Unit – IV

Advanced water Treatment:

Aeration:-

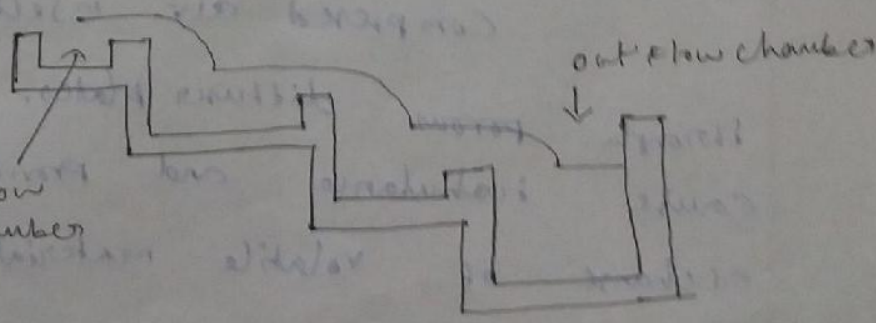
This method of supplying air for the process is known as aeration.

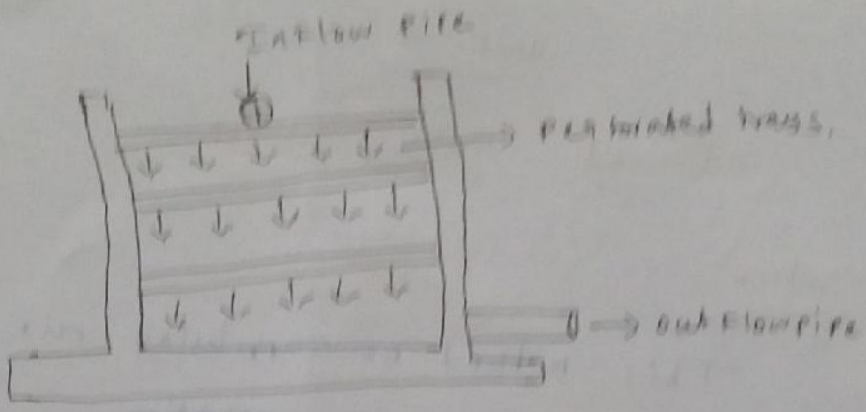
Types of aerators:-

(i) Gravity Aerators:-

Those forming drops or thin of water exposed to the atmosphere to come with ambient air. They utilize weirs, water falls, cascades, vertical towers with uplift air, perforated towers filled with contact media such as coke or stone.

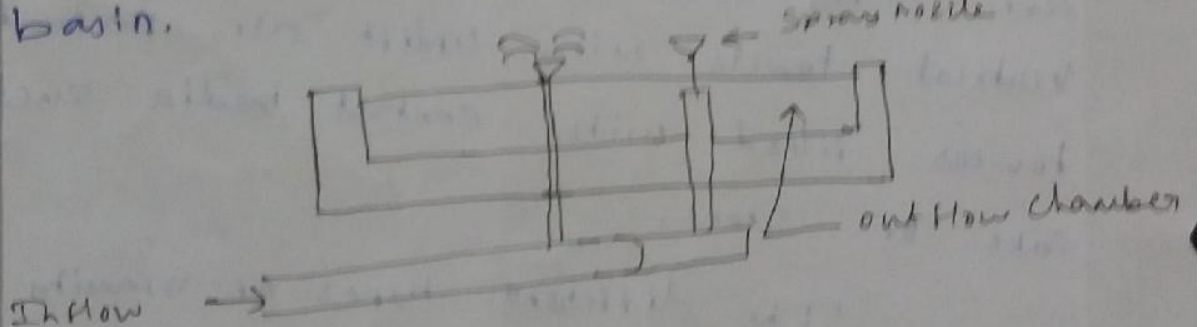
The different types of gravity aerators are (i) Cascade ii) apron iii) tower. iv) multiple tray.





(ii) Spray aerators:-

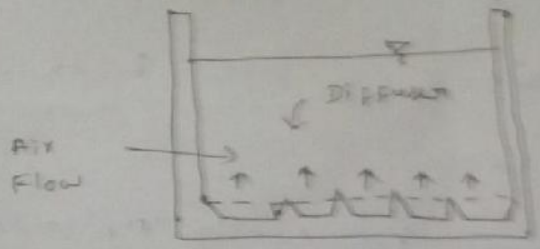
Spray aerators spray droplets of water into air from moving stationary orifice or nozzle. The water rises either vertically or at an angle and falls into a collecting apron or collecting basin.



Spray aerator.

(iii) Diffused - air aerators:-

Compressed air injected into the tank through porous diffuser plates. Ascending air bubbles cause turbulence and provide opportunity for exchange of volatile materials between air and

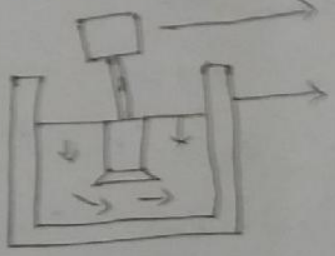


Diffused aeration

(ii) Mechanical Aeration:-

Mechanical aerators employ either motor driven impeller or a combination of impeller with air injection devices.

Common types of devices are submerged paddles, surface paddles, turbine aerators, draft tube aerators.



Removal of Iron & manganese from water:-

Iron & manganese salts are generally found in dissolved state. when their content exceed about 0.3 mg/L & 0.05 mg/L, they become objectionable, due to the following reasons.

(i) They cause discoloration of clothes in such waters due to red or brown

(ii) They cause incrustation of water mains due to deposition of ferric hydroxide & manganese oxide.

(iii) They make the water unpleasant in taste.

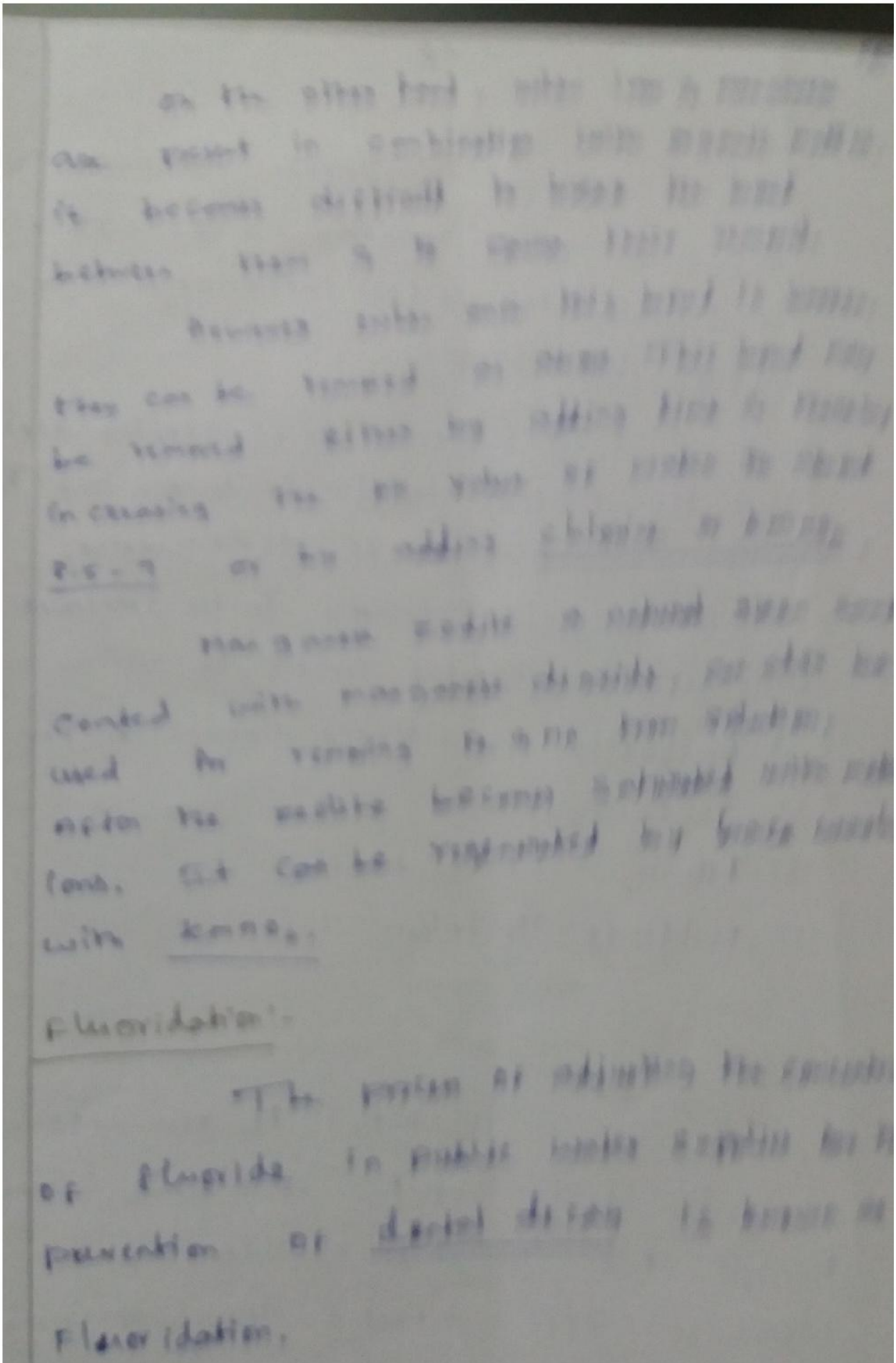
(iv) They reduced iron in water promotes the growth of autotrophic bacteria in distribution mains.

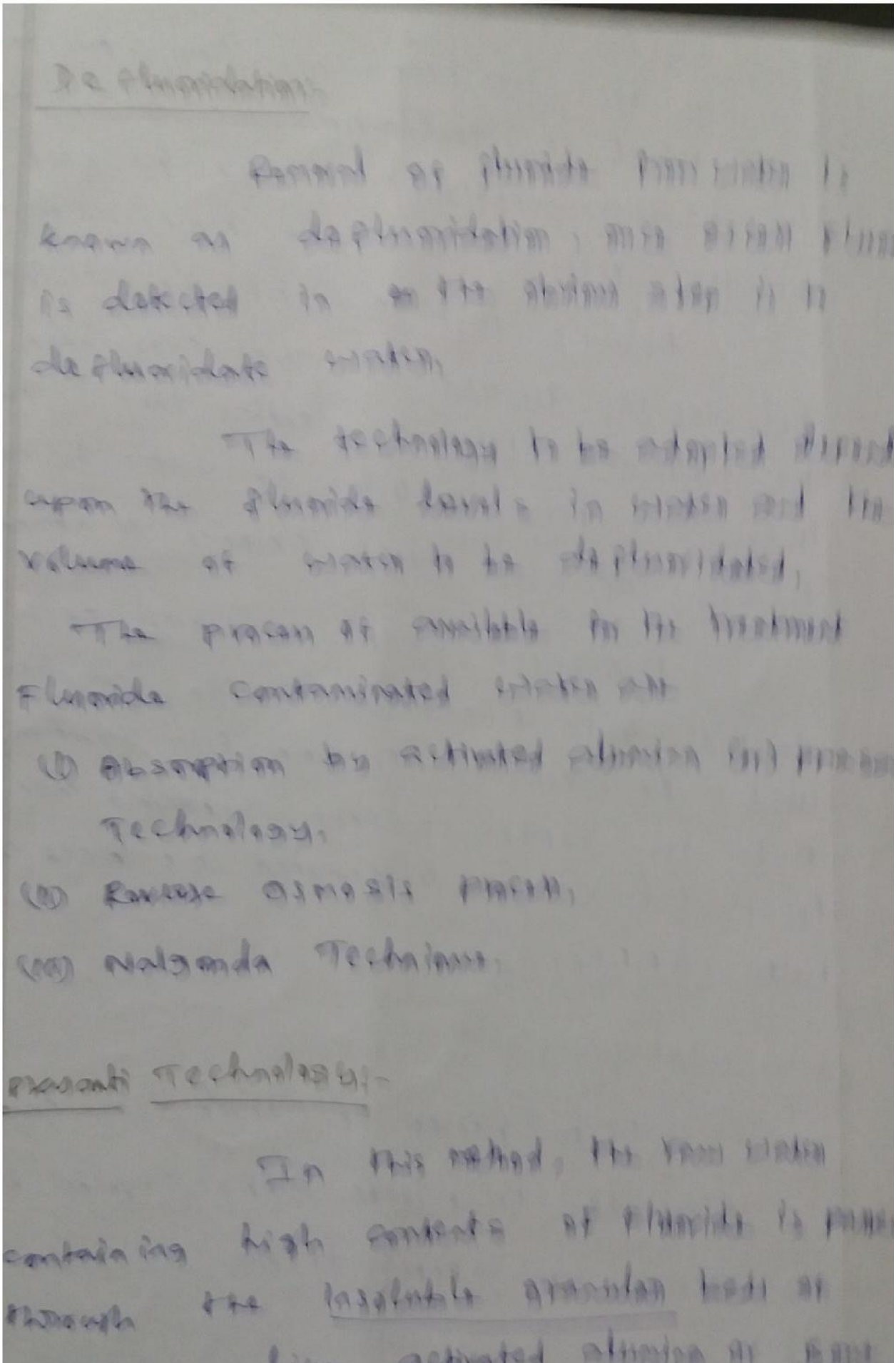
(v) Periodic flushing of small distribution pipes may be effective in removing accumulated of rust particles. However elimination of iron bacteria is generally difficult & expensive.

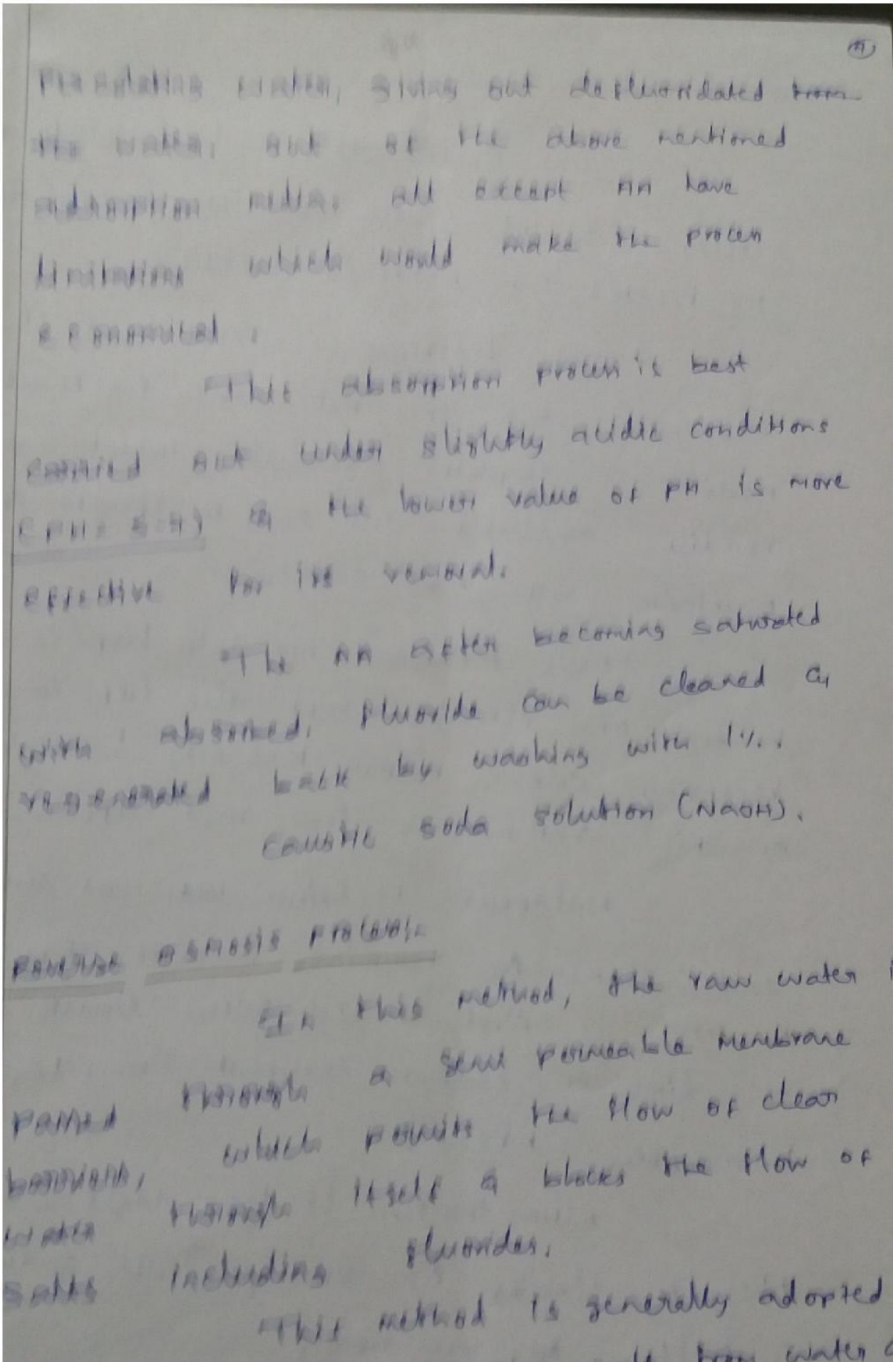
(vi) The iron and manganese may be present in water either in combination with organic matter or without such combination when present without combination with org matter.

(vii) They can be easily removed by aeration followed by coagulation, sedimentation & Filtrati

(viii) During aeration, the soluble ferrous manganous compounds present in the water may into insoluble ferric & manganic







(47)

Precipitating fluoride, giving out defluoridated from the water. But of the above mentioned adsorption media all except AA have limitations which would make the process economical.

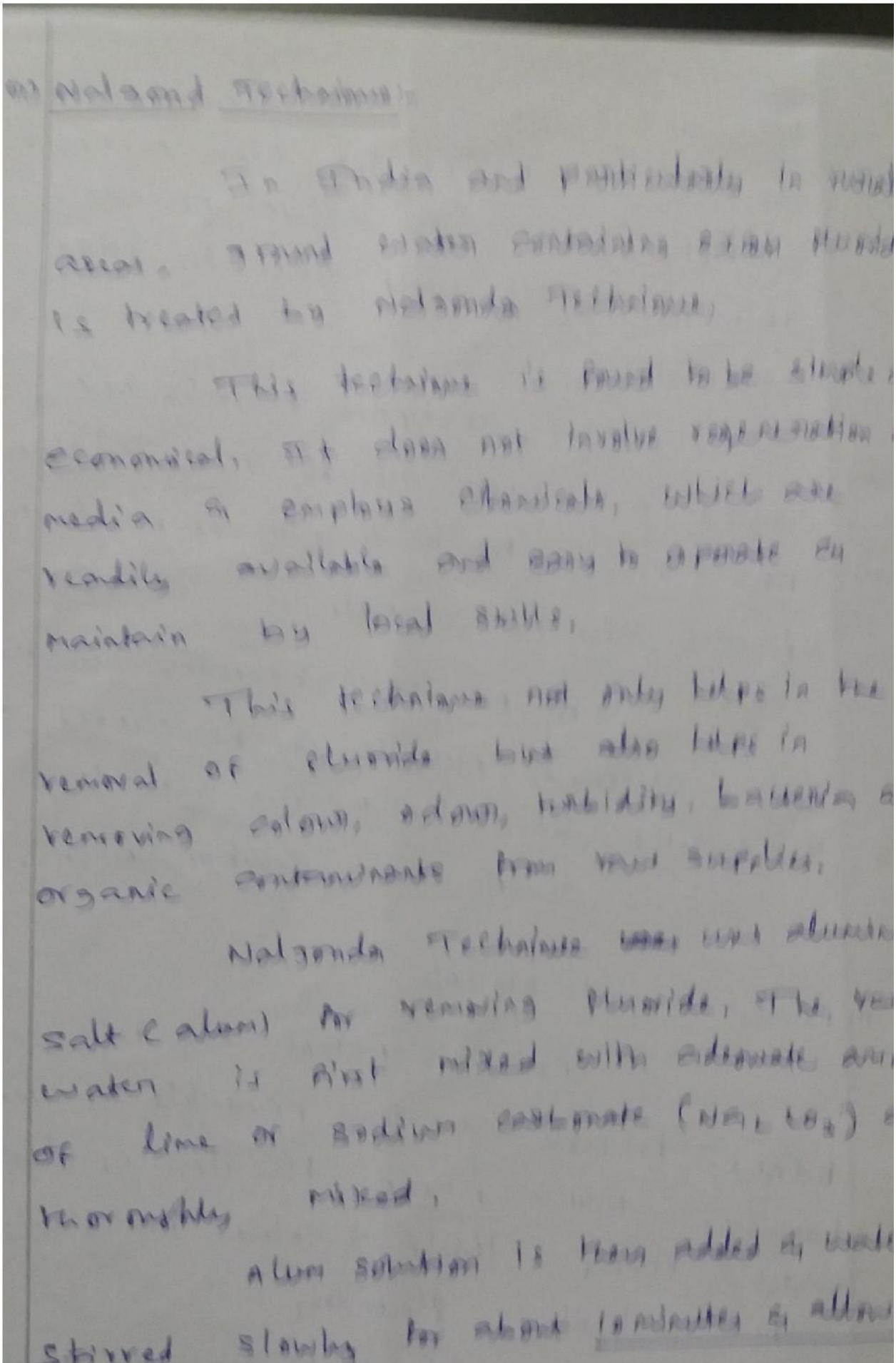
The absorption process is best carried out under slightly acidic conditions (pH = 5-6) & the lowest value of pH is more effective for the removal.

The AA after becoming saturated with absorbed fluoride can be cleared & regenerated back by washing with 1% caustic soda solution (NaOH).

REVERSE OSMOSIS PROCESS:

In this method, the raw water is passed through a semi permeable membrane which permits the flow of clear water through it & blocks the flow of salts including fluorides.

This method is generally adopted



discarded and the clear supernatant containing permissible amount of fluoride is withdrawn for use.

The added lime or Na_2CO_3 helps to ensure adequate alkalinity required for effective hydrolysis of aluminium salts, so that the residual aluminium does not remain in the treated water.

× — × — ×

Desalination:-

Desalination is a process that removes dissolved minerals from seawater, salinity content (or) salt content more in brackish water or treated waste water.

The technologies generally adopted for the desalination of saline water into fresh water are as follows.

(i) Distillation.

(ii) Reverse osmosis.

(iii) Electrodialysis method.

(iv) Freezing process.

The effective weight of the particle

= Total wt − Buoyancy

$= \frac{4}{3}\pi r^3 \gamma_s - \frac{4}{3}\pi r^3 \gamma_w$

$\gamma_s \rightarrow$ unit wt. of particle.

$\gamma_w \rightarrow$ unit wt. of water.

$= \frac{4}{3}\pi r^3 (\gamma_s - \gamma_w)$ — (2)

Eqn (1) + (2) will become equal when γ becomes equal V_s in Eqn (1)

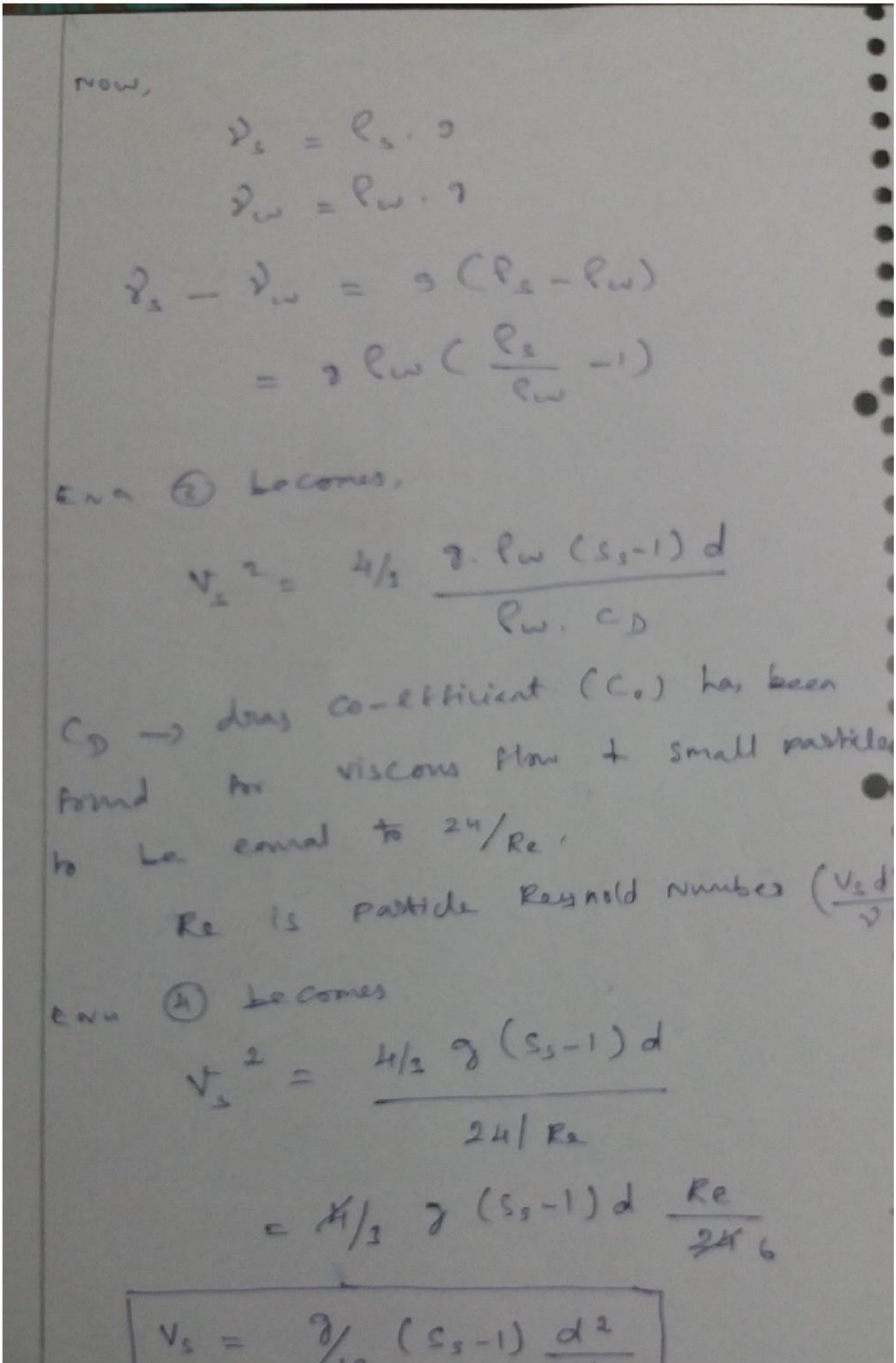
$$C_D A \rho_w \frac{V_s^2}{2} = \frac{4}{3}\pi r^3 [\gamma_s - \gamma_w]$$

$A = \pi r^2$

$$C_D \pi r^2 \rho_w \frac{V_s^2}{2} = \frac{4}{3}\pi r^3 [\gamma_s - \gamma_w]$$

$$V_s^2 = \frac{4}{3} \frac{r(\gamma_s - \gamma_w)}{\rho_w \cdot C_D} \cdot 2$$

$$V_s^2 = \frac{\frac{4}{3} \cdot (\gamma_s - \gamma_w) \cdot d}{\rho_w \cdot C_D} \quad \text{— (3)}$$



Now,

$$\gamma_s = \rho_s \cdot g$$

$$\gamma_w = \rho_w \cdot g$$

$$\gamma_s - \gamma_w = g(\rho_s - \rho_w)$$

$$= g\rho_w\left(\frac{\rho_s}{\rho_w} - 1\right)$$

Eqn (2) becomes,

$$V_s^2 = \frac{4}{3}\,\frac{g \cdot \rho_w (S_s - 1)\, d}{\rho_w \cdot C_D}$$

C_D → drag co-efficient (C_D) has been found for viscous flow & small particles to be equal to $24/Re$.

Re is particle Reynold Number $\left(\frac{V_s d}{\nu}\right)$

Eqn (4) becomes

$$V_s^2 = \frac{4/3\; g\,(S_s - 1)\, d}{24/Re}$$

$$= \frac{4}{3}\,g\,(S_s - 1)\,d\,\frac{Re}{24}$$

$$\boxed{V_s = \frac{g}{18}\,(S_s - 1)\,d^2}$$

Distillation:-

Distillation involves the evaporation of water. The evaporated water leaves behind all hardness compounds and becomes soft.

Distillation plants produce a high-quality product water that ranges from 1 to 50 ppm TDS.

In distillation process, feed water is heated and evaporated to steam and separating out the dissolved minerals.

The steam is then condensed & collected as product water. when the water is boiled most contaminants do not vaporize & therefore do not pass to the condensate. The most common methods of distillation include solar distillation multistage flash distillation.

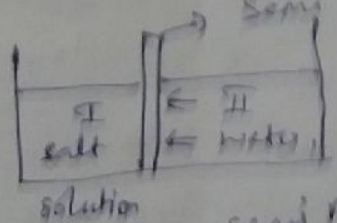
Multi flash Distillation:-

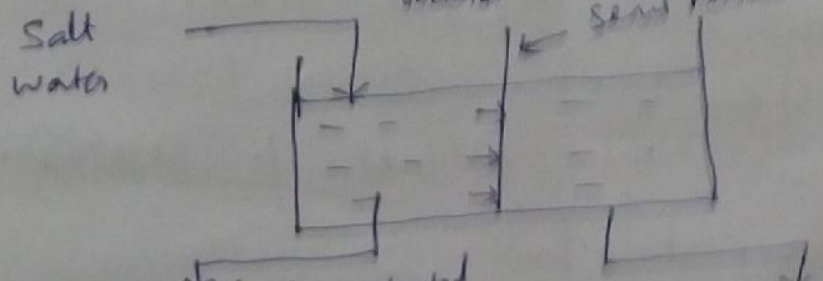
In multistage flash distillation the feed water is heated & the pressure is lowered so the water flashed into steam. This

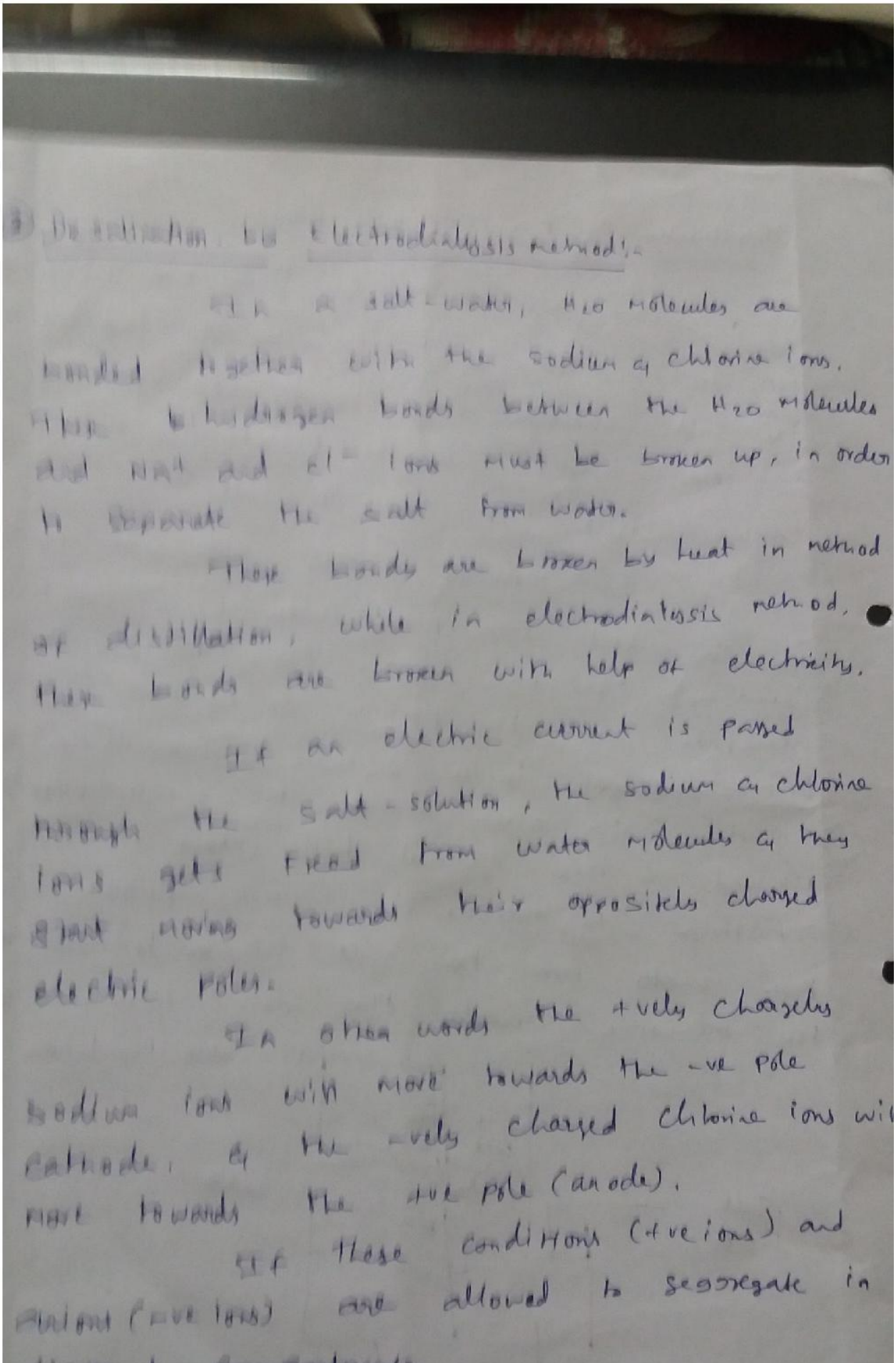
Desalination by Reverse osmosis Process:

In this method of desalination, the water molecules and the salt ions are separated by forcing the salt solution against a semi permeable membrane barriers, which permits the flow of water through itself but stops the salt.

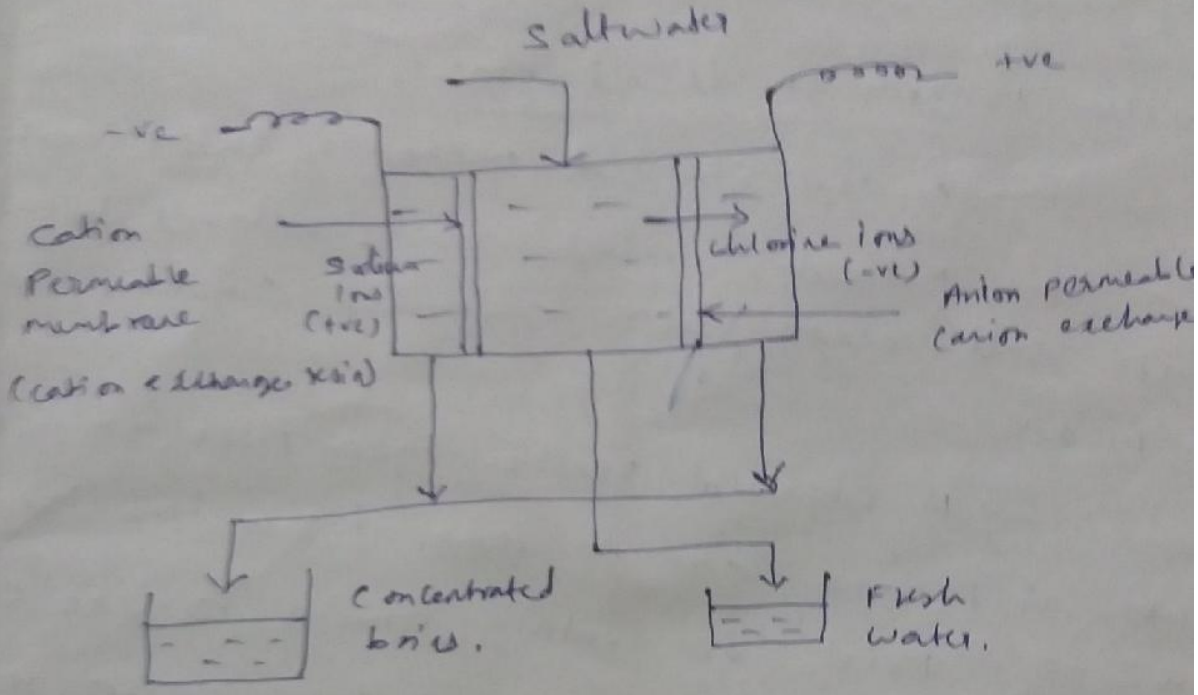
In ordinary osmosis when salt solution is separated from pure water by a semi permeable membrane, the pure water flows across the membrane until the pressure on the pure water become equal to the osmotic pressure of the salt solution. In other words, the osmotic pressure is reversed & this external high pressure working in opposition to natures low-osmotic pressure, forces pure water from the salt solution to pure water through the membrane towards the side containing pure water.







The segregation is achieved by means of thin plastic like sheets called membrane. They are made of peculiar chemical substance called ion exchange resins.



Desalination by Freezing process:-

This method is based upon the fact that when salt water freezes, the ice formed begining is almost free from salt. This ice, when melted, can give good water. A plant using this principle has been in United States.

The quality of water obtained

5) Solar distillation method:-

This is an ancient method but remai
ignored for many years, because it seemed to b
an impractical method for providing large quantitie
of water at reasonable cost.

6) other methods of desalination:-

A new chemical method is under investiga
In this method, propane gas is allowed to come
with salt water under controlled condition of
& pressure.

A chemical reaction takes place b/w salt
water & propane gas at temp. higher than the
freezing point of water, forming ice like cry
These crystals reject the salt & accept only
pure water in their composition.

Demineralization:-

Demineralization or deionization of
water is the removal of essentially all ions in
salt by ion exchange.

(14)

Ion Exchange process:-

It is another effective and economical process, for removal of nitrate from drinking water as also removal of nitrate from drinking water as also remove undesired ions such as Ca^{2+}, Mg^{2+}, Fe^{2+}, Mn^{2+}, NH_4^+, NO_3^-, F and other cations and anions. Ion exchange is also used to demineralise the water.

In both case, the ion exchange medium consists of (i) solid phase

(ii) a mobile ion attached to an immobile functional group. The mobile ions in the resins are exchanged with ions in the water. The spent resins is regenerated as revised. The ion exchange system can be either operated in batch mode or continous mode.

The exchange resins are cationic or anionic resins exchange position ions and anionic resins exchange negative ions. Sodium cation exchangers remove hardness causing bivalent cation as replace them with Sodium ions available in market.

The bed is regenerated with Nacl solution
If hydrogen ions are exchanged for various
positive ions present in water (Ca^{2+}, Mg^{2+}).
The hydrogen cation exchanger is regenerated w
a mineral acid (H_2SO_4).

Weakly Basic Anion Exchanger:-

Reaction with Acid:-

$2\,RNH_3OH + H_2SO_4 \longrightarrow (RNH_3)_2SO_4 + 2H_2O$

Anion Exchanger (Insoluble)
H_2SO_4
2HCl
$2HNO_3$
Acid (Soluble)
$(RNH_3)_2SO_4$
$2\,RNH_3Cl$
$2\,RNH_3NO_3$
(Anion Exchanger with acid) (Insoluble.

Regeneration:-

$(RNH_3)_2SO_4 + NA_2CO_3 \longrightarrow 2\,RNH_3OH + NA_2SO_4.$

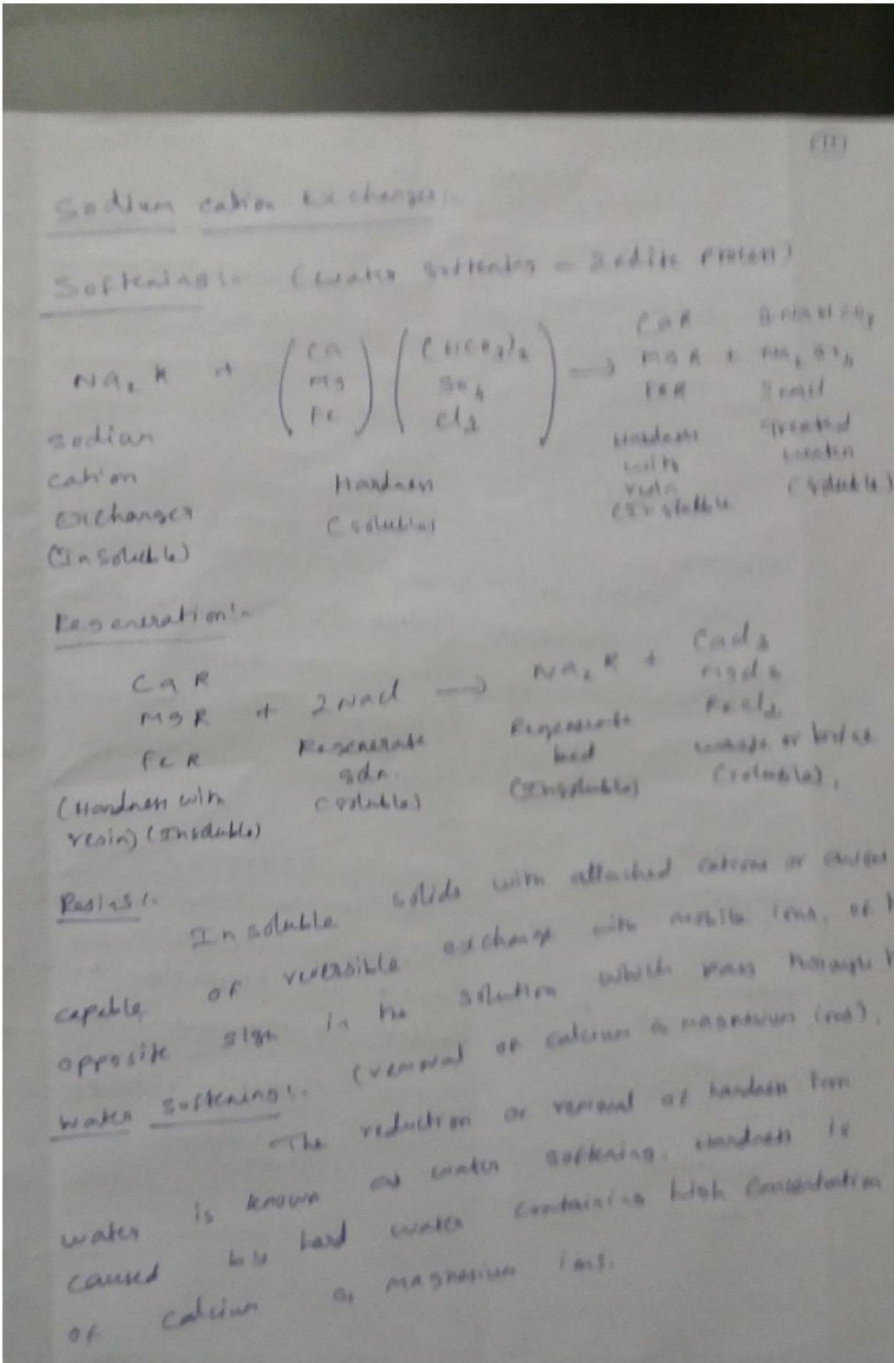
$2NH_3Cl$
$2NH_3NO_3$
Regeneration Soln (Soluble)
(Insoluble) 2Nacl + CO

Strong Basic Anion Exchanger:-

Reaction:- with acid

$2\,RNOH + H_2SO_4 \longrightarrow (RN)_2SO_4 + 2H_2$

Anion Exchanger (Insoluble)
H_2SO_4
2HCl
$2HNO_3$
$2H_2CO_3$
$2H_2SiO_3$
$(RN)_2SO_4$
2RNCl
$2RNHCO_3$
$2RNO_3$
$2RNHSiO_3$



(11)

Sodium cation exchange:-

Softening:- (water softening = Zeolite Process)

NA_2R + $\begin{pmatrix} Ca \\ Mg \\ Fe \end{pmatrix}\begin{pmatrix} (HCO_3)_2 \\ SO_4 \\ Cl_2 \end{pmatrix}$ → $\begin{matrix} CaR \\ MgR \\ FeR \end{matrix}$ + $\begin{matrix} NaHCO_3 \\ Na_2SO_4 \\ NaCl \end{matrix}$

Sodium cation exchanger (Insoluble) — Hardness (soluble) — Hardness with resin (Insoluble) — Treated water (soluble)

Regeneration:-

$\begin{matrix} CaR \\ MgR \\ FeR \end{matrix}$ + 2NaCl → NA_2R + $\begin{matrix} CaCl_2 \\ MgCl_2 \\ FeCl_2 \end{matrix}$

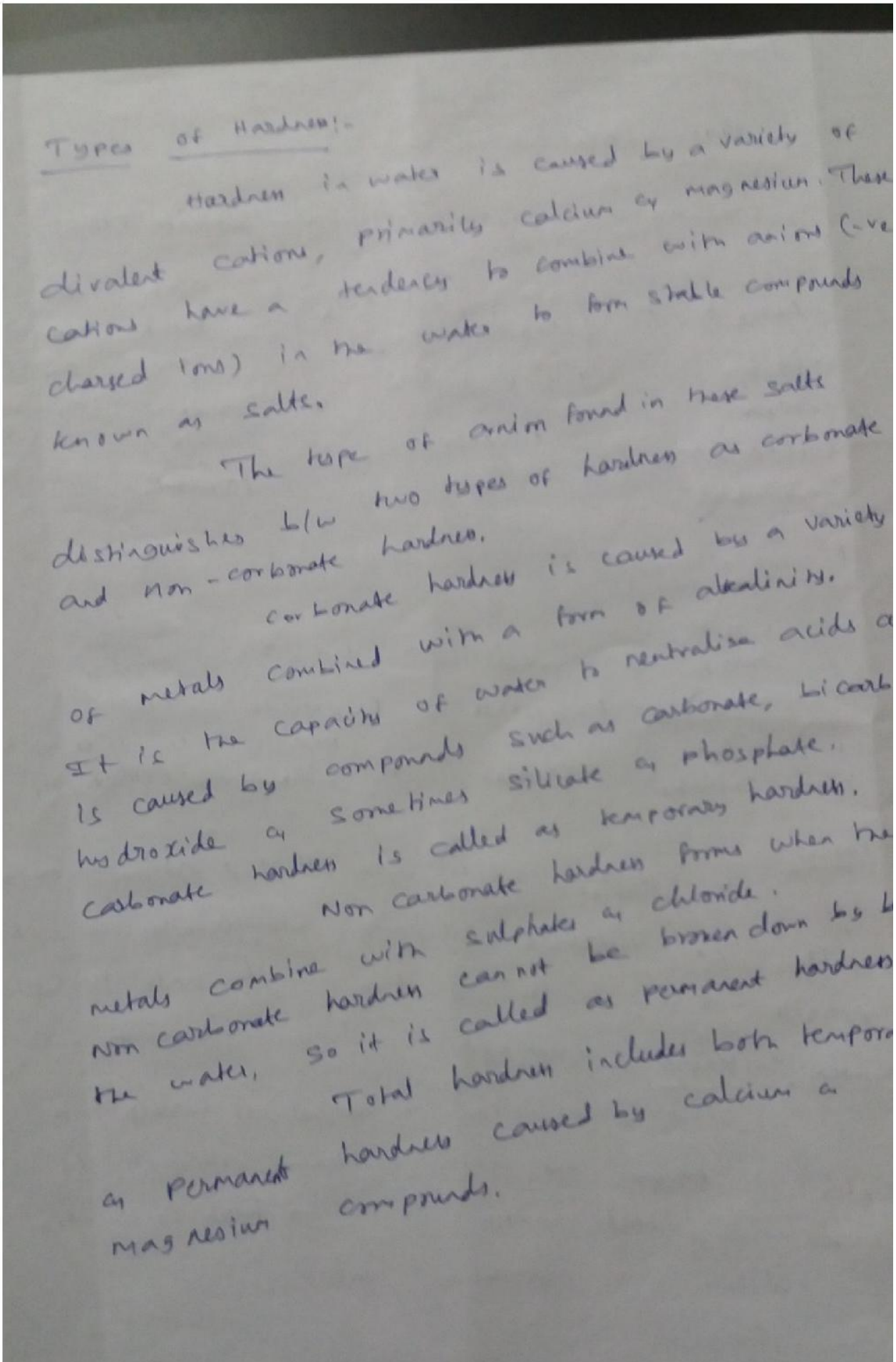
(Hardness with resin) (Insoluble) — Regenerate Nacl (soluble) — Regenerate bed (Insoluble) — waste or brine (soluble).

Basics:-

Insoluble solids with attached cations or anions capable of reversible exchange with mobile ions of opposite sign in the solution which pass through it.

Water softening:- (removal of calcium & magnesium ions).

The reduction or removal of hardness from water is known as water softening. Hardness is caused by hard water containing high concentration of calcium or magnesium ions.



Types of Hardness:-

Hardness in water is caused by a variety of divalent cations, primarily calcium & magnesium. These cations have a tendency to combine with anions (-ve charged ions) in the water to form stable compounds known as salts.

The type of anion found in these salts distinguishes b/w two types of hardness as carbonate and non-carbonate hardness.

Carbonate hardness is caused by a variety of metals combined with a form of alkalinity.

It is the capacity of water to neutralise acids a is caused by compounds such as carbonate, bicarb hydroxide & sometimes silicate & phosphate.

Carbonate hardness is called as temporary hardness.

Non carbonate hardness forms when the metals combine with sulphates & chloride. Non carbonate hardness cannot be broken down by b the water. So it is called as permanent hardness

Total hardness includes both tempora & permanent hardness caused by calcium & magnesium compounds.

(11)

Method of removing Temporary Hardness:-

(i) Boiling:-

Calcium carbonate being only slightly soluble will usually exists in water as calcium bicarbonates because it easily dissolved in natural waters containing carbon-di-oxide. when such water is boiled the CO_2 gas will get out, Loading to precipitation of $CaCO_3$. which can be sedimented out in settling tank. The reaction can be presented as.

$$Ca(HCO_3)_2 + \text{Heat} \rightarrow \underset{\text{Cal. carbonate (insoluble).}}{CaCO_3 \downarrow} + CO_2 \uparrow + H_2O$$

(ii) Addition of Lime:-

Lime (CaO), generally hydrated lime $Ca(OH)_2$ is added to water. The following reaction takes place.

$$MgCO_3 + Ca(OH)_2 \rightarrow \underset{\text{insoluble}}{Mg(OH)_2 \downarrow} + \underset{\text{insoluble}}{CaCO_3 \uparrow}$$

$$Mg(HCO_3)_2 + Ca(OH)_2 \rightarrow Ca(HCO_3)_2 + Mg(OH)_2$$

$$Ca(HCO_3)_2 + Ca(OH)_2 \rightarrow 2CaCO_3 \downarrow + 2H_2O.$$

Methods of removing permanent Hardness:-

The permanent hardness is more permanent and difficult to remove. It can removed by certain special methods, It is called as water softening methods.

Lime - soda process:-

In this process, lime $Ca(OH)_2$ and soda Na_2CO_3 are added to the hard water, which react with the calcium and magnesium salts so as to form insoluble precipitates of calcium carbonate and magnesium hydroxide ($Mg(OH)_2$).

These precipitate can be sedimented out in a sedimentation tank. The chemical reaction which may be involved are.

(i) $Ca(HCO_3)_2 + Ca(OH)_2 \rightarrow 2CaCO_3 \downarrow + 2H_2O$

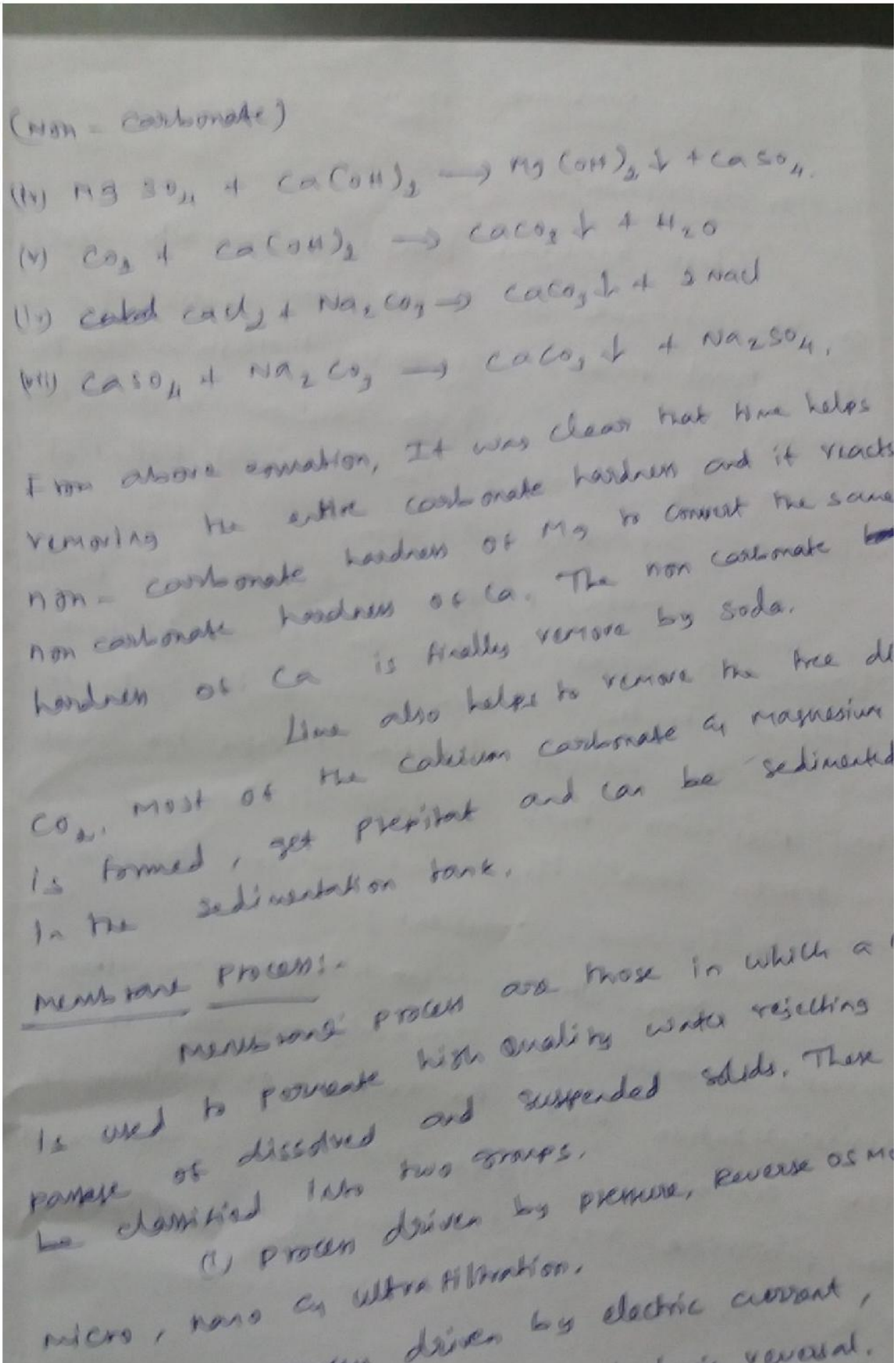
Lime

(ii) a) $Mg(HCO_3)_2 + Ca(OH)_2 \rightarrow Ca(HCO_3)_2 + Mg(OH)_2 \downarrow$

$MgCO_3 + Ca(OH)_2 \rightarrow Mg(OH)_2 \downarrow + CaCO_3$

$MgCl_2 + Ca(OH)_2 \rightarrow Mg(OH)_2 \downarrow + CaCl_2$

(iii)



(Non - Carbonate)

(iv) $MgSO_4 + Ca(OH)_2 \rightarrow Mg(OH)_2 \downarrow + CaSO_4$.

(v) $CO_2 + Ca(OH)_2 \rightarrow CaCO_3 \downarrow + H_2O$

(vi) $CaCl_2 + Na_2CO_3 \rightarrow CaCO_3 \downarrow + 2NaCl$

(vii) $CaSO_4 + Na_2CO_3 \rightarrow CaCO_3 \downarrow + Na_2SO_4$.

From above equation, It was clear that lime helps removing the either carbonate hardness and it reacts non-carbonate hardness of Mg to convert the same non carbonate hardness of Ca. The non carbonate hardness of Ca is finally remove by soda.

Lime also helps to remove the free CO_2. Most of the calcium carbonate & magnesium is formed, get precipitat and can be sedimented in the sedimentation tank.

Membrane Process:-

Membrane process are those in which a is used to separate high quality water rejecting some of dissolved and suspended solids. These can be classified into two groups.

(i) Process driven by pressure, Reverse osmosis micro, nano & ultra filtration.

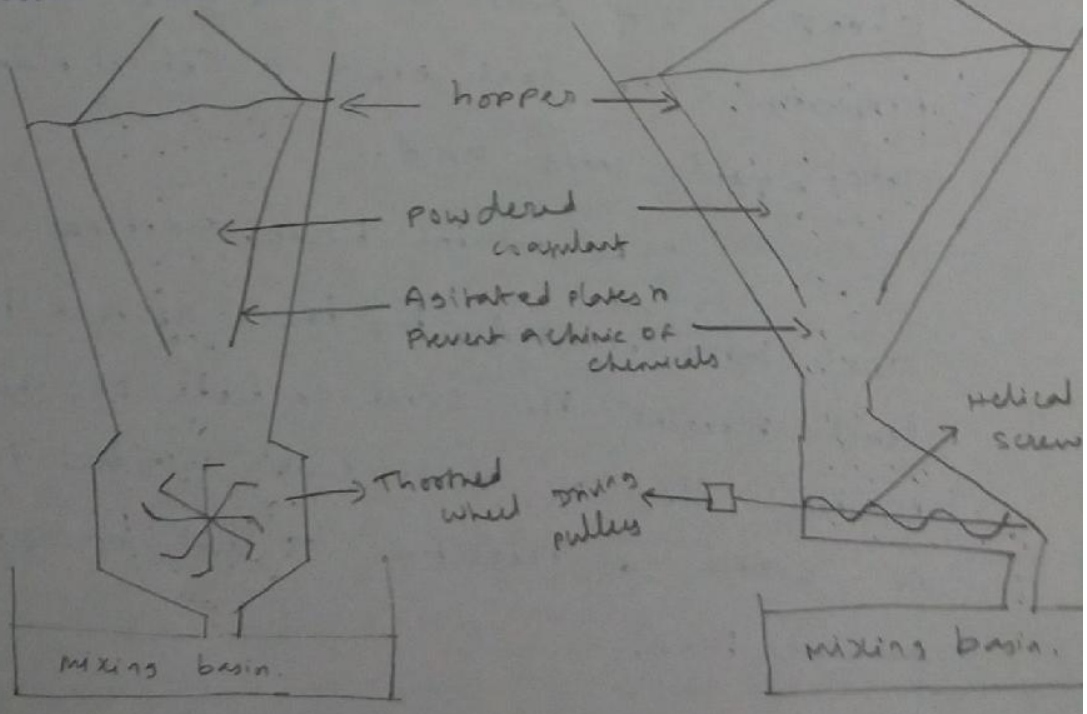
driven by electric current,

reversal.

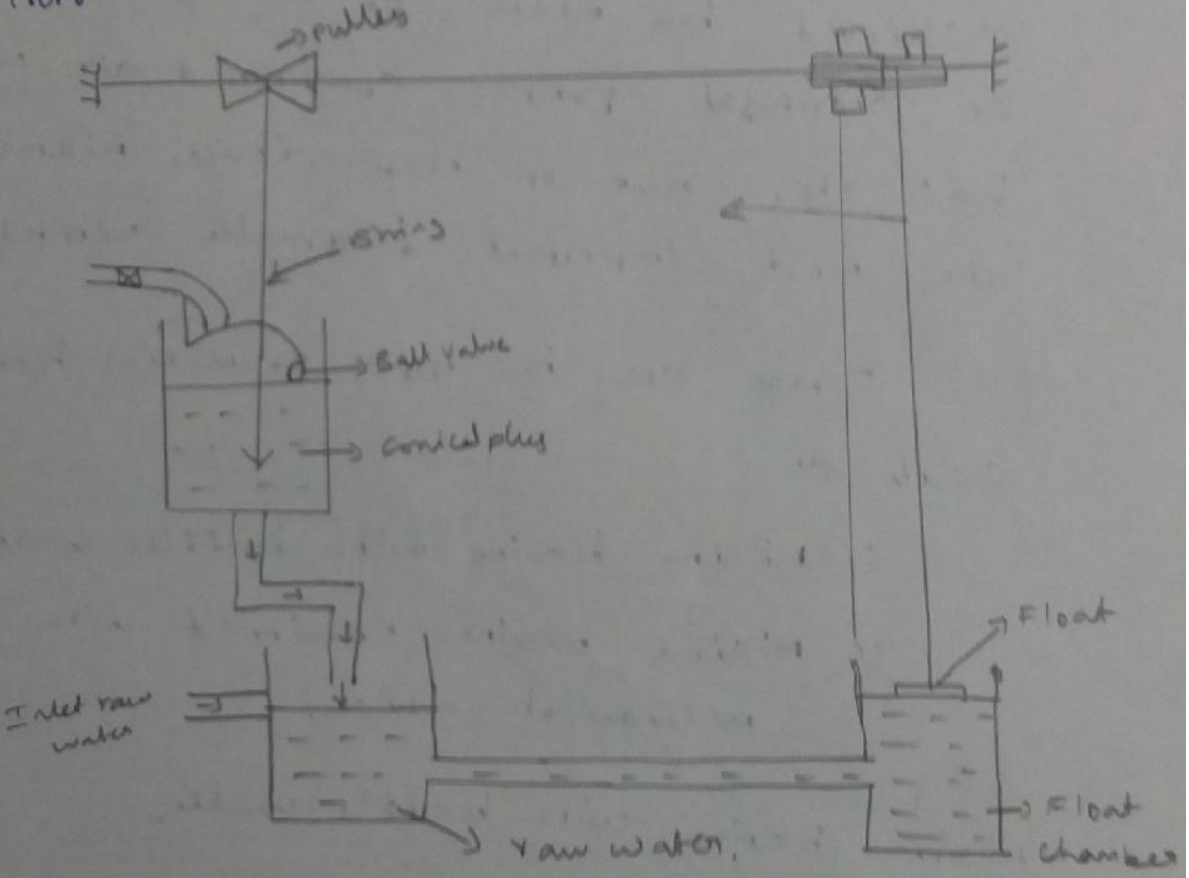
ii) Dry Feeding devices:-

The common devices used are in the form of a tank with a hopper bottom inside the tank, agitating plates are placed. so as to prevent arching of the coagulant. The coagulant, in the powdered form is filled in the tank & is allowed to fall in the mixing basin.

Its dose is regulated by the speed of a notched wheel or a helical screw. The speed of both is controlled by connecting it to a venturi device installed in the raw water pipes bringing water to mixing basin.



The water in the float chamber increases thereby increasing & lifting the float of float chamber. As the float rises, the pinion and pulley rotates in the same direction, thereby lifting the conical plug and allowing more quantity of coagulant solution to fall into the mixing basin.



Mixing Devices:-

After the addition of the coagulant is the raw water, the mixture is thoroughly and vigorously mixed. So that the coagulant gets fully distressed into the entire mass of water.

The violent of mixing devices such achieved by means of mixing devices such as centrifugal pumps, compressed air, mixing basin etc. Out of these devices mixing basins are most important & normally adopted.

There are two types of mixing basin, such as

(i) Mixing basins with battle walls.

(ii) Mixing basins equipped with mechanical devices.

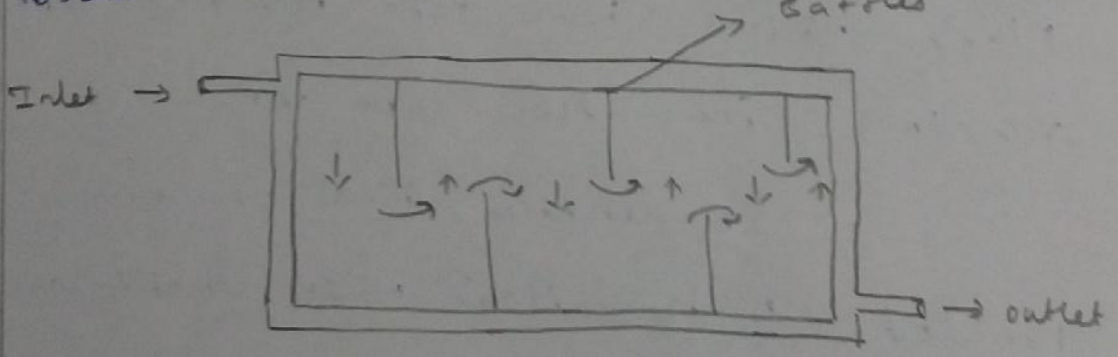
Mixing basins with battle walls:-

There are two types of mixing basin with baffles. In the horizontal or round the end type basin.

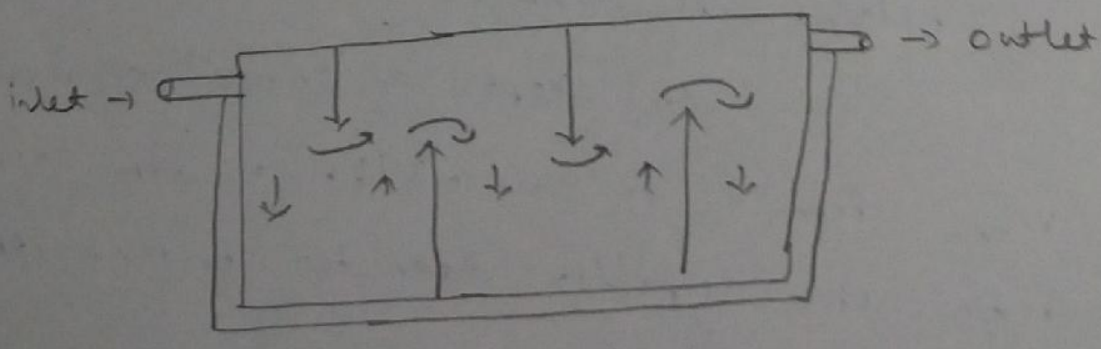
The water flows horizontally for a short distance make a complete turn, continues back and forth around the ends of the baffles.

This causes turbulence and hence the mixing. Another type known as vertical or over & under type used in smaller plants has vertically hanging baffle walls due to which water flows up & down.

mixing basins with baffle walls are not used now because of high head losses and variations in the velocities.



① Round the end type.



Mixing basins with mechanical devices.

Most of the modern water treatment plants now have mixing basin with mechanical devices.

Fig shows a typical flash mixer in which the raw water & the coagula are agitated vigorously by a paddle operated by a variable speed motor.

The intensity of mixing is depend upon the temporal mean velocity gradient Flash mixers, have high revolving speeds ranging from 1100 - 1400 rpm.

A detention time of 30-60 sec is provided in the flash mixer which are deep circular or square tanks with the ratio of height to diameter or side of 1:1 to 3

'G' kept as 300 s^{-1} or more for rcn. from 1 to 3 w/ m^3/hr of flow. The ratio of impeller diameter to tank diameter

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