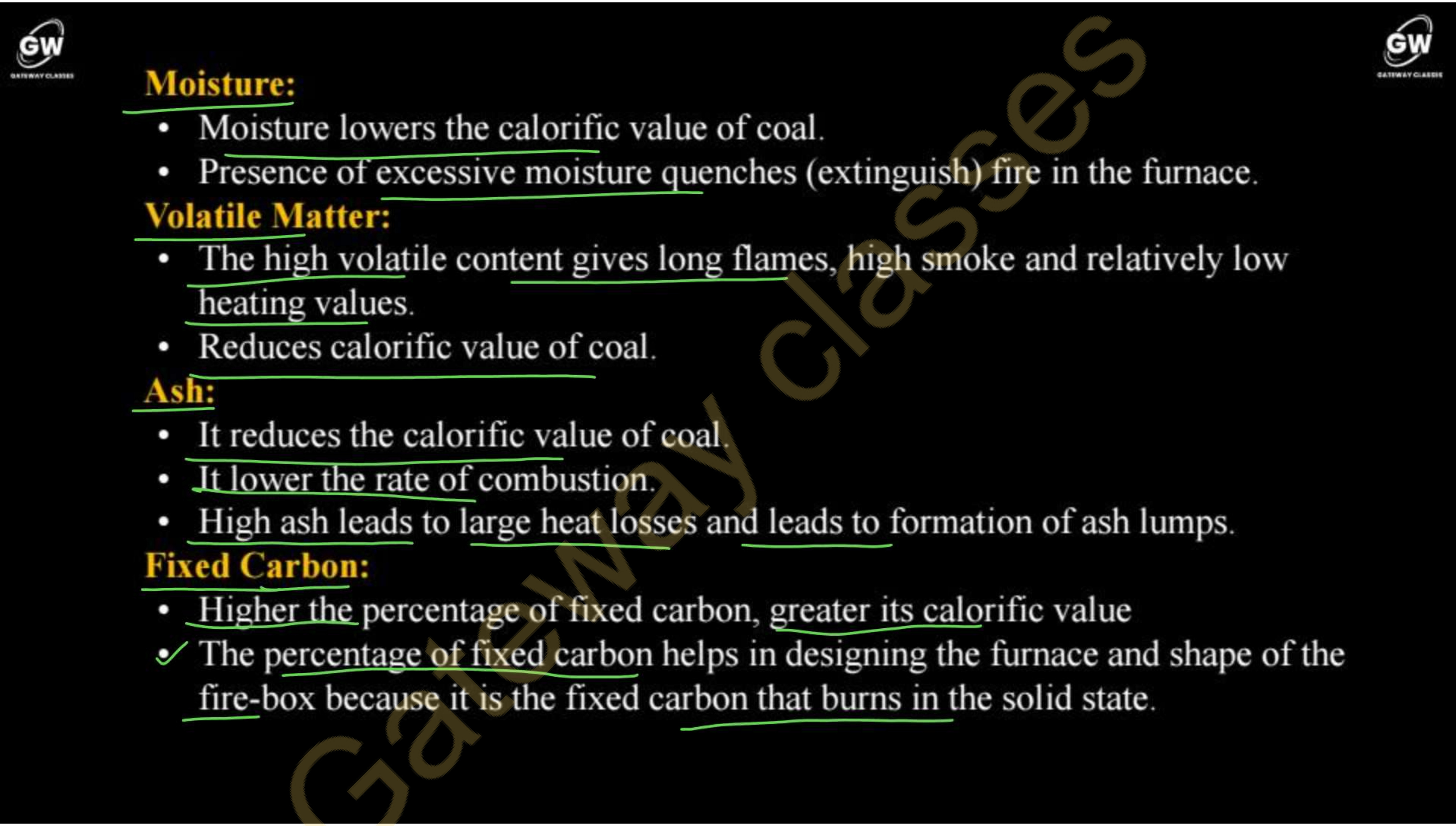
$$\%\ \text{Moisture} = \frac{\text{wt. of moisture}}{\text{wt. of coal sample}} \times 100$$

$$\underset{\text{(Coal without moisture)}}{\text{Remaining coal}} \xrightarrow[\text{7 min}]{925^\circ c} \underset{\text{(cool down)}}{\text{fuel amount}} \longrightarrow \text{weigh}$$

$$\% \text{ V.M} = \frac{\text{wt. of V.M}}{\text{wt of coal sample}} \times 100$$

$$\% \text{ Ash (Residue)} = \frac{\text{wt. of ash}}{\text{wt. of coal sample}} \times 100$$

$$\% \text{ of } \underline{\text{fixed Carbon}} :- 100 - (\% \text{ of Moisture} + \% \text{ of V.M} + \% \text{ of Ash})$$



Moisture:

- Moisture lowers the calorific value of coal.
- Presence of excessive moisture quenches (extinguish) fire in the furnace.

Volatile Matter:

- The high volatile content gives long flames, high smoke and relatively low heating values.
- Reduces calorific value of coal.

Ash:

- It reduces the calorific value of coal.
- It lower the rate of combustion.
- High ash leads to large heat losses and leads to formation of ash lumps.

Fixed Carbon:

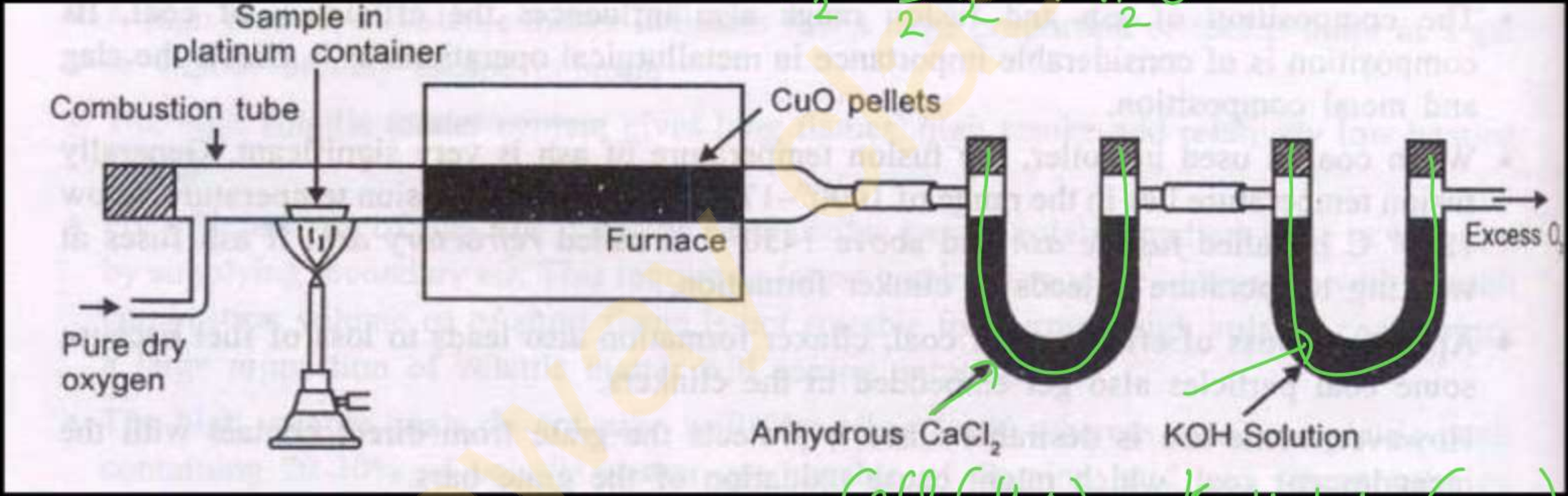
- Higher the percentage of fixed carbon, greater its calorific value
- ✓ The percentage of fixed carbon helps in designing the furnace and shape of the fire-box because it is the fixed carbon that burns in the solid state.

(2) Ultimate analysis of coal:

Analysis of coal in which % of C, H, O, N, S and % ash are found out is known as ultimate analysis.

$C + O_2 \rightarrow CO_2$

$H_2 + \frac{1}{2}O_2 \rightarrow H_2O$



$CaCl_2$ (H_2O)   KOH tube (CO_2)

$$\underset{12}{C} + \underset{32}{O_2} \longrightarrow \underset{44}{CO_2}$$

$$\% C = \frac{\text{increase in wt. of KOH tube} \times 12}{\text{wt. of coal sample} \times 44} \times 100$$

$$\underset{2}{H_2} + \underset{\frac{16}{2}}{\frac{1}{2}O_2} \rightarrow \underset{18}{\boxed{H_2O}}$$

$$\% H = \frac{\text{increase in } CaCl_2 \text{ tube}}{\text{wt. of coal sample}} \times \frac{2}{18} \times 100$$

$$\% N = \frac{\text{Volume of acid}}{\text{wt. of coal sample}} \times \text{Normality} \times 1.4$$

$$\% S = \frac{\text{wt. of } \boxed{BaSO_4} \text{ ppt.} \times 32}{\text{wt of coal sample} \times 233} \times 100$$

$$\% \text{Ash} = \frac{\text{wt of ash}}{\text{wt of coal sample}} \times 100$$

$$\% O = 100-(C\% + H\% + N\% + ash\% + S\%)$$

Importance of Ultimate Analysis

- Carbon: Greater the % of carbon in coal, better is the coal quality and calorific value.
- Hydrogen: Hydrogen is in the form of moisture and volatile matter. It decreases the calorific value and quality of coal.
- Nitrogen: Nitrogen has no calorific value. A good quality coal should have negligible N%.
- Sulphur: A good quality coal should have low S%.
- Oxygen: Decreases the calorific value of coal, decreases the coal quality.

BIOGAS

Biogas is an environmentally-friendly, renewable energy source. It's produced when organic matter, such as food or animal waste, is broken down by microorganisms in the absence of oxygen, in a process called anaerobic digestion.

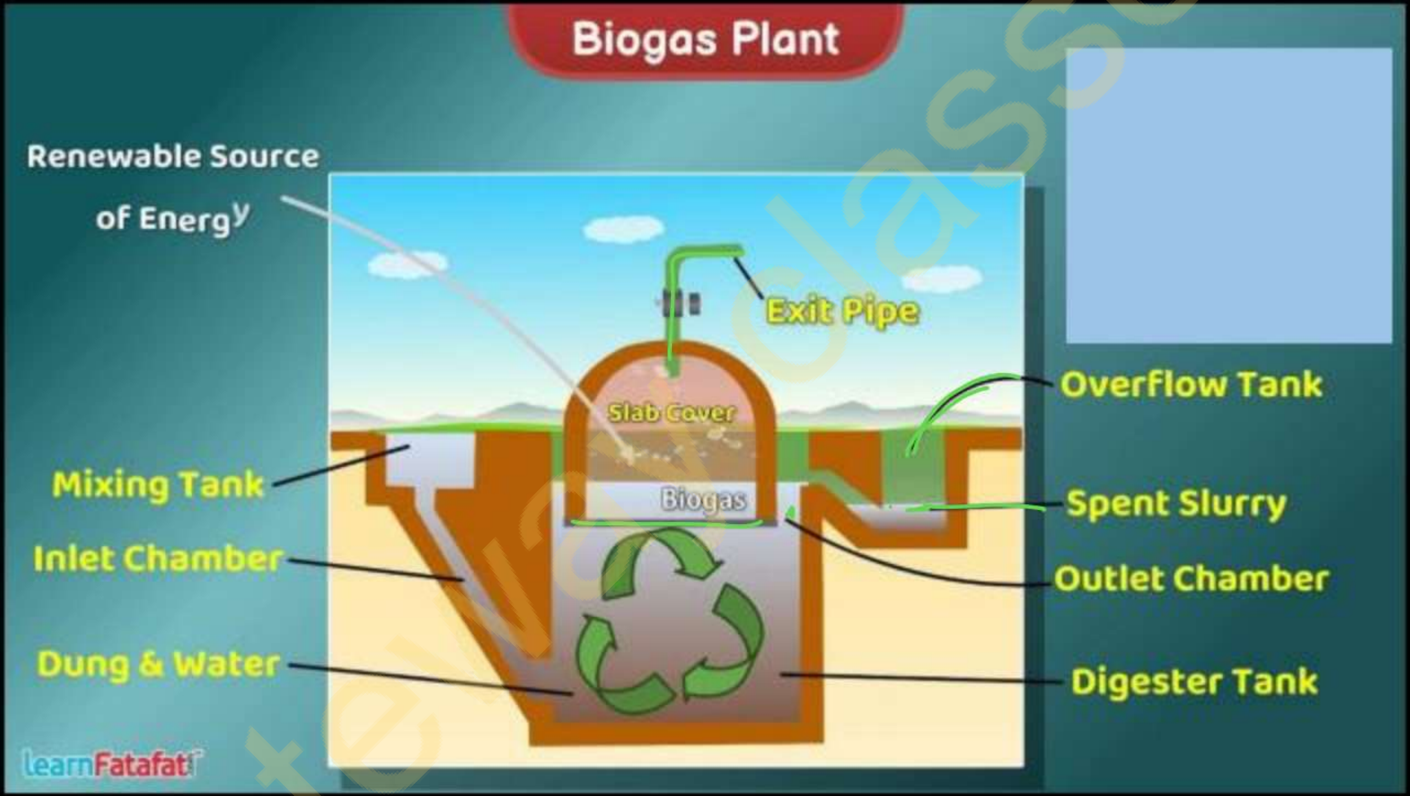
COMPOSITION OF BIOGAS

Constituents	%composition
Methane, CH_4	55 – 65
Carbon dioxide, CO_2	35-45
Hydrogen sulphide H_2S	0-1
Nitrogen, N_2	0-1
Hydrogen, H_2	0-1
Carbon monoxide (CO)	0-3
Oxygen, O_2	0-2

RAW MATERIAL FOR BIOGAS

- Animal dung
- Vegetable waste
- Waste paper and cotton cloths
- Plants waste (grass, husk, leaves, skins, weeds)
- Human excreta
- Birds excreta etc.

Biogas Plant



Mixing tank – It is a medium size tank made up of brick and cement at a height. In this tank cow dung, agricultural waste and other biomass is collected and mixed with water.

Inlet chamber – It is a larger size tank than mixing tank. It is also made up of brick and cement. It connects the mixing tank to the digester.

Digester – It is the largest chamber of biogas plants where the process of anaerobic fermentation takes place. It has a valve on the top from where the produced biogas is released according to the requirement.

Outlet Chamber – It is linked to the digester. It collects slurry and manure after fermentation.

Working of biogas plants

- Cow dung, dead plants, agricultural waste, food waste etc. various forms of biomass are mixed with an equal amount of water in the mixing tank. This mixture is called slurry.
- Now this slurry is moved into the digester through the inlet chamber. When the digester is almost half filled with slurry, the introduction of slurry is stopped.
- Digester is closed and oxygen is prevented from entering the digester to let the fermentation process take place actively.
- pH level in digester should be neutral or seven while temperature should be 30-35°C for maximum yield.

Uses of Biogas

- It is commonly used in rural areas as cooking gas.
- It can be used for the production of electricity.
- It can be used in instruments used for water heating, space (room) heating etc.
- It can replace compressed natural gas (CNG) for use in vehicles.
- It can be used in hydrogen fuel cells as well.

DETERMINATION OF ALKALINITY OF WATER

The alkalinity of water is a measure of its capacity to neutralize acids. The Alkalinity of water is due to presence of the:

(i) Caustic alkalinity (due to OH^- and CO_3^{2-} ions) and

(ii) Temporary hardness (due to HCO_3^- ions)

These can be estimated separately by titration against standard acid, using phenolphthalein and methyl orange as indicators. The determination is based on the following reactions:

(i) $[OH^-] + [H^+] \rightarrow H_2O$

(ii) $[CO_3^{2-}] + [H^+] \rightarrow [HCO_3^-]$

(iii) $[HCO_3^-] + [H^+] \rightarrow H_2O + CO_2$

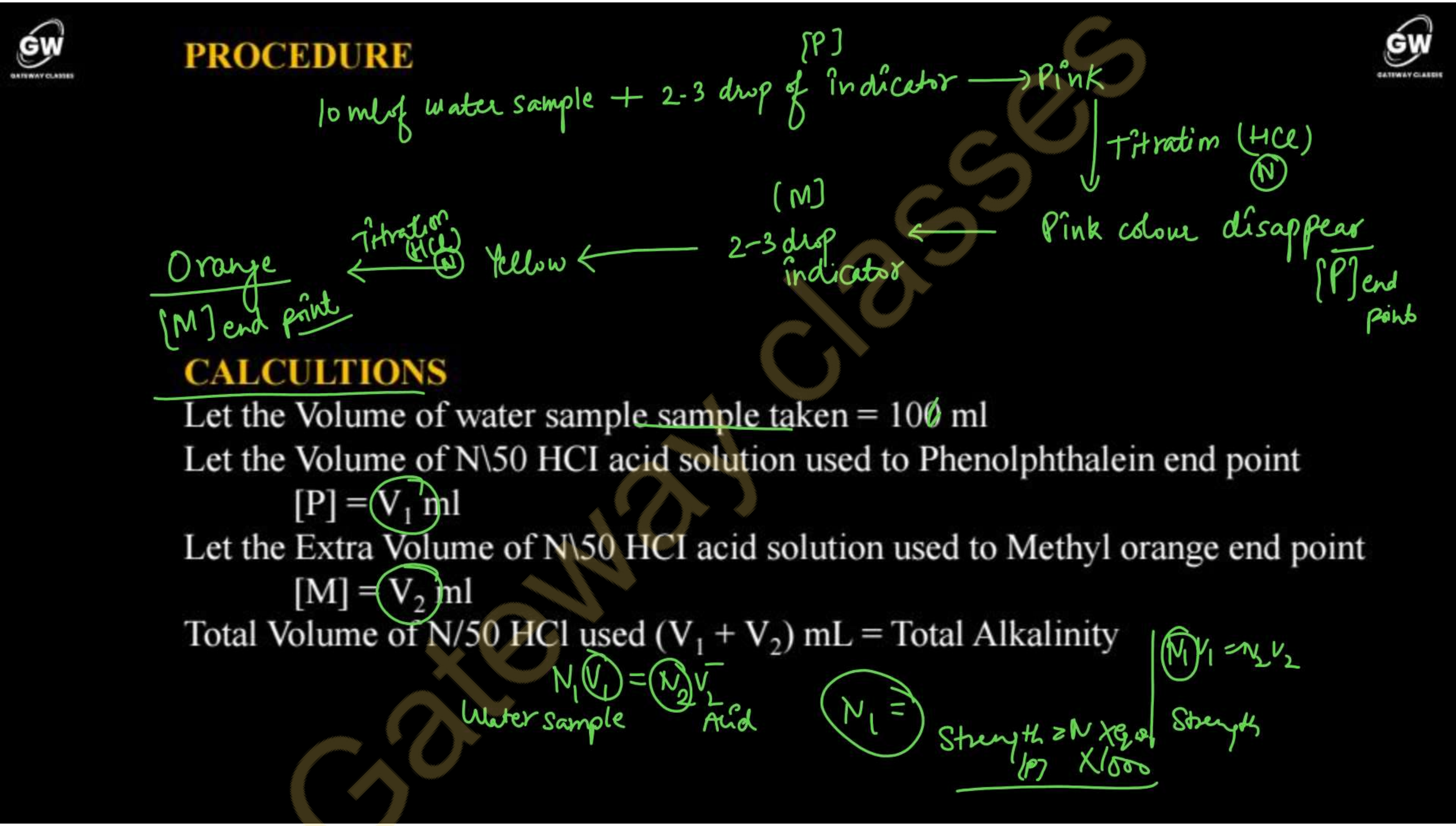
The possible combinations of ions causing alkalinity in water are:

(i) OH^- only
(ii) CO_3^{2-} only
(iii) HCO_3^- only
(iv) OH^- and CO_3^{2-} together
(v) CO_3^{2-} and $HCO3^-$ together

The possibility of OH^- and HCO_3^- ions cannot exist together in water because they combine instantaneously to form CO_3^{2-}

$$OH^- + HCO_3^- \rightarrow CO_3^{2-} + H_2O$$

$$NaOH + NaHCO_3 \rightarrow Na_2CO_3 + H_2O$$



PROCEDURE

10 ml of water sample + 2-3 drop of [P] indicator → Pink

↓ Titration (HCl) Ⓝ

Pink colour disappear [P] end point

← 2-3 drop (M) indicator ← Yellow ← Titration (HCl) Ⓝ ← Orange

[M] end point

CALCULTIONS

Let the Volume of water sample sample taken = 100 ml

Let the Volume of N\50 HCI acid solution used to Phenolphthalein end point

[P] = V_1 ml

Let the Extra Volume of N\50 HCI acid solution used to Methyl orange end point

[M] = V_2 ml

Total Volume of N/50 HCl used $(V_1 + V_2)$ mL = Total Alkalinity

$N_1 V_1 = N_2 V_2$

Water sample   Acid

$N_1 =$

Strength = N × Eq. wt. [P] × 1000

$N_1 V_1 = N_2 V_2$

Strength

Q. Covert 30 ppm hardness of water in terms of mg/L, degree Fench and degree Clarke.

Solution:

$$\underline{1\,\text{ppm} = 1\,\text{mg/L}} = \underline{0.1°\text{F} = .07°\text{Cl}}$$

$$30\ \text{ppm} = \underline{30\ \text{mg/L}}$$

$$30\ \text{ppm} = 30 \times 0.1\ °\text{F}$$

$$\underline{= 3\ °\text{F}}$$

$$30\ \text{ppm} = 30 \times 0.07\ °\text{Cl}$$

$$\underline{= 2.10\ °\text{Cl}}$$

GW
GATEWAY CLASSES

Q. A water sample contains 115 mg of $CaSO_4$ per liter. Calculate the hardness in terms of $CaCO_3$ equivalent. (2012)

Solution:

$$\text{Hardness} = \underline{\text{Strength}} \times \frac{\text{eq. wt of } CaCO_3}{\text{eq. wt of } CaSO_4}$$

$$= 115 \times \frac{50}{68}$$

$$= 84.56 \text{ ppm } / \text{ mg/L}$$

$$\begin{array}{r} 40 \\ 32 \\ 64 \\ \hline 136 \end{array}$$

$$\frac{136}{2} = 68$$

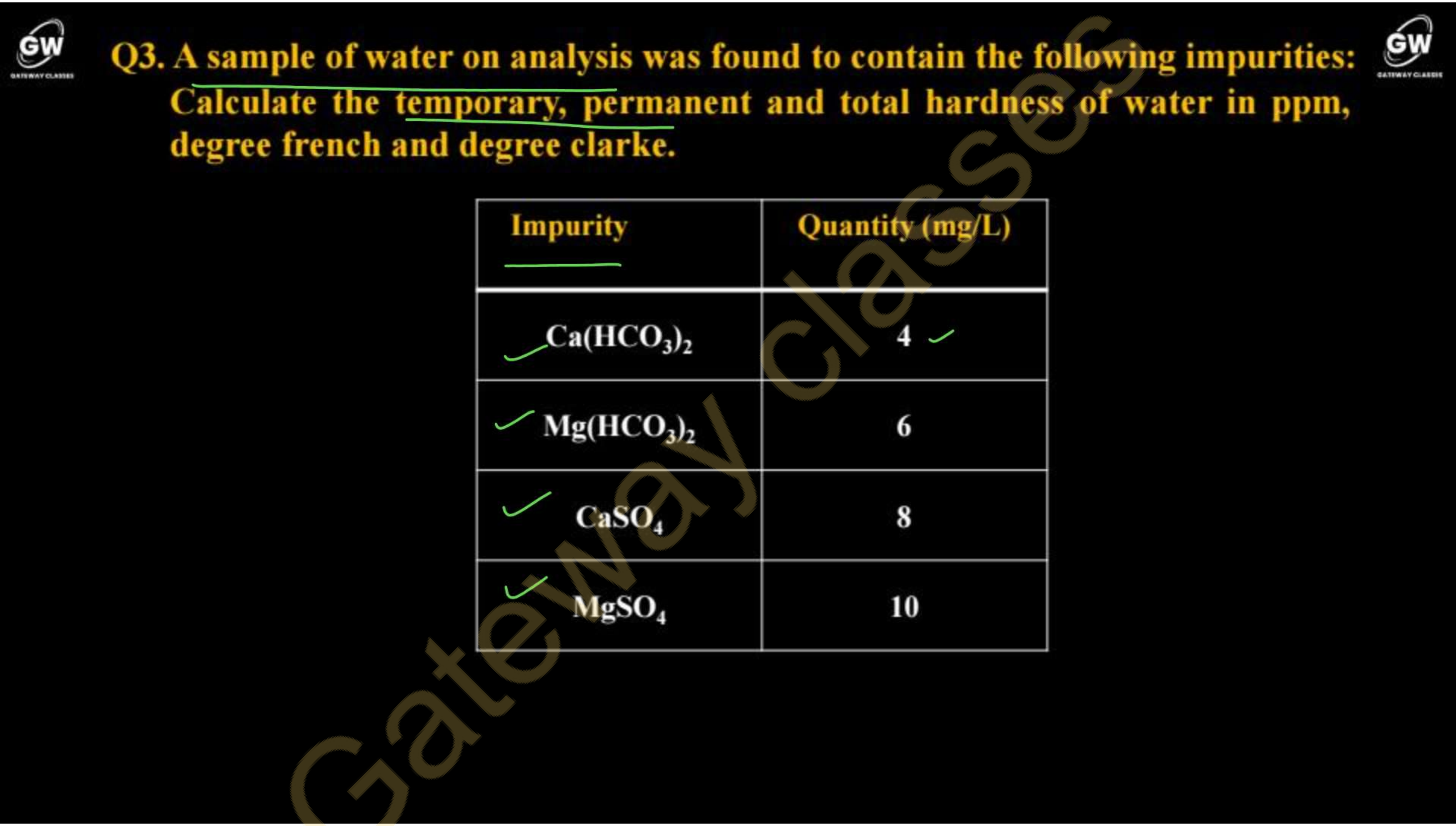
Q. How many grams of $MgCO_3$ dissolved per litre gives 94 ppm hardness?

Solution: $$\text{Hardness} = \frac{\text{Strength} \times \text{Eq. wt of } CaCO_3}{\text{Eq. wt. of } MgCO_3}$$

$94 = \text{Strength} \times 50/42$

$\text{Strength} = 94 \times 42/50 = 78.96 \text{ mg/L}$

78.96 mg/L of MgCO3 dissolved per litre gives 94 ppm hardness.



Q3. A sample of water on analysis was found to contain the following impurities: Calculate the temporary, permanent and total hardness of water in ppm, degree french and degree clarke.

Impurity	Quantity (mg/L)
✓ $Ca(HCO_3)_2$	4 ✓
✓ $Mg(HCO_3)_2$	6
✓ $CaSO_4$	8
✓ $MgSO_4$	10

Impurity	Quantity (mg/L)	Mol. Wt.	Hardness
$Ca(HCO_3)_2$	4	162 ✓	4×100/162=2.47 mg/L
$Mg(HCO_3)_2$	6	146	6×100/146=4.11 mg/L
$CaSO_4$ ✓	8	136	8×100/136=5.88 mg/L
$MgSO_4$ ✓	10	120	10×100/120=8.33 mg/L

Temporary Hardness = 2.47 + 4.11 = 6.58 mg/L = 6.58 ppm

6.58 mg/L =6.58 × 0.1°F = 0.658°F

6.58 mg/L = 6.58 × 0.07°Cl = 0.460°Cl

Permanent Hardness = 5.88 + 8.33 = 14.21 mg/L = 14.21 ppm

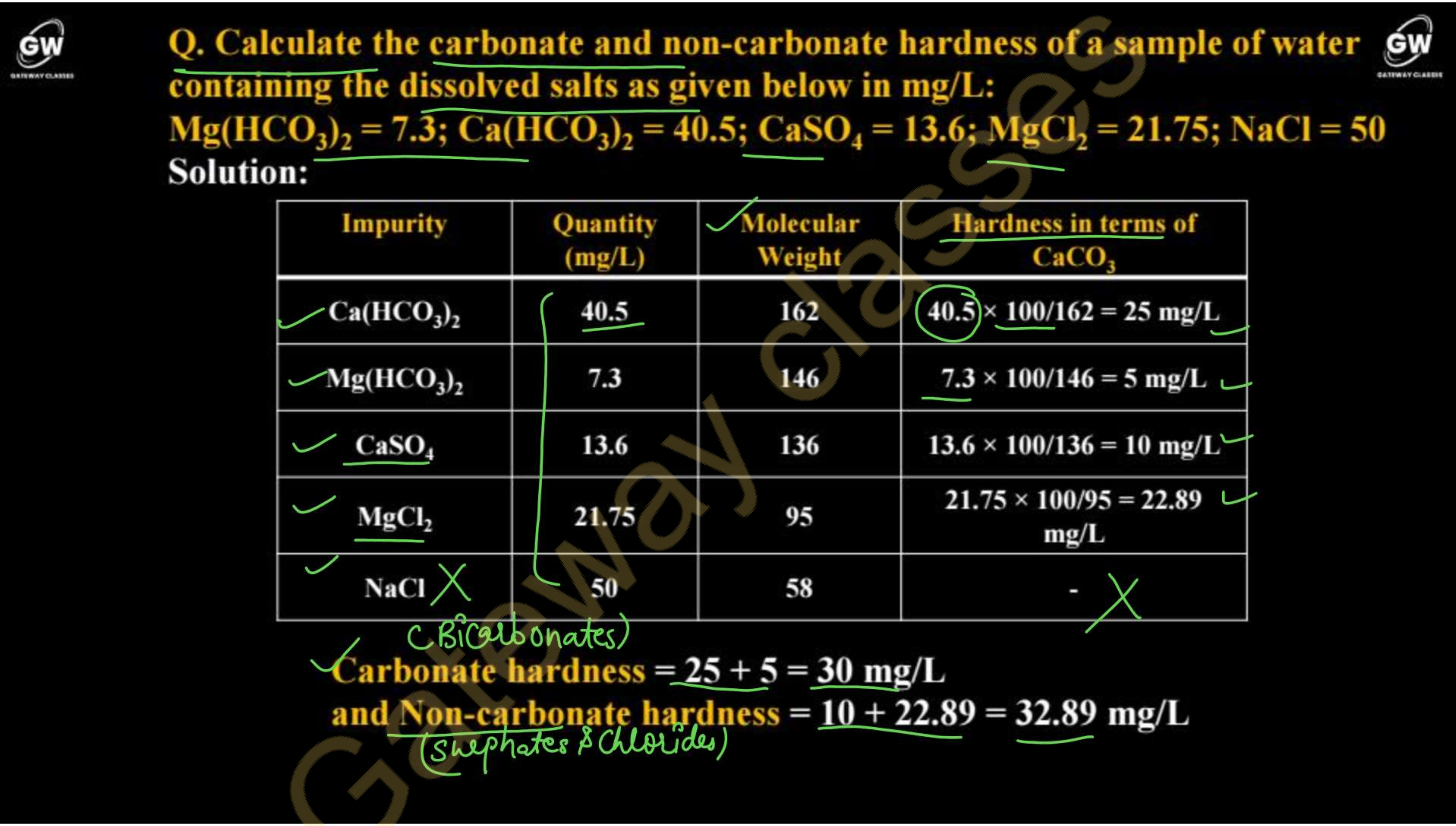
14.21 mg/L = 14.21× 0.1°F = 1.421°F

14.21 mg/L = 14.21× 0.07°Cl = 0.9947°Cl

= 0.995°Cl

Total hardness = 6.58 + 14.21

= 20.79 mg/L = 20.79 ppm



Q. Calculate the carbonate and non-carbonate hardness of a sample of water containing the dissolved salts as given below in mg/L:

$Mg(HCO_3)_2$ = 7.3; $Ca(HCO_3)_2$ = 40.5; $CaSO_4$ = 13.6; $MgCl_2$ = 21.75; NaCl = 50

Solution:

Impurity	Quantity (mg/L)	Molecular Weight	Hardness in terms of $CaCO_3$
✓ $Ca(HCO_3)_2$	40.5	162	40.5 × 100/162 = 25 mg/L
✓ $Mg(HCO_3)_2$	7.3	146	7.3 × 100/146 = 5 mg/L
✓ $CaSO_4$	13.6	136	13.6 × 100/136 = 10 mg/L
✓ $MgCl_2$	21.75	95	21.75 × 100/95 = 22.89 mg/L
✓ NaCl ✗	50	58	- ✗

(Bicarbonates)

✓ Carbonate hardness = 25 + 5 = 30 mg/L

and Non-carbonate hardness = 10 + 22.89 = 32.89 mg/L

(Sulphates & Chlorides)

Q. Calculate the quantities of lime and soda required for softening of 20,000 litre of water containing salts in ppm (16.4 ppm $NaAlO_2$ used as a coagulant):
Ca^{+2} = 160 ppm; Mg^{+2} = 72 ppm; HCO_3^- = 73.2 ppm; CO_2 = 44 ppm; $Al_2(SO_4)_3$ = 34.2 ppm and HCl = 36.5 ppm.

Impurity	Quantity (ppm)	Molecular Weight	Hardness in terms of $CaCO_3$
Ca^{+2}	160	40	160 × 100/40 = 400 mg/L
Mg^{+2}	72	24	72 × 100/24 = 300 mg/L
HCO_3^-	73.2	61 ×2	73.5 × 100/122 = 60.25 mg/L
CO_2	44	44	44 × 100/44 = 100 mg/L
$Al_2(SO_4)_3$	34.2	342	34.2 × 3 × 100/342 = 30 mg/L
HCl	36.5	36.5	36.5 × 100/36.5 = 100 mg/L
$NaAlO_2$	16.4	164	16.4 × 100/164 = 10 mg/L

Lime = (74/100) {temp. Ca salts + (2 × temp. Mg salts) + Perm. Mg salts + CO_2 + l + H_2SO_4 + HCO_3^- + salts of Fe^{2+}, Al^{3+} - $NaAlO_2$ } all in terms of CaCO3 equivalent (100/ % purity) × volume of water

$= 74/100\ \{\boxed{300} + 100 + 30 + 100 + 60.25 - 10\} \times 2 \times 10^4$

$= \dfrac{74\ \{580.25\} \times 2 \times 10^4}{\boxed{100} \times 10^6}$ {Divide by 10^6 to convert in kg}

$= 85877/10000$

$= 8.59$ kg

Soda = (106/100) {Perm (Ca salts + Mg salts) + salts of Fe^{2+}, Al^{3+} + HCl + H_2SO_4 – HCO^- – $NaAlO_2$} all in terms of $CaCO_3$ equivalents × (100/ % purity) × volume of water

$= 106/100\ \{400 + 300 + 30 + 100 - 60.25 - 10\} \times \boxed{2 \times 10^4}$

$= \dfrac{106\ \{759.75\} \times 2 \times 10^4}{100 \times 10^6}$ {Divide by 10^6 to convert in kg}

$$\frac{\cancel{10^4}\ 1}{\cancel{10^8}\ 10^4}$$

$= 161067/\ 10000$

$= 16.11$ kg

Q. By passing 50 litres of NaCl solution containing 250 gm/litre of NaC exhausted zeolite softener bed was regenerated. Calculate the litres of hard water sample (hardness equal to 200 ppm as $CaCO_3$) which can be softened by regenerated bed of zeolite softener.

Solution:

$$\text{Hardness} = \frac{\text{Conc. of NaCl (g/L)} \times \text{Volume of NaCl} \times \text{Eq. wt. of CaCO3} \times 1000}{\text{Volume of water sample} \times \text{Eq. wt. of NaCl}}$$

$$200\ \text{ppm} = 200\ \text{mg/L} = 0.2\ \text{g/L}$$

$$0.2 = \frac{250 \times 50 \times 50 \times 1000}{\text{Vol. of Water Sample} \times 58.5} \checkmark$$

$$\text{Vol. of Water sample} = \frac{250 \times 50 \times 50 \times 1000}{0.2 \times 58.5} = \underline{53418.80\ \text{litre}}$$

Q. Hardness of 77500 litres of water was completely removed by zeolite methc The exhausted zeolite softener then required 15 litres of NaCl (2%). For generation calculate hardness of water sample.

1 litre = 2%
= 20gm

Solution:

$$\text{Hardness} = \frac{\text{Conc. of NaCl (g/L)} \times \text{Volume of NaCl} \times \text{Eq. wt. of CaCO3} \times 1000}{\text{Volume of water sample} \times \text{Eq. wt. of NaCl}}$$

$$\text{Hardness} = \frac{20 \times 15 \times 50 \times 1000}{77500 \times 58.5}$$

$$= 3.308 = 3.31 \ \underline{ppm}$$

Q. Following data obtained in a bomb calorimeter experiment. Wt. of coal burnt = 0.994gm, Wt. of water in calorimeter = 2592 gm, Wt. of bomb calorimeter = 3940gm, Rise in temp. = 2.732^{0}C, Specific heat of apparatus = 0.098. Find GCV, if fuel contain 8% hydrogen & calculate NCV if Latent heat of condensation = 587 cal/gm.

Solution:

Wt. of coal = x = 0.994 gm

$W = 2592$ gm

$w = 3940 \times 0.098 = 386.12$

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

$$= \frac{(2592 + 386.12)(2.732)}{0.994} = \boxed{8185.34} \text{ cal/gm}$$

$$NCV = GCV - 0.09 \times \%H \times 587 = 8185.34 - 0.09 \times 8 \times 587 = \boxed{7762.7} \text{ cal/gm}$$

Q. A sample of coal contain C= 91 %, H= 5.5%, N= 2.5%, and ash= 2%. The following data were obtained when above coal was tested in bomb calorimeter:

Weight of coal burnt= 1.029g x

Weight of water taken= 570 g W

Water equivalent of bomb and calorimeter= 2200 g w

Rise in temperature= 3.3°C $(t_2 - t_1)$

Fuse wire correction= 3.8 cal (C_f)

Acid correction= 62.6 cal (C_A)

Cotton thread correction= 1.6 cal (C_{CT})

Cooling correction= 0.047 °C (C_c)

Assuming that the latent heat of condensation is 587 cal/gm, calculate net and gross calorific values of coal.

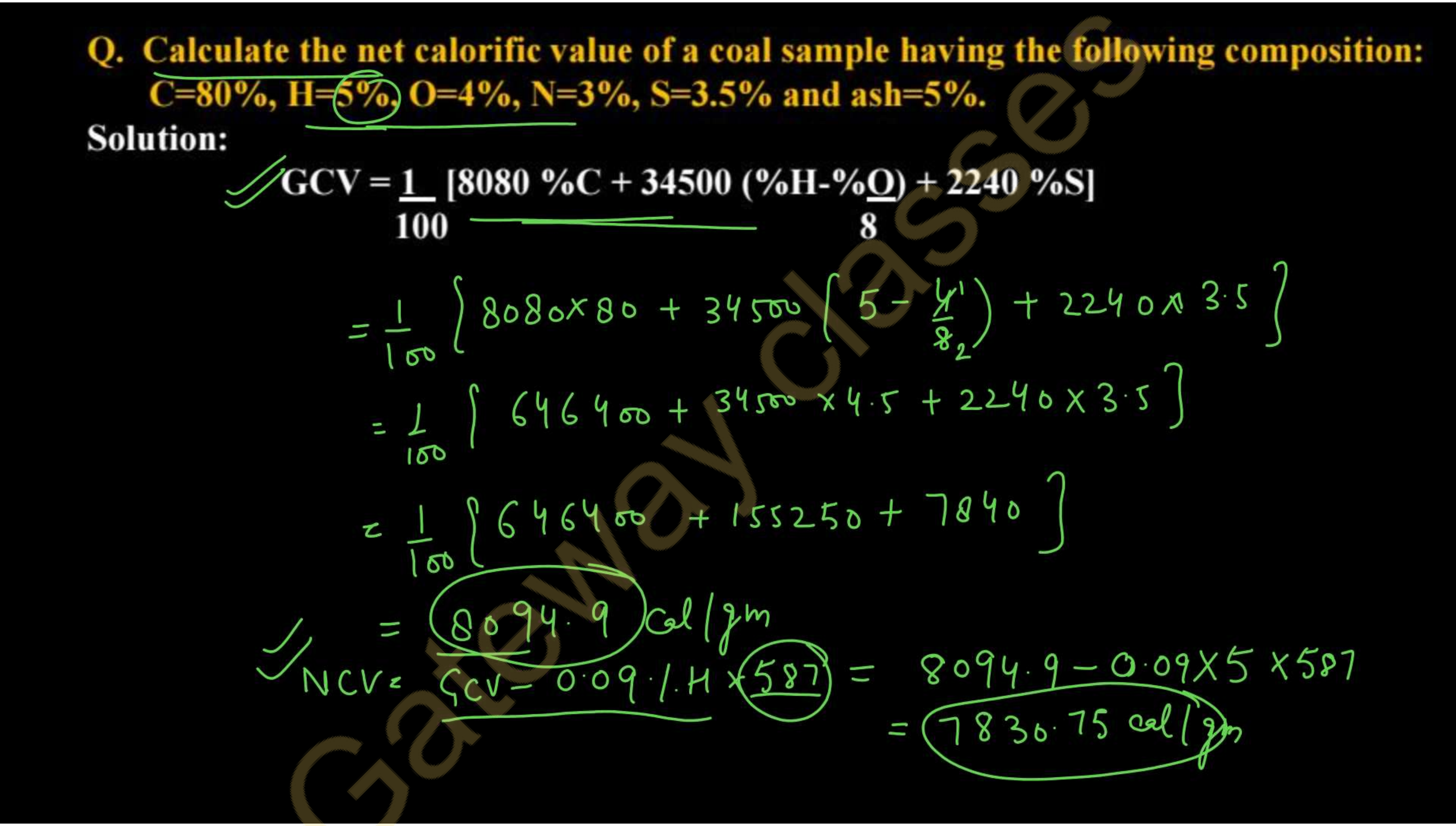
Solution: $$\text{GCV} = \frac{(W+w)(t_2-t_1+C_C)-\{(C_A+C_F+C_{CT})}{x} = \frac{(570+2200)(3.3+0.047)-[62.6+1.6+3.8]}{1.029}$$

$$= \frac{(2770)(3.347)-(68)}{1.029} = \boxed{8943.82 \text{ Cal/gm}}$$

$$\text{NCV} = \text{GCV} - 0.09 \times 5.5 \times 587$$

$$= 8943.82 - 290.57$$

$$= \boxed{8653.26} \text{ Cal/gm}$$



Q. Calculate the net calorific value of a coal sample having the following composition: C=80%, H=5%, O=4%, N=3%, S=3.5% and ash=5%.

Solution:

$$\text{GCV} = \frac{1}{100}\left[8080\ \%C + 34500\left(\%H - \frac{\%O}{8}\right) + 2240\ \%S\right]$$

$$= \frac{1}{100}\left\{8080 \times 80 + 34500\left(5 - \frac{\cancel{4}^{1}}{\cancel{8}_{2}}\right) + 2240 \times 3.5\right\}$$

$$= \frac{1}{100}\left\{646400 + 34500 \times 4.5 + 2240 \times 3.5\right\}$$

$$= \frac{1}{100}\left\{646400 + 155250 + 7840\right\}$$

$$= \boxed{8094.9}\ \text{cal/gm}$$

$$\text{NCV} = \text{GCV} - 0.09\ \%H \times \boxed{587} = 8094.9 - 0.09 \times 5 \times 587$$

$$= \boxed{7830.75\ \text{cal/gm}}$$

Q. 3.25 g of coal was kjeldahlized and NH_3 gas thus evolved was absorbed in 45 ml of 0.1 N H_2SO_4. To neutralize excess of acid, 11.5 ml of 0.1N NaOH was required. Calculate N%.

Solution:

$$\% N = \frac{\text{Volume of acid} \times \text{Normality} \times 1.4}{\text{Weight of coal sample}}$$

$$V = 45 - 11.5 = 33.5$$

$$= \frac{33.5 \times 0.1 \times 1.4}{3.25}$$

$$\boxed{\% N = 1.44}$$

Q. 0.25 g coal sample on burning in combustion chamber in current of pure O_2 was found to increase weight of $CaCl_2$ U-tube by 0.08 g and KOH U-tube by 0.5 g. Find % of carbon and hydrogen in coal.

Solution:

$$\%\,C = \frac{\text{Increase in weight of KOH tube} \times 12 \times 100}{\text{Weight of coal sample} \times 44}$$

$$\%\,C = \frac{0.5 \times 12 \times 100}{0.25 \times 44} = 54.55$$

$$\%\,H = \frac{\text{Increase in weight of } CaCl_2 \text{ tube} \times 2 \times 100}{\text{Weight of coal sample} \times 18}$$

$$\%\,H = \frac{0.08 \times 2 \times 100}{0.25 \times 18} = 3.56$$

Q. 1 g of coal loses 0.03 g at 110°C and then complete combustion leaves 0.08 g residue. 1 g of same coal loses 0.22 g at 950°C. Calculate fixed carbon %.

Solution:

Moisture content (%) = (weight of moisture/ Weight of coal sample) x 100

$$= \frac{0.03}{1} \times 100 = 3\,\%$$

Ash content (%) = (weight of ash / weight of coal sample) x 100

$$= \frac{0.08}{1} \times 100 = 8\,\%$$

Wt. of moisture + V.M = 0.22 g

V.M = 0.22 - 0.03 = 0.19 gm

Volatile Matter content (%) = (weight of volatile matter/ weight of coal sample) x 100

$$= \frac{0.19}{1} \times 100 = 19\,\%$$

Fixed carbon content (%) = 100 - (%M + %Ash + %V.M)

$$= 100 - (3 + 8 + 19) = 70\,\%$$

Q. Calculate %S in coal sample when 0.55 g of coal is combusted in bomb calorimeter. Solution from bomb on treatment with $BaCl_2$ forms 0.025 g $BaSO_4$.

Solution: $$\% S = \frac{\text{Weight of BaSO4 precipitate} \times 32 \times 100}{\text{Weight of coal sample} \times 233}$$

$$= \frac{0.025 \times 32 \times 100}{0.55 \times 233}$$

$$\boxed{\% S = 0.624}$$

Ans

Q. Calculate the volume of air required for complete combustion of 1m³ of gaseous fuel having the composition: CO=46%, methane=10%, hydrogen = 4%, C_2H_4 = 2%, H_2 = 1% and remaining being CO_2.

Solution:

Fuel	Composition	Combustion reaction	Vol of O_2 (m³)
CO	$\frac{46}{100} \times 1 = 0.46 m^3$	$CO + \frac{1}{2}O_2 \rightarrow CO_2$	$0.46 \times \frac{1}{2} = 0.23$
CH_4	$\frac{10}{100} \times 1 = 0.1 m^3$	$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$	$0.1 \times 2 = 0.2$
C_2H_4	$\frac{2}{100} \times 1 = 0.02 m^3$	$C_2H_4 + 3O_2 \rightarrow 2CO_2 + 2H_2O$	$0.02 \times 3 = 0.06$
H_2 ✓	$\frac{4}{100} \times 1 = 0.04 m^3$	$H_2 + \frac{1}{2}O_2 \rightarrow H_2O$	$0.04 \times \frac{1}{2} = 0.02$

Total volume of O_2 (m³) $= 0.23 + 0.2 + 0.06 + 0.02$

$= 0.51 \, m^3$

Volume of air $= \frac{0.51 \times 100}{21} = 2.43 \, m^3$

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Thank You