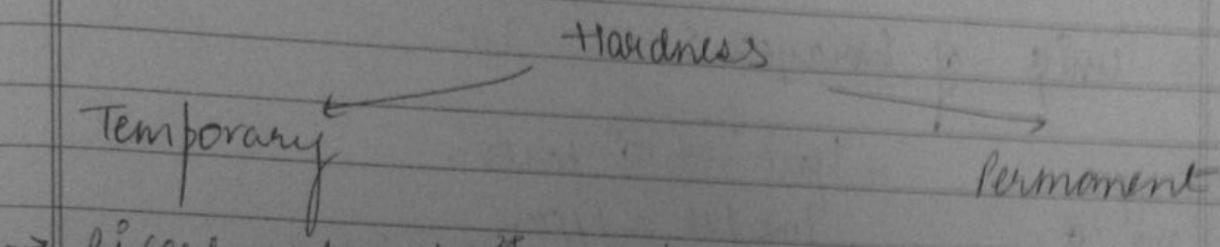
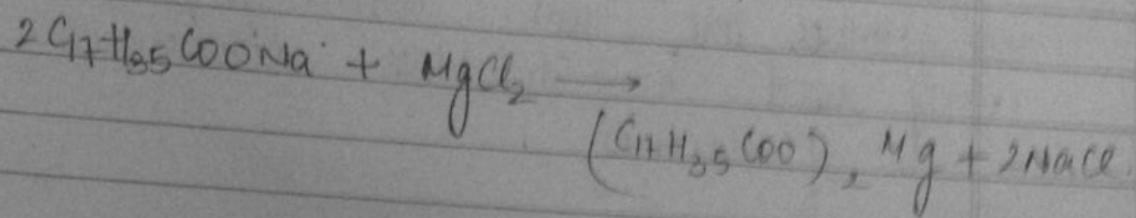
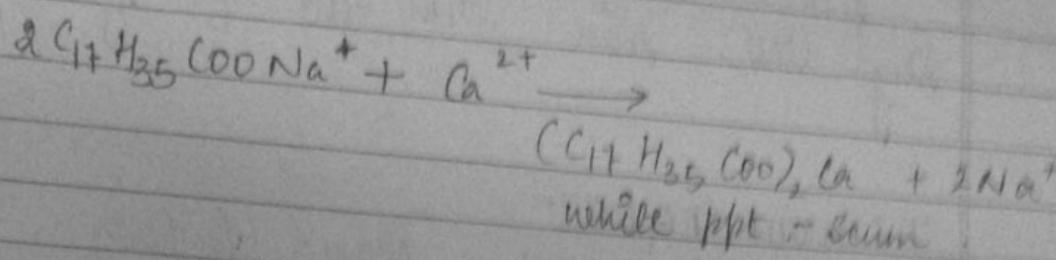


21st Dec 2016

MODULE I :- WATER TREATMENT.

Date _____
Page No. _____

- Hardness :- is the soap consuming capacity of H_2O caused due to the presence of calcium & magnesium salts.

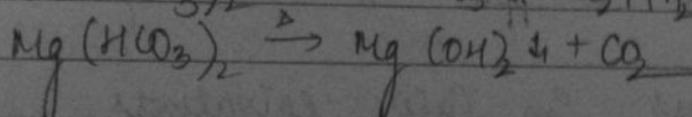
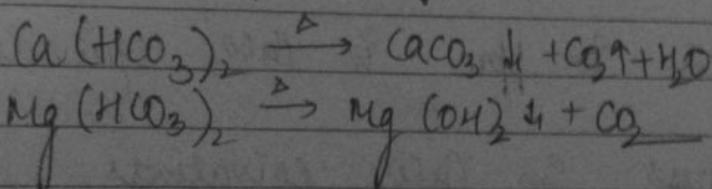


→ Bicarbonates of Ca^{2+} and Mg^{2+} .

chlorides or sulphates
of Ca^{2+} & Mg^{2+} .

→ Removed by boiling.

Removed by lime Soda,
Zeocite and Ion
exchange process.



→ Carbonate hardness

Non Carbonate
hardness. indirectly

determined by

→ Titration with HCl using
methyl orange as indicator.

Complexometric titration
vs EDTA using EPBT

ADVANTAGES OF HARD WATER

- certain amount of minerals are required by our body.
- if water is flowing by a pipe to the scale formed due to the material of pipe say lead mix with the go flowing.

DISADVANTAGES:-

- clothes are not cleaned properly
- if used in industries decrease of the efficiency of machines.

Units of hardness :-

- ppm 1 part $\rightarrow 10^6$ parts.
- mg/lit 1mg/lit = 1 ppm
- degree clarks ($^{\circ}\text{Cl}$) 1 part $\rightarrow 10^5$ parts.
- degree french ($^{\circ}\text{Fr}$) 1 part $\rightarrow 40000$ parts

22nd December 2016

- * hardness measured in ppm in CaCO_3 equivalents
- We find hardness in CaCO_3 equivalents by converting mass of salts causing hardness into CaCO_3 equiv.

★ $\text{CaCO}_3 = \text{mass of hardness} \times \frac{\text{equivalents}}{\text{molecular weight of substance}} \times \left\{ \begin{array}{l} \text{chemical eqwt of } \text{CaCO}_3 \\ \text{chemical eqwt of hardness} \\ \text{producing substance} \end{array} \right\}$

↓
multiplication factor.

HARDNESS CAUSING SALTS

Salt	Molecular wt	Eqwt	Multiplication factor
$\text{Ca}(\text{HCO}_3)_2$	162	81	50/81
$\text{Mg}(\text{HCO}_3)_2$	146	73	50/73
CaSO_4	136	68	50/68
CaCl_2	111	55.5	50/55.5
MgSO_4	120	60	50/60
MgCl_2	95	47.5	50/47.5
CaCO_3	100	50	1
MgCO_3	84	42	50/42
CO_2	44	22	50/22

Other ions which may react

Ions	Mol wt	Eq wt	M.F
$\text{Na}^+(\text{NO}_3)_-$	148	74	50/74
HCO_3^-	61	61	50/61
OH^-	17	17	50/17
CO_3^{2-}	60	30	50/30
$\text{Na}^+(\text{NO}_3)_2$	92	92	50/92
$\text{Al}_2(\text{SO}_4)_3$	342	57	50/57
$\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$	278	139	50/139
H^+	1	1	50/1
HCl	36.5	36.5	50/36.5

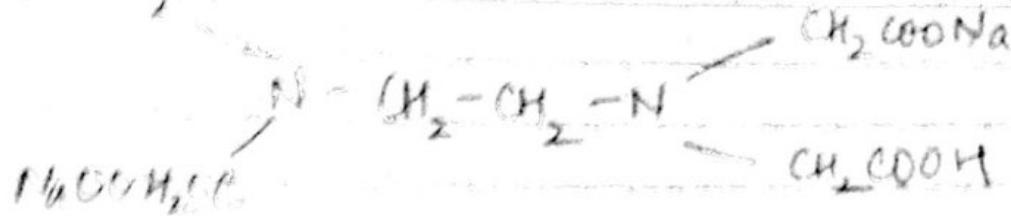
2nd January 2017

Complexometric Titration method.

Legend - EDTA → forms complex with M^+
 Ca^{2+}

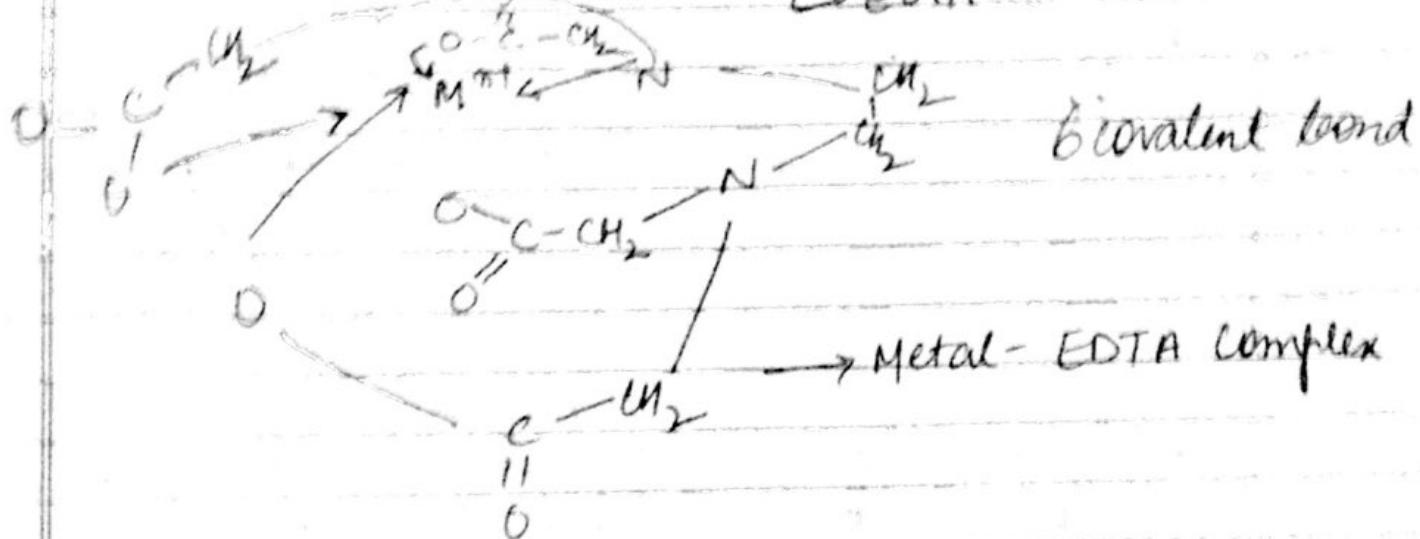
ethylene diamine tetra acetic acid.

HEDTA

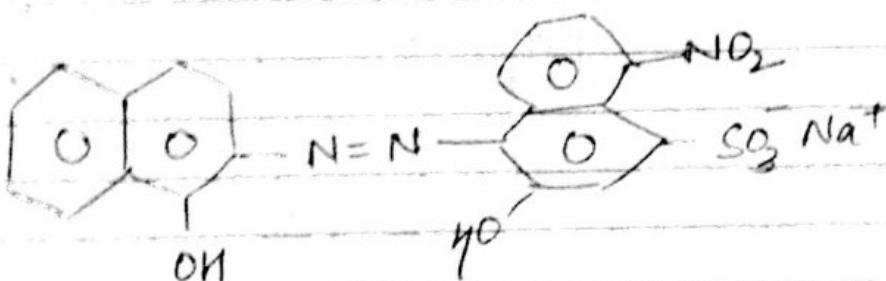


EDTA - not soluble that's why dinitro gen salt used

\hookrightarrow disodium salt \hookrightarrow EDTA



EBT :- Eriochrome Black T



Water - Black
of Powder

	if Red
pH < 7	(Acidic)
pH > 12	→ Orange (Base)
pH b/w (7 to 12)	→ blue

pH > 12
In³⁺

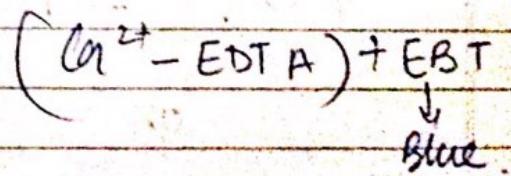
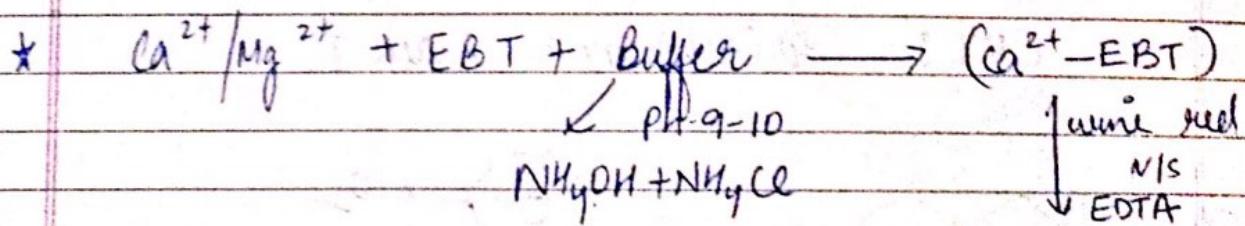
Highly alkaline (3^o molar pts)

Buffer → acidic → weak acid + salt of its strong base
DD → basic - WB + salt of st acid

→ neutral → salt from WA & WB

(salt of WA &
salt of WB)

- Doesn't allow pH to change
- Combination of Salt of weak acid and weak base or salt weak acid & weak acid



→ wine red to blue

Add of alkaline Buffer needed :-

- distinct colour change, colorless from red to blue.
- also $\text{Ca}^{2+}-\text{EDTA}$ complex is more stable at pH(9-10)

- To maintain pH (9-10)

Alternative - Calgonite
Indicator

as problem EBT decomposes on standing
over long period.

Procedure :-

1) Standardisation of EDTA - by - standard hard H_2O
 |
 (SHW)
 → contains given
 mg / ml
 $CaCO_3$
 (dissolved in HCl)

- 25ml of SHW + 10ml buffer + 2-3 drops of EBT wine red.
 ↓ v/s EDTA
 Blue \sim_1 (ml)
 ↓
 of EDTA (Burette)

2) Determination of total Hardness.

25ml sample + 10ml EBT $\xrightarrow[v/s]{EDTA}$ Blue
 H_2O buffer
 \downarrow
 \sim_2 (ml)

3) Determination of Permanent Hardness. 110.
 100ml sample $\xrightarrow{v/s}$ $\frac{10}{4}$ vol \rightarrow cool, filter \rightarrow

make vol to 100 ml distilled H_2O

(Otherness hardness
against)

25 ml boiled H_2O + EBT + Buffer

EDTA | v/s
↓

Blue (v_3 ml)

↳ EDTA with boiled H_2O

SHW - 1mg/ml of $CaCO_3$

25 ml SHW $\xrightarrow{\text{requires}}$ $\frac{1}{4}$ ml of EDTA

25 mg $CaCO_3$

1ml of EDTA = $\frac{25}{\frac{1}{4}}$ mg $CaCO_3$

1ml = 100 mg $CaCO_3$

Total hardness

25 ml sample $\xrightarrow{\text{contains}}$
= N_2 ml EDTA

1ml = $\frac{25}{N_2}$ mg $CaCO_3$

$$\therefore V_2 \text{ ml} = \frac{25}{V_1} \times V_2 \text{ mg CaCO}_3$$

$$\therefore 1000 \text{ ml} \rightarrow \frac{V_2 \times 25}{V_1} \times \frac{1000}{25} \text{ mg/litre CaCO}_3 \text{ to change}$$

$$= \frac{V_2}{V_1} \times 1000 \text{ mg/litre CaCO}_3$$

Permanent hardness

$$25 \text{ ml boiled water} = V_3 \text{ ml of EDTA} = \frac{V_3 \times 25}{V_1} \text{ mg CaCO}_3$$

$$1000 \text{ ml} = V_3 \times \frac{25}{V_1} \times \frac{1000}{25} \text{ mg/litre CaCO}_3$$

$$= \frac{V_3}{V_1} \times 1000 \text{ ppm CaCO}_3$$

Total hardness =

$$\frac{V_2 (\text{EDTA}) \times V_{\text{SHW}} \times \text{mg/lme CaCO}_3 \times 1000}{V_1 (\text{EDTA}) \times V_{\text{sample}}}$$

Permanent hardness

$$V_2 (\text{EDTA}) \times V_{\text{SHW}} \times \frac{\text{mg/l}}{\text{ml}} \text{ CaCO}_3 \times 1000$$

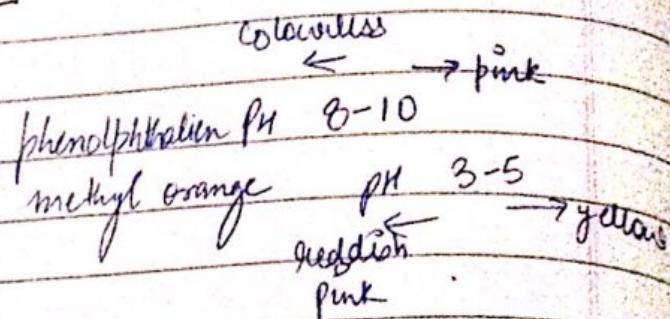
July 2016

day

Alkalinity :-

TYPES :-

- Only OH^-
- Only CO_3^{2-}
- Only HCO_3^-
- $\text{OH}^- + \text{CO}_3^{2-}$
- $\text{CO}_3^{2-} + \text{HCO}_3^-$

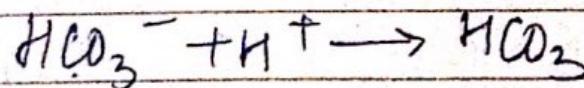
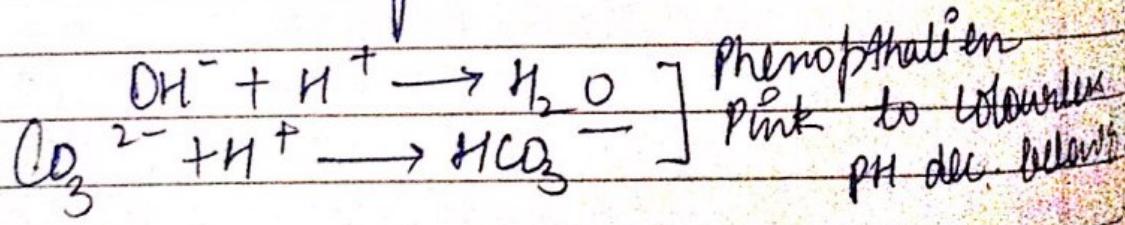


All the three can't be present together because hydroxide reacts with bicarbonate to give carbonate ion.

Combinations of $\text{OH}^- + \text{HCO}_3^-$ not possible
 - OH^- reacted with HCO_3^- to give CO_3^{2-} ions.

Titration - (Addⁿ of 2 indicator)

first ion to get neutralised - OH^-



We can't use methyl orange alone as we won't identify exact content of each ion - OH^- , CO_3^{2-} , HCO_3^-

∴ two indicators are used

\hookrightarrow Phenolphthalein + MO.

I) 10ml Sample + phth $\xrightarrow[\text{(pink)}]{\text{HCl}}$ colourless
↓
 HCl required to neutralise OH^-

completely neutralised and CO_3^{2-} converted to HCO_3^-

But alkalinity not removed
so two methods.

I

Same solⁿ + MO (yellow)
HCl v/s

red pink (v_2 ml)

HCl required
to neutralise HCO_3^- ions

II

Different solⁿ

10ml Sample +
MO (yellow)

v/s HCl
red pink

$(v_1 + v_2)$ ml or
 v ml

HCl required.

Calculations :-

Phth -

$$\frac{N' V'}{V_{\text{water}}} = \frac{N'' V''}{V_{\text{HCl}}}$$

$$N_{\text{water}} = \frac{\text{Alkalid } V}{V_{\text{water}}}$$

$$\text{Strength} = N_w \times \text{eq wt (CaCO}_3)$$

As all calc
wt CaCO₃

$$\frac{N A V_1}{V_w} \times 50 \text{ gm/lit}$$

$$P = \frac{N A V_1}{V_w} \times 50 \times 1000 \text{ ppm} \Rightarrow (\text{mg/lit})$$

for methyl orange $M = \frac{N A (V_1 + V_2)}{V_w} \times 50 \times 1000$
 (Same soln)

$$\frac{M}{(\text{diff soln})} = \frac{N A V_1 \times 50 \times 1000}{V_w} \text{ ppm}$$

Boiler Water Problems :- $\text{alkalinity OH} = 0.2 \text{ to } 0.5 \text{ Mm}$

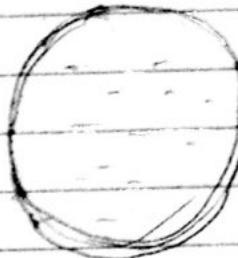
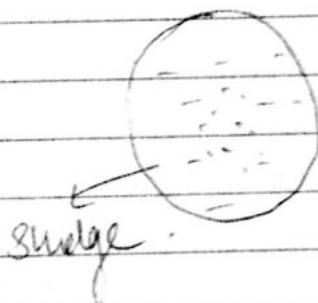
$\text{alkalinity CO}_3^{2-} = 0.5 \text{ to } 1 \text{ Mm}$

i) Sludge and Scale.

$I_p < K_{sp}$ Salt Solution

$I_p = K_{sp}$ — Saturated

$I_p > K_{sp}$ — ppt.



Scale

Sludge :- Soft, loose, shiny ppt

- cooler region of boiler

- salts - solubility ↑ with ↑ temp

- MgCO_3 , MgSO_4 , CaCO_3

Disadvantages :-

- Boiler efficiency ↓

- Can get deposited along cracks.

Prevention :-

- Using soft H_2O .

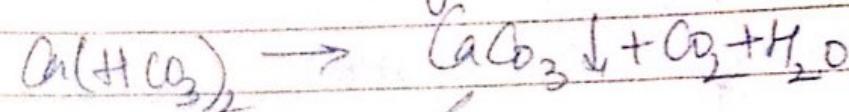
- Blow down operations.

SCALE :-

hard, adherent deposit, walls

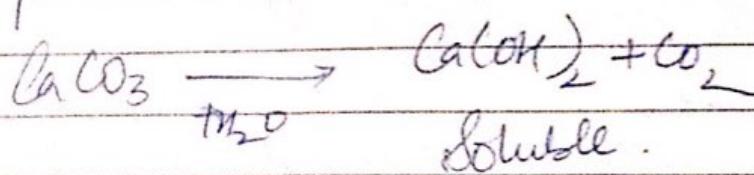
rotten region

salt - solubility ↓ with ↑ temp

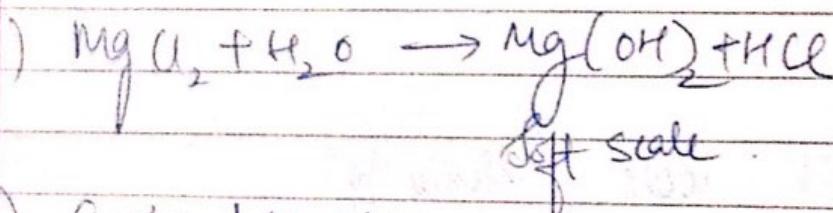


low pressure boilers.

In high pressure boiler



$CaSO_4$.



$CaSiO_3$ & $MgSiO_3$.

disadvantage.

wastage of fuel

boiler efficiency ↓

Boiler explosion

II

Prevention | Removal.

Mechanical

Scraping

thermal shock

blow down.

Chemical

- EDTA

- HCl.

III

IV

* Differentiate BPT scale & Sludge

Green House
Date _____
Page No. _____

SLUDGE

soft

older

bump ↑ solubility ↑

examples.

SALT

hard

hotter

salt - solubility ↓
with ↑ temp

II Priming and Carryover.

↓
Steam + water droplets.

steam + H_2O droplets
impurities present.

Causes

- faulty design of boilers.
- non uniform heating.
- high steam velocity.

Prevention:-

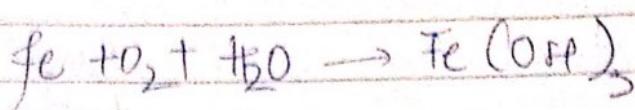
- proper designing
- uniform heating
- proper steam velocity

III Foaming :- oil / alkali.

↓ efficiency

→ anti foaming agents / acid for neutralization

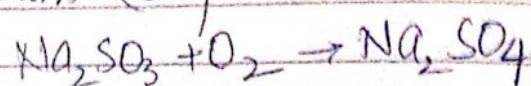
IV Boiler Corrosion

O_2 

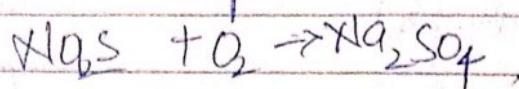
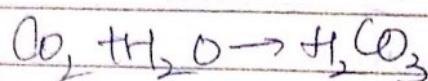
Removal of O_2 — hydrogine $H_2 + O_2 \rightarrow N_2 + H_2O$

mineral
nitrates

Sodium Sulphate



Sodium Sulphate

 CO_2 

Removal of $CO_2 \rightarrow$ Mechanical deaeration.

↓
passing through a lime stone bed

Add $NaOH$

↑

Mineral acids HCl / H_2SO_4 .

Removed by alkali.

(*) GASTIC EMBRITTLEMENT.

↳ (NaOH.)

Caused by



Lime Soda

↓
Fe (Corrosion)

Sodium ferrocyanate

Prevention :-

→ use Sod. phosphate instead of Sod. carbonate

→ Add tannin / lig nium.

Q/A.

Q A standard hard water contains 15 gm CaCO_3 per l. 20 ml of this sol' required 25 EDTA. 100 ml sample water required 10 ml EDTA and 50 ml after boiling reqd 6 ml EDTA calc. temporary hardness.

Q A standard hard water contains 22 g/l calcium carbonate 100 ml of this solution required 30 ml EDTA 75 ml sample water required 20 ml EDTA and 50 ml after boiling required 5 ml EDTA. calc temporary de per. hardness.

Q 500 ml Sample $\frac{1}{2}$ O on titration with $\text{N}/50 \text{ H}_2\text{SO}_4$ gave a value of 29 ml for phenolphthalein end point and another 500 ml a value of 58 ml for methyl orange

end pH . . calc. alkalinity.

50 ml H₂O sample on titrations with
N/10 NaOH required 7 ml for
phenolphthalein end pt. & 14 ml for
methyl orange end point calculate alkalinity

Total hardness = 25.

$$\frac{4 \times 26 \times 15 \times 1000}{525 \times 100}$$

$$\text{Permane} = \frac{6 \times 50 \times 15 \times 1000}{25 \times 50}$$

11th January 2014.

Green House

Date

Page No.

Boiler Water treatment

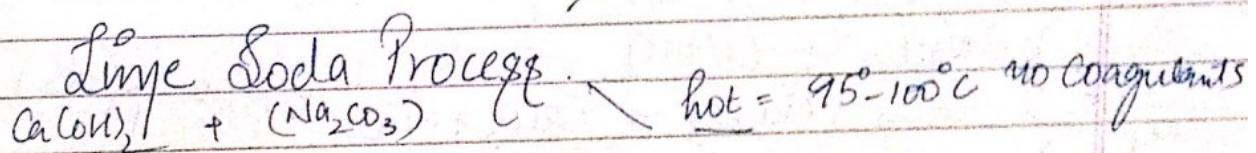
External

- Before adding in boiler
- Prevention
- lime soda
- Zeolite
- Ion exchange

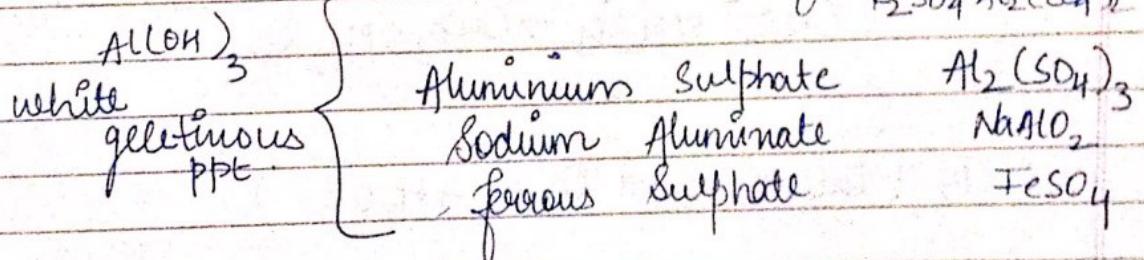
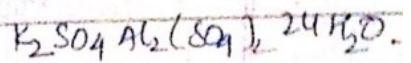
Internal

- Inside Boiler
- corrective
- colloidal
- phosphate
- Colagen
- carbonate

Cold = room temp + coagulants

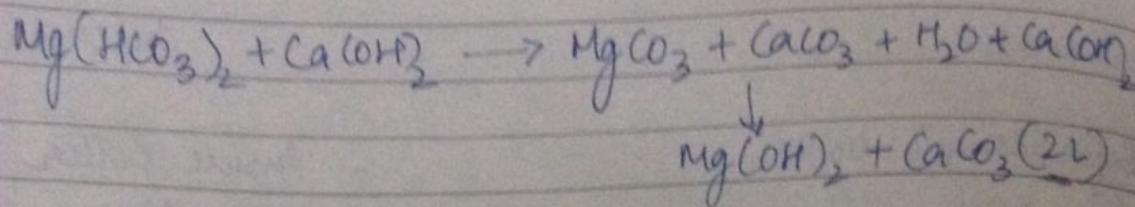
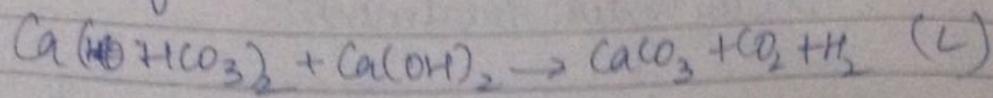


Done in the process of coagulants \rightarrow Alum

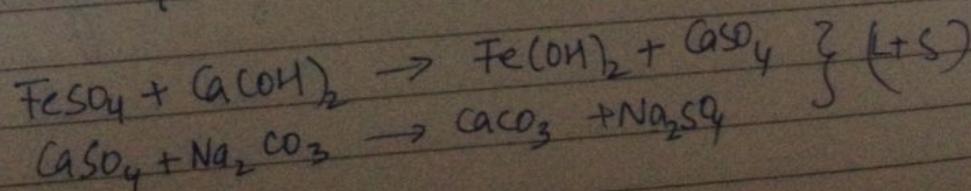
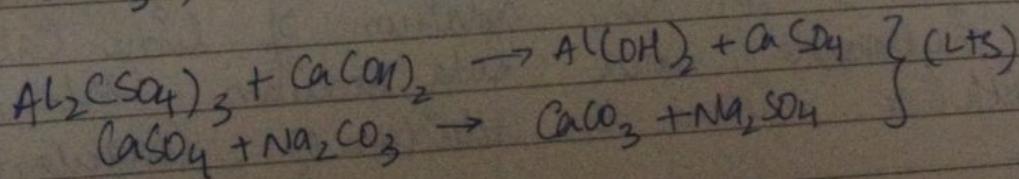
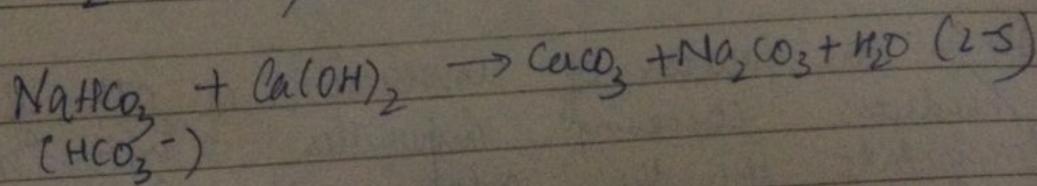
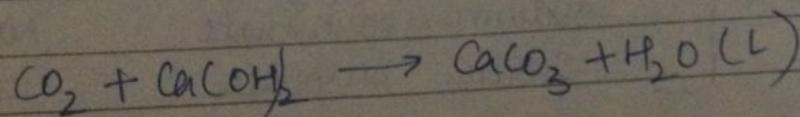
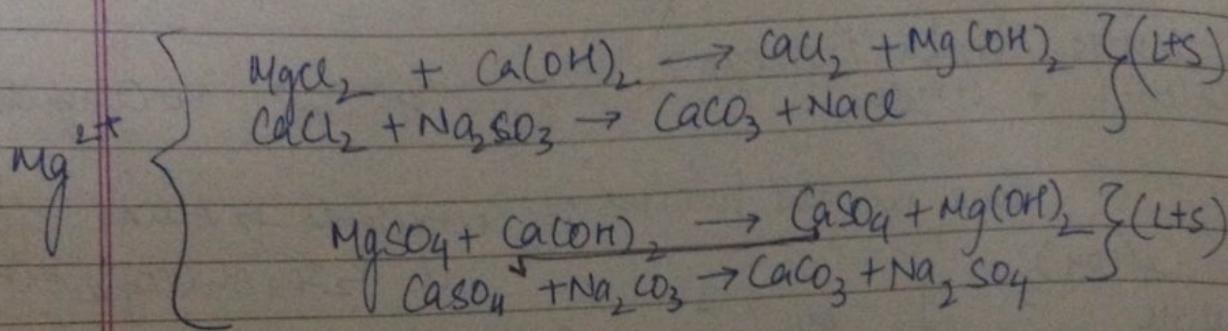
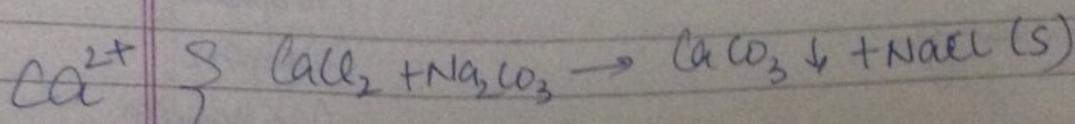


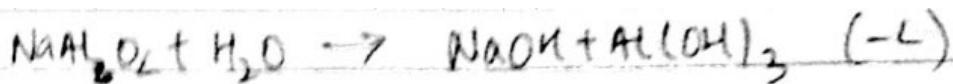
It is the process of conversion of all soluble hardness causing impurities into insoluble precipitates by the addition of lime calcium hydroxide and soda sodium carbonate with or without the addition of coagulants.

Temporary hardness :-

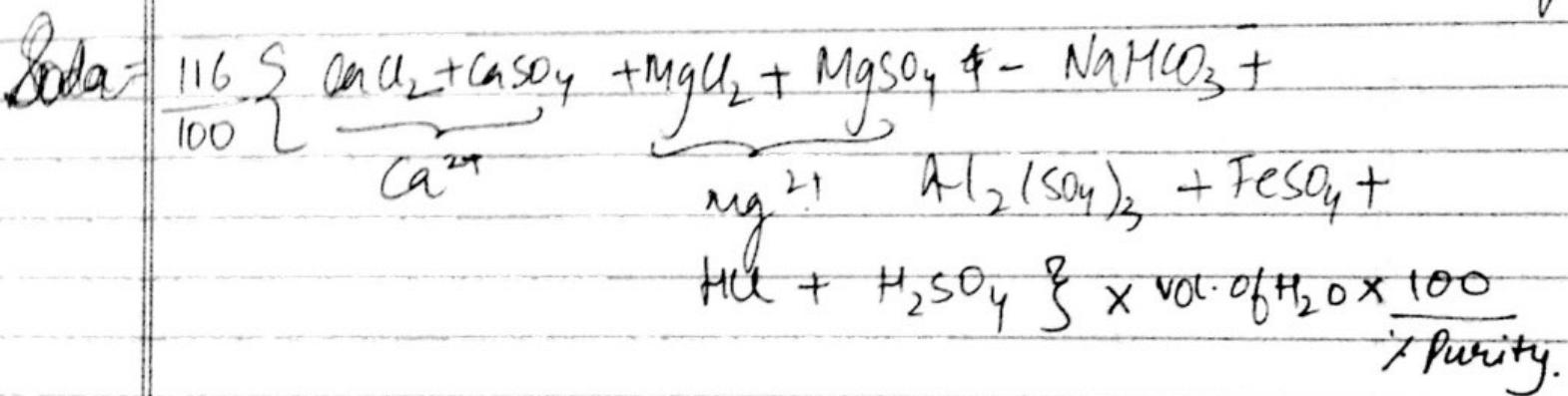
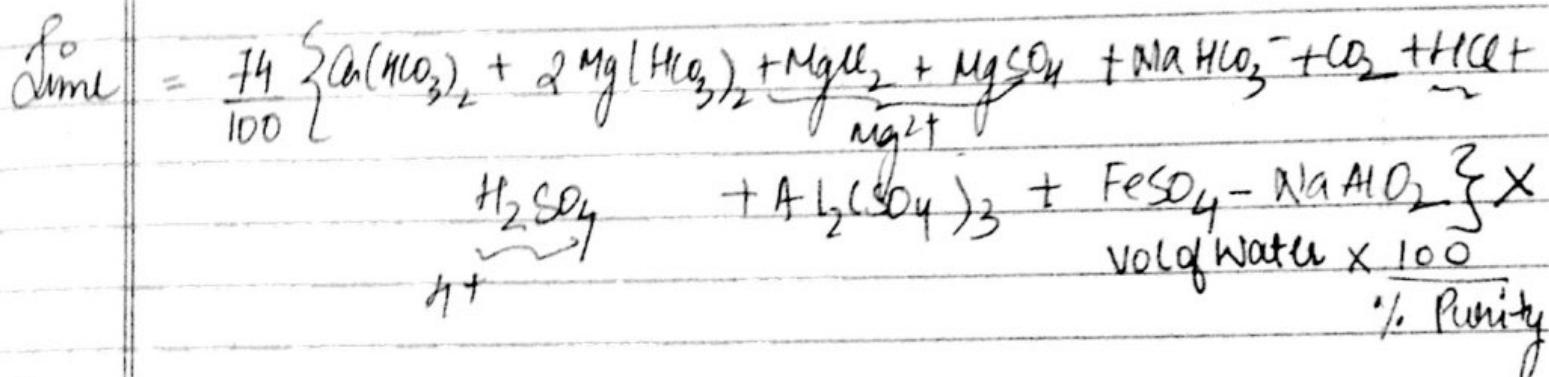
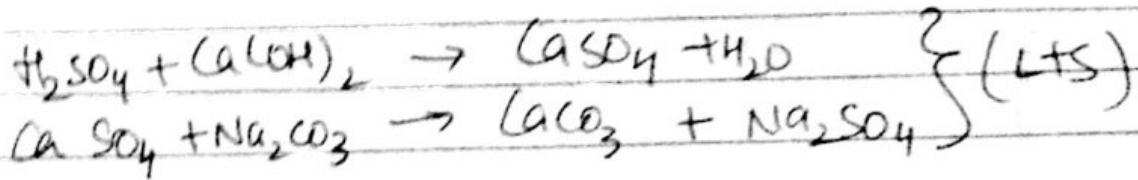
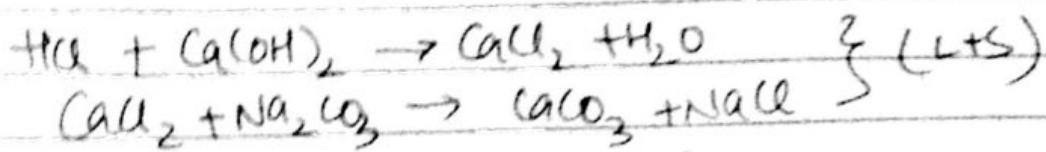


Permanent hardness :-





Acid:-



Questions: A H_2O sample contains $\text{Mg}(\text{HCO}_3)_2 = 73 \text{ ppm}$

$\text{CaCl}_2 = 222 \text{ ppm}$ $\text{MgSO}_4 = 120$ $\text{Ca}(\text{NO}_3)_2 = 164$
 If lime is 74% pure and soda is 90% pure. calculate
 the tot. amt req. for softening 5000 l of H_2O .

$$\text{Mg}(\text{NO}_3)_2 = \frac{24 \times 2 \times 50}{73} = 50$$

2L

$$\text{CaCl}_2 = \frac{232 \times 50}{55.5} = 200$$

S

$$\text{MgSO}_4 = \frac{120 \times 50}{60} = 100$$

L+S

$$\text{Ca}(\text{NO}_3)_2 = \frac{164 \times 50}{82} = 100$$

S

III formula.

$$\text{Soda} = \frac{74}{100} \left\{ 2\text{Mg}(\text{NO}_3)_2 + \text{MgSO}_4 \right\} \times V \times \frac{100}{7.1} = \frac{74}{100} \left\{ 2 \times 50 \times 100 \right. \\ \left. + \frac{X 5000 \times 100}{74} \right\} \\ = 10^6 \text{ mg} = 1 \text{ kg.}$$

$$\text{Soda} = \frac{106}{100} \left\{ \text{CaCl}_2 + \text{MgSO}_4 + \text{Ca}(\text{NO}_3)_2 \right\} \times V \times \frac{100}{7.1}$$

$$= \frac{106}{100} \left\{ 100 + 200 \right\} \times 5000 \times \frac{100}{90}$$

$$= 2.35 \times 10^6 \text{ mg}$$

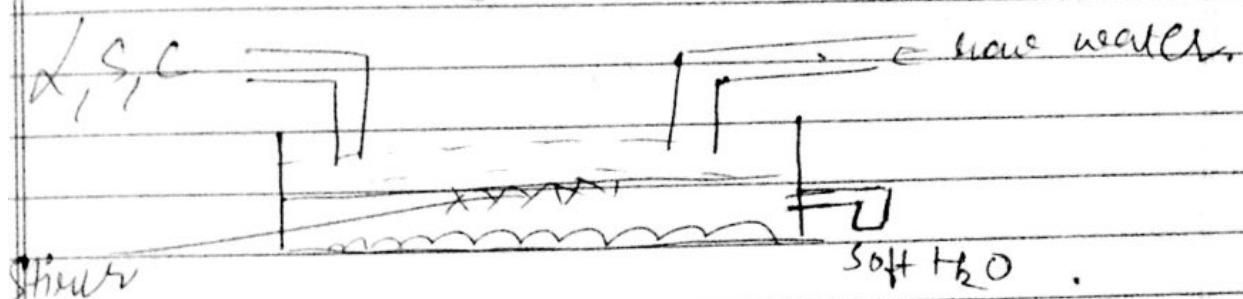
$$= 2.35 \text{ kg.}$$

January 2017.

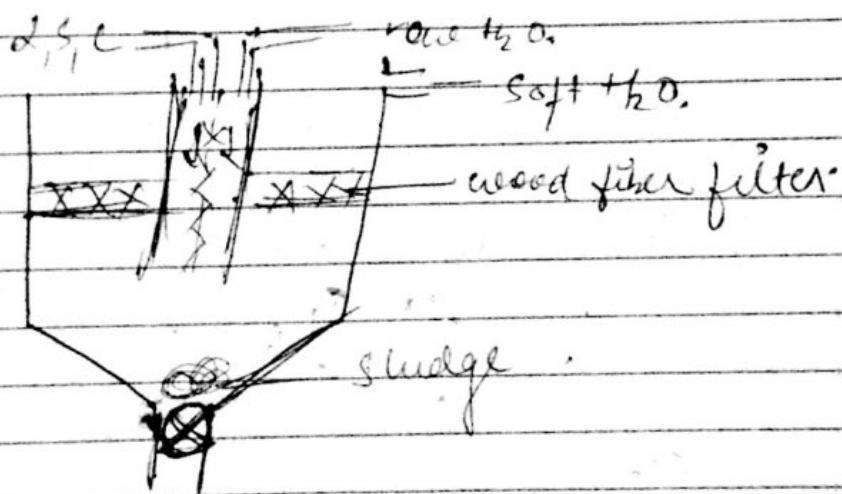
Lime Soda Process.

1) Cold L-S process

2) Batch Process.



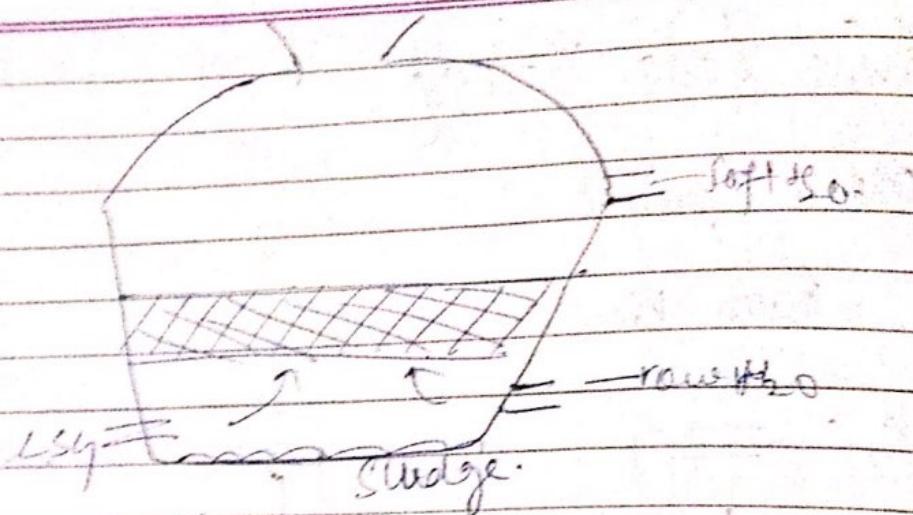
3) Continuous Process.



Sludge blanket type.

Catalyst type.

money can't buy me love ☺



Hot L-S Process

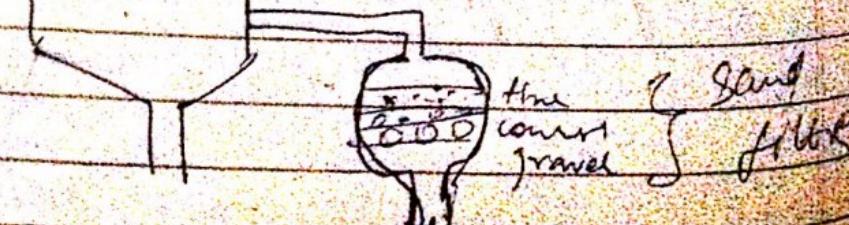
In batch Process only L,S is used.

Continuous Process.

L,S -> Super heated Steam
vess water.

Reaction tank.

Sedimentation tank.



Ques

Ques

Ans

ADVANTAGES of hot lime Soda process

faster

the settling capacity is higher because of higher
temp of water

no coagulants required

dissolved gases like CO_2 are removed
residual hardness is low.

Cold

room temp

no. coagulants

softening cap is low
slower

dissolved gases are
not removed

residual hardness is

Hot

92-100°C

no coagulants req.
soft cap is high

faster

disolved gass
are removed

R.H is 15-30%

$$\text{Mg}^{2+} = \frac{48 \times 50}{12}$$

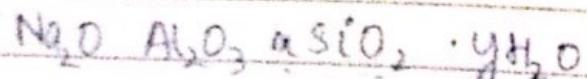
$$\text{Ca}^{2+} = \frac{16 \times 50}{20}$$

any 2017

Natural

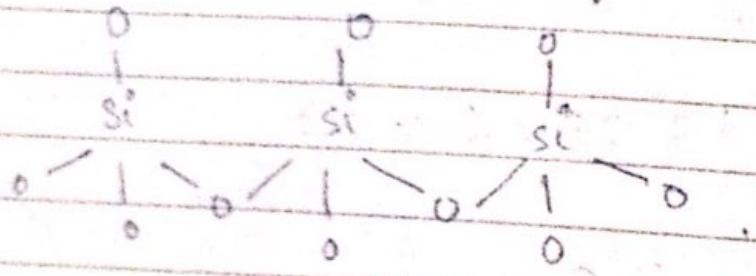
Zcolite Process → Synthetic

hydrated Sodium Aluminosilicates.

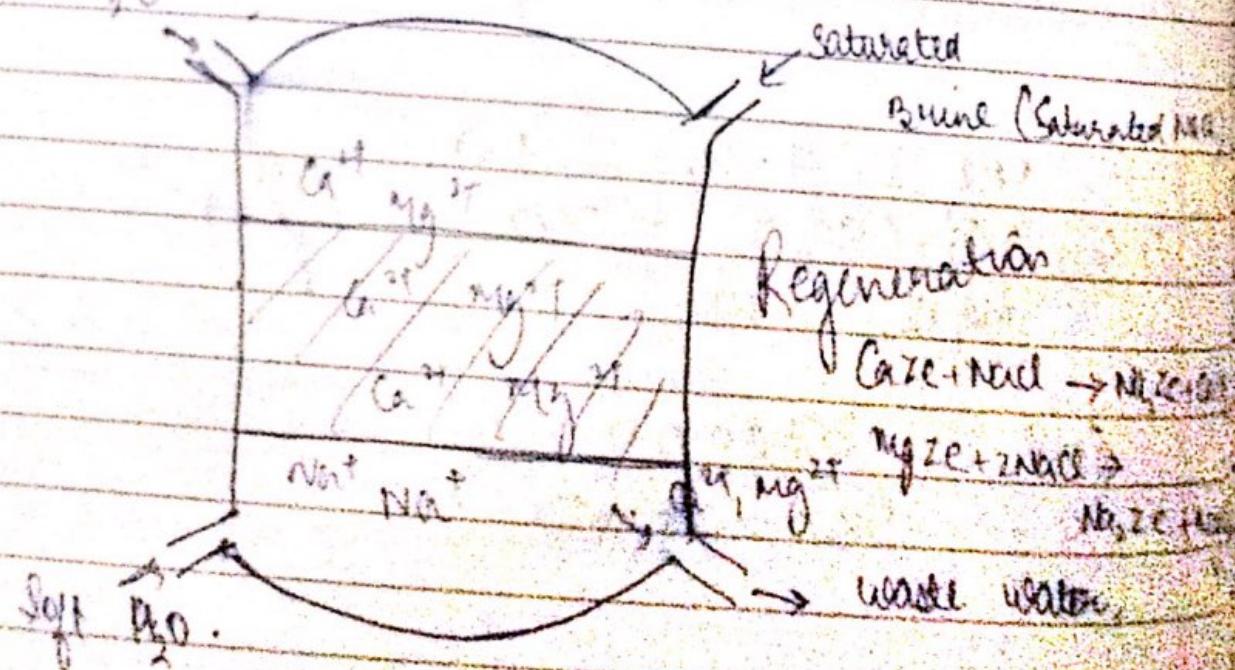


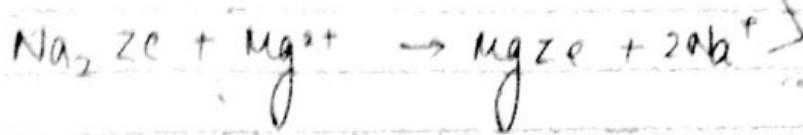
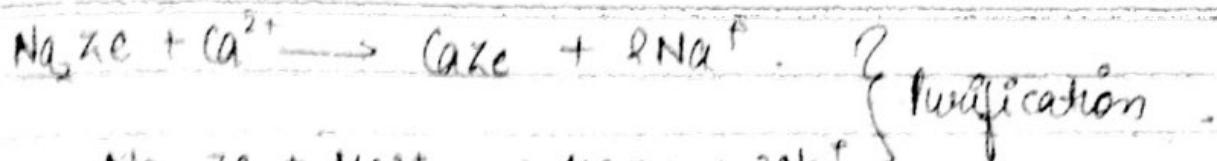
$$\alpha = 2-10$$

$$y = 2-6$$



hard H₂O





ADVANTAGES:-

- The apparatus is a compact.
- It is a clean process.
- No impurities formed so no sludge formation.
- Residual hardness is 10 ppm.

DISADVANTAGE:-

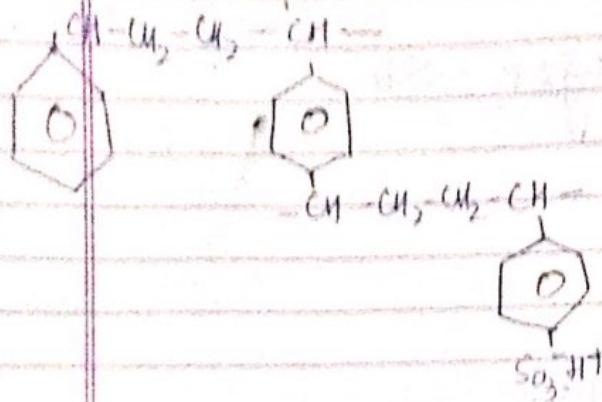
- If the water is turbid the pores may get blocked.
- Mineral acids destroy the zeolite.
- hot H₂O dissolves the zeolite.
- Presence of Mn²⁺ and Fe²⁺ are difficult to regenerate.
- Anions are not removed. Only cations are removed.

Soy Exchange Process. (Styrene dimethyl benzene)

Principle: It is the process by which ions are held on the porous insoluble solid which are exchanged for ions in the solution.

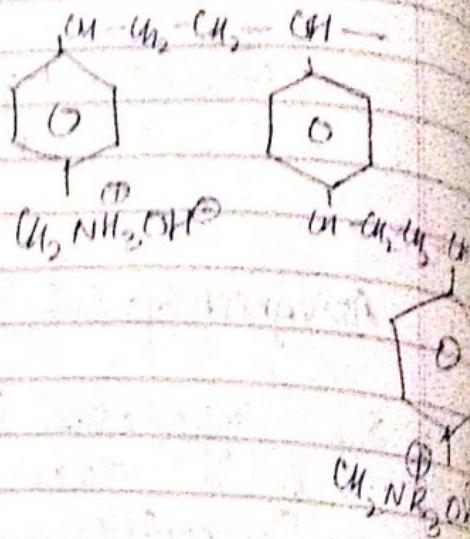
These resins are insoluble, crosslinked, high mol. wt. organic polymers.

Cationic Ion Exchange

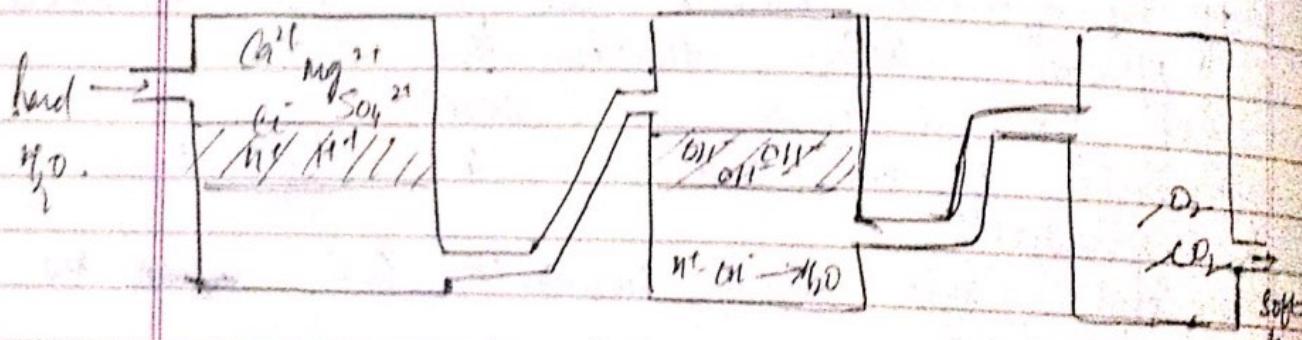


Ambipore TR-120
dowex 50

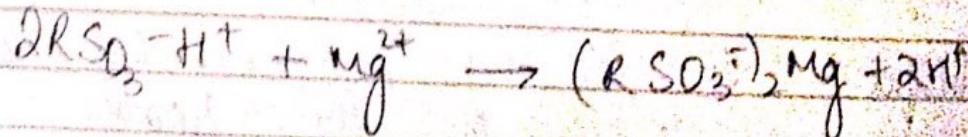
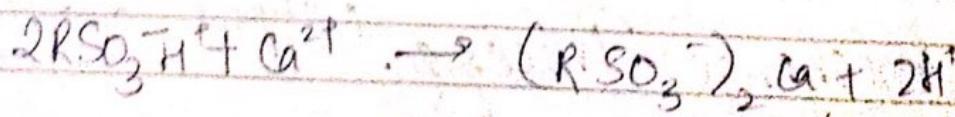
Anion exchange resin



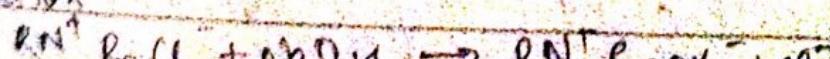
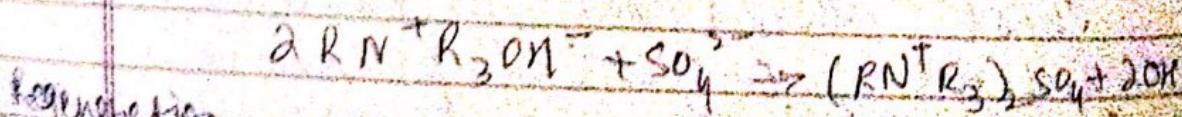
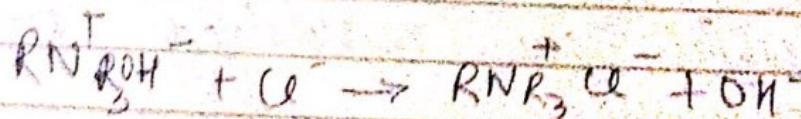
Ambipore 400
dowex 3



Cation: Regeneration: - (RSO₃⁻)₂Ca + 2HCl → RSO₃⁻H⁺ + CaCl₂



Anion:



- faster process
- more efficient as both cations and anions are removed
- residual hardness is $\approx 0\text{ppm}$

Disadvantages

- installation cost is very high
- treated water uses efficiency.

~~Q. 10000 lit of hard water was soften using a zeolite which then required 200 lit NaCl containing 150 gm/liter lit for regeneration. Ca²⁺ hardness.~~

Q. A zeolite was regenerated by passing 150 lit NaCl having strength 150 g/l of the hardness is 500 ppm what is the vol of the that can be purified.

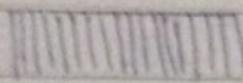
Ans: Total amt of NaCl = 200×150
 $= 30000\text{g}$

$$= \frac{30000 \times 50}{58.5} \times 10^3 \text{ mg}$$

$$\text{lit} = \frac{1500000}{585} = 2564.10$$

Domestic Water treatment :-

Scouring



2) Sedimentation

3) Sedimentation + Coagulation -

4) Filtration → Sand filter

slow

rapid

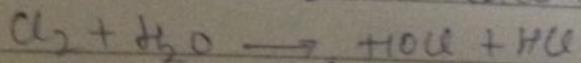
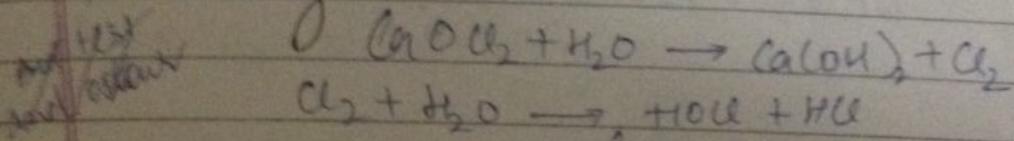
gravity

5) Disinfection -

Characteristics of a disinfectant.

- non-toxic
- economical
- must destroy pathogenic microorganisms at room temp.
- It must prevent contamination over a period of time during storage and transportation.

(i) Bleaching Powder:-



hypochlorous acid

Disadvantages:-

- In excess give bad taste and odour ^②
Stable but deteriorates with time
- ③ Introduces Ca^{2+} ions into the H_2O .

chlorine — solid

— gaseous

pH < 5 Cl₂

pH 5 - 8 HOCl

pH > 8 OCl⁻

— pH

— Hmp.

— time

But

Formation of

Destruction of

Reduction of chloramines &

chloramines to

Oxidizing chloro organic

Chloro-organic

Compounds: compounds

Compound

free residual

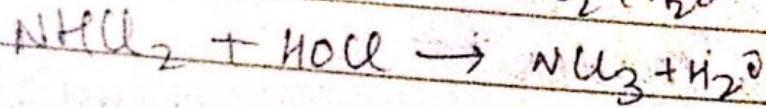
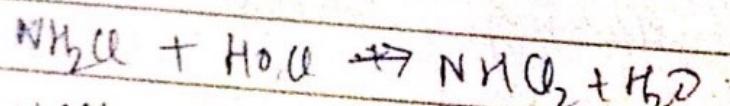
Break point

Chlorine

minimum of chlorine

to break

Applied Cl₂



Advantages of Chlorination.

- economical
- stable & doesn't deteriorate
- can be used at low & high temp
- doesn't introduce any impurities

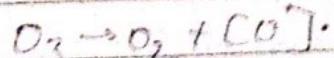
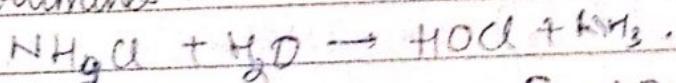
Disadvantage:-

- excess cl⁻ gives bad taste & odour.
- can cause irritation of eyes & throats
- not effective at all pH values

Dechlorination :-

- a) activated carbon.
- b) $\text{SO}_2 + \text{Cl}_2 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{SO}_4 + \text{HCl}$.
- c) $\text{Na}_2\text{SO}_3 + \text{Cl}_2 + \text{H}_2\text{O} \rightarrow \text{Na}_2\text{SO}_4 + \text{HCl}$.

(iii) Chloramines :-



- Advantages:-
- better disinfectants
 - more stable
 - don't give bad taste & odour.

(iv) Ozone $\text{O}_3 \rightarrow \text{O}_2 + [\text{O}]^{\cdot}$

(v) UV light .

(vi) KMnO₄ → wells .

Internal treatment of water.

(a) Conditioning
resin, agar-agar.

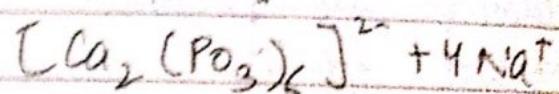
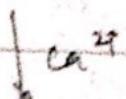
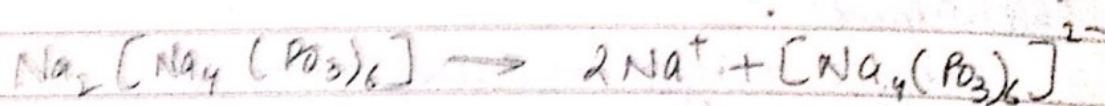
Ques

Carbonate conditioning



Calgon conditioning.

→ calcium meta phosphate.



Soluble complex.

Ques

Phosphate conditioning

Na_3PO_4 - sodium phosphate

Na_2HPO_4 - disodium hydrogen phosphate

NaH_2PO_4 - sodium dihydrogen phosphate

Ques



Iodometric
titration

Fuel

A substance which on combustion releases heat which can be used for domestic and industrial purposes.

One of the main constituents of this substance is carbon.

Natural fuels

Solid	Liquid	Gas
wood		Methane
coal		Natural gas

Synthetic fuels

Solid	Liquid	Gaseous
coke	Petrol	CNG
Charcole	Kerosene	LPG

Characteristics of a good fuel

- high calorific value
- moderate ignition temp.
- low moisture content
- non polluting by products.
- moderate velocity of combustion.
- easily available
- economical.
- easy to store & transport.

CALORIFIC VALUE:-

It's the amount of heat liberated per unit mass of the fuel burnt.

High/Gross Cal Value

It is the amount of heat liberated

When a unit mass of a fuel is

Burnt completely and the products are cooled back to room temp.

Low/Wet Cal Value

It is the amount of heat given out when a unit mass of a fuel is burnt completely at the

temperature at which water vapour escape.

units of heat .

Calorie : The amt of heat req. to raise the temp. of 1g. of H₂O by 1°C.

Kcal : amt of heat req. to raise the temp. of 1kg of H₂O by 1°C.

British thermal unit : The amt of heat required to raise the temp. of 1 pound of H₂O by 1°F.

Centigrade heat unit : - amt of heat req. to raise the temp. of 1 pound of H₂O by 1°C.

Determination of CV.DULONG'S FORMULA.

$$HCV = \frac{1}{100} \{ 80800C + 34500(H - \frac{O}{8}) + 2240S \}$$

$$\Delta CV = HCV - \text{mass of hyd} \times 9 \times 587$$

$$\left(\frac{1-H}{100} \right)$$

\hookrightarrow different

heat of steam

Combustion \rightarrow O₂ — air.

22.4 L of gas at 0°C and 160 mm pressure has a mass = 1 mole.

Air contains 21% oxygen by volume and 23% oxygen by weight.

$$1 \text{ m}^3 \text{ of O}_2 \rightarrow 4.76 \text{ m}^3 \text{ air}$$

$$1 \text{ kg of O}_2 \rightarrow 4.35 \text{ kg of air}$$

The molar mass of air is 29.94 g.

The min O₂ required for comb = theoretical

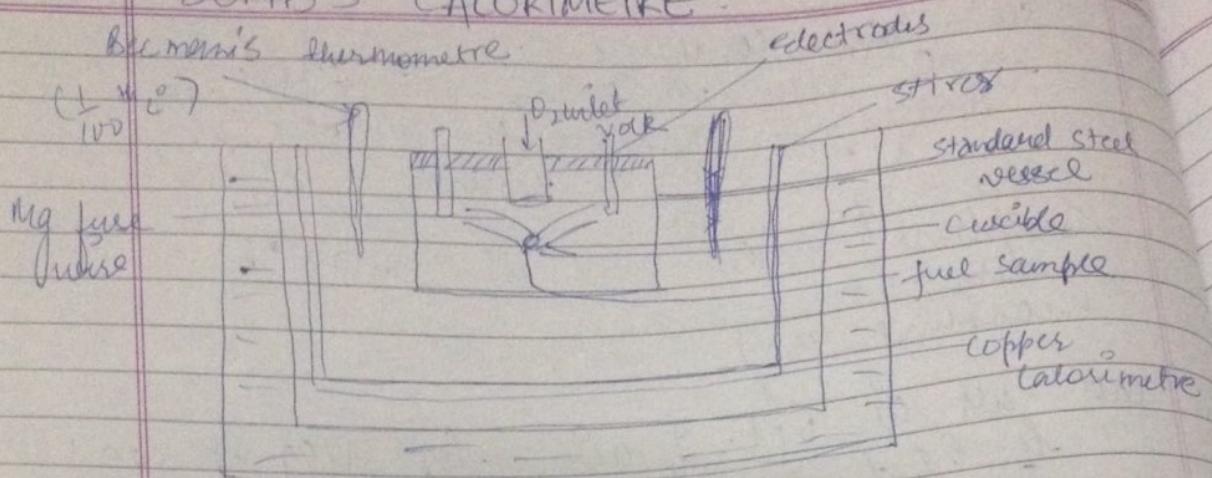
Oxygen = O₂ mole
present
by weight

Moles of gas can be converted to vol of a given temp and pressure by assuming that the gas behaves ideally.

Hydrogen in the sample is present in the free form or combined form.
Combined hydrogen is not combustible.

BOMB'S CALORIMETRE

Becquerel's thermometer



Principle Heat loss = heat gained

$$\text{Heat loss} = (W + w)(t_2 - t_1)$$

$$\frac{\text{Heat loss}}{\text{Heat value}} = \frac{(W + w)(t_2 - t_1)}{\text{cal value} \times \text{wt of } H_2O}$$

Water equivalent
 (heat stored thermally
 censitile)

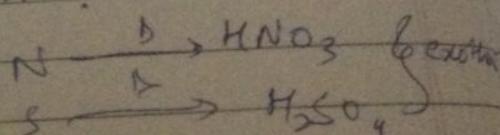
$$L_{CVR} = \frac{(W + w)(t_2 - t_1)}{x}$$

$$L_{CVR} = HCV - \frac{H}{100} \times 9 \times 587$$

Corrections

① fuse were correction

② fluid correction



$$1 \text{ ml } \frac{N}{10} \text{ HNO}_3 = 1.43 \text{ cal}.$$

$$1 \text{ mg S} = 2.25 \text{ cal}.$$

(b) Cooling correction

$$HCV = (w+w_e) (t_s - t_f + \text{cooling correction})$$

- (Acid + fuse ash correction)

$$n = 9305.2 - \frac{8}{100} \times 9 \times 582$$

Ques A sample of coal contained carbon 89% hydrogen 1% and ash content 3%.
Wet coal taken 0.85 g
wet of $H_2O = 650 \text{ g}$.

$$H_2O \text{ equiv value} = 2500 \text{ g}.$$

$$\text{Rese in temp} = 2.5^\circ\text{C}.$$

$$\text{cooling corr} = 0.03^\circ\text{C}.$$

$$\text{false ash} = 1 \text{ cal}.$$

$$\text{Acid corr} = 50 \text{ cal}.$$

initial

HCV? LCV?

2.5.

$$HCV = (650 + 2500) (2.53 + 0.03)$$

~~2.53~~
~~2.53~~

$$63150 (2.53) - (50 + 0.05)$$

~~10~~
50.25