Major method of Disinfection.

(i) Treatment with chlorine (Cl)

→ When chlorine added with water reacts it at pH >5 8 heads to formation of highly unstable Hypochlorous acid (HOCl) which further dissociates into Hypochlorite ion (OCl⁻) at PH >7.

→ Here all three above forms of chlorine are collectively termed as freely available chlorine and is capable of carrying out disinfection. But HOCl is most distructive disinfectant amongs them. (80 times more effective than hypochloride ion) Hence PH during disinfection is maintained slightly less than <7.

→ Chlorine enters into cell wall of m/o and destroy the enzyme responsible for metabolism in them in order to carry out disinfection. "ENZYMATIC HYPOTHESIS"

metabolism = Catabolism + Anabolism

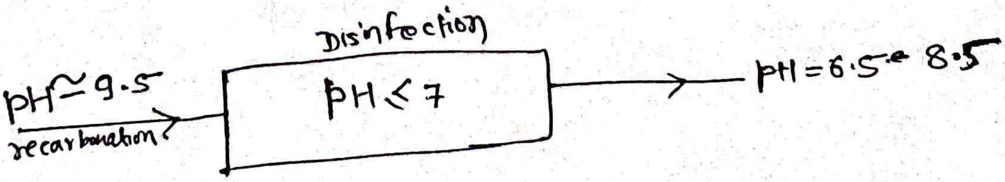
Metabolism is the process in which bigger nutrients consumed by living organism are broken into lighter nutrients and energy is released (CATABOLISM.) and this energy is further used by body for the growth of new cell (Anabolism)

$$Cl_2 + H_2O \overset{PH}{\rightleftharpoons} HOCl$$

$$HOCl \underset{PH<7}{\overset{PH>8}{\rightleftharpoons}} OCl^- + H^+$$

$$\underbrace{Cl_2, HOCl, OCl^-}_{\text{free availavable chlorine.}}$$

PH	form of chlorine.
<5	Cl_2
5-7	HOCl
7-8	HOCl, OCl⁻
>8	OCl⁻



→ Chlorine when added in water immediately reacts with ammonia and form chloramine which are also termed as combined form of Chlorine and are capable of carrying out disinfection but are 25 times less effective than free Chlorine.

$$NH_3 + Cl_2 \xrightarrow{PH > 7.5} NH_2Cl + HCl$$

(monochoramine)

$$NH_3 + 2Cl_2 \xrightarrow{PH = 5\text{-}6.5} NHCl_2 + HCL$$

(~~dich~~DI-CHLORAMINE) [Pre-dominant]

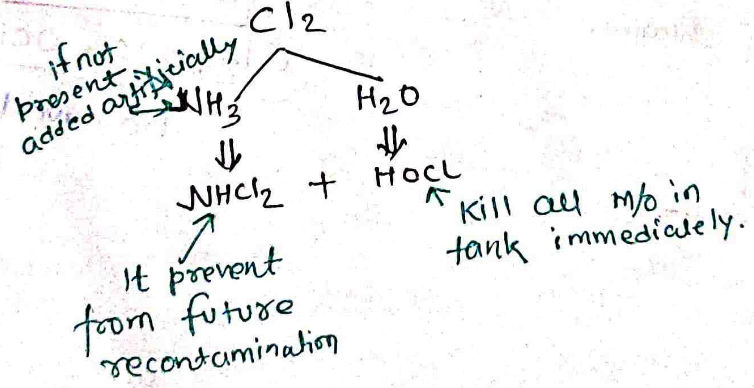
$$NH_3 + 3Cl_2 \xrightarrow{PH < 4.4} NCl_3 + HCL$$

(TRICHLORAMINE/
NITROGEN TRICHLORIDE

→ Effectiveness of chloramine in killing M/O.

$NHCl_2 > NH_2Cl > NCl_3$

→ Does of Chlorine is added in such a residual of 0.2mg/l is injured at the contact period of 10 minutes



Q 20 mg/lit of chlorine is added in water to carry out disinfection equilibrium of which is governed by following reaction.

$$HOCl \underset{pH<7}{\overset{pH>8}{\rightleftharpoons}} OCl + H^+$$

$K = 2.5 \times 10^{-7}$ moles/lit.

~~(i) compute~~

(i) fraction of HOCl in water at pH = 7.

(ii) Concentration of OCl⁻ at this pH, considering chlorine added dissosiates in HOCl & OCl⁻.

(iii) At what pH of water 0.7 fraction of OCl⁻ would be available in water.

$$K_f = \frac{[OCl^-][H^+]}{[HOCl^-]}$$

$$K_b = \frac{[HOCl^-]}{[OCl^-][H^+]}$$

$K_f \cdot K_b = 1.$

$$aA + bB \rightleftharpoons cC + dD$$

$$K_f = \frac{[C]^c [D]^d}{[A]^a [B]^b}$$

where a, b, c, d are no. of moles.

(i) $pH = 7 \Rightarrow [H^+] = 10^{-7}$ moles/lit

$$K_f = \frac{[OCl^-]'[H^+]'}{[HOCl]'}$$

$$2.5 \times 10^{-7} = \frac{[OCl^-][10^{-7}]}{[HOCl^-]}$$

$$[HOCl^-] = 0.4\,[OCl^-]$$

At $pH \leq 7$
OCl^- HOCl
Both present

$$f[HOCl^-] = \frac{[HOCl]}{[HOCl] + [OCl^-] + \cancel{[H^+]}} \rightarrow \text{neglect.}$$

$$= \frac{0.4}{1.4} = 0.285$$

$$f[HOCl^-] = 0.285$$
$$= 0.285 \times 100$$
$$= 28.5\%.$$

(ii) At pH = 7

$[HOCl] = 0.4[OCl^-]$ — (i)

moles of chlorine added. $= [Cl_2] = [HOCl] + [OCl^-]$

$\frac{20\times10^{-3}}{71} = [HOCl] + [OCl^-]$ — (ii)

$\frac{20\times10^{3}}{71} = 0.4[OCl^-] + [OCl^-]$

$[OCl^-] = \frac{20\times10^{-3}}{71\times1.4} = 2.01\times10^{-4}$ moles/lit

(iii) $f[OCl^-] = 0.7$

$\frac{[OCl^{-1}]}{[OCl^-] + [HOCl^-] + \underbrace{[H^+]}_{}} = 0.7$ → neglect.

$[Ocl^{-1}] = 0.7[OCl^-] + 0.7[HOCl^-]$

$0.3[OCl^{-1}] = 0.7[HOCl^-]$

$\frac{[OCl^-]}{[HOCl]} = \frac{7}{3}.$

$\Rightarrow K_F = \frac{[OCl^-][H^+]}{[HOCl]}$

$2.5\times10^{-7} = \frac{7}{3}[H^+]$

$[H^+] = 1.07\times10^{-7}$ moles/lit.

$pH = -\log_{10}(1.07\times10^{-7})$

$= 6.97$

Different forms of addition of Chlorine in Water.

(i) Free chlorine (Cl_2) (solid, liquid, gas)

→ free Chlorine is added in liquid phase in treatment plant in order to carry out disinfection as handling of liquid chlorine is much easier.

→ It is highly sensitive to temperature. It freezes below 10°C. and burns the container above 92°C in which it is kept for storage.

→ Optimom temp. for Chlorination is 32°C to 48°C.

→ It does not lead to formation of sludge while disinfection and its quality ~~and~~ is not deterioated during storage.

→ Temperature problem, so chlorination is not used in european countries (Distribution system temp.).

(ii) Hypochlorites and Bleaching Powder.

→ In this case either hypochlorite ion (OCl^-) and ~~hypo~~ HOCl carries out the disinfection depending upon the pH of water.

→ For 100% pure calcium hypochlorite freely availabe chloration availability is approximately 72%. which also goes on decrease in with time.

→ For 100% pure bleaching powder, freely available chloration availability is approximately 40% which also goes on decreasing with time.

→ Use of these forms also leads to formation of sludge while disinfection. Hence it is not suitable for treatment in plant but can be used for swiming pool.

$Ca(OCl)_2 \longrightarrow$	$OCl^- + Ca^{2+}$
1mole	2mole
143 gram	103 gm
1gm	$\frac{103}{143} = 0.72$ gm.

$CaOCl_2 \longrightarrow$	$OCl^- + Ca^{2+} + Cl^-$
1mole	1 mole
127 gm	51.5gm
1gm	$\frac{51.5}{127} = 0.4$gm.

(iii) Chloramine

→ It is added in treatment plant for disinfection in case when phenol is present in water.

(ii) Chlorine dioxide (ClO_2)

When we add chlorine is sodium chloride

$$NaClO_2 + Cl_2 \longrightarrow ClO_2 + NaCl$$

→ It is strong oxidising reagent (2.5 times more effective than free chlorine.) which can remove both microorganism and OM from water but it is not capable of safegarding water against future recontamination.

→ It can also be used When phenol is present in water.

Q Freely available unit oxidising power of free chlorine is 35.5 and that of dichloramine is 21.48. find the % of free Cl_2 in diachloramine.

$Cl_2 \rightarrow 35.5$

$NHCl_2 \rightarrow 21.48$

$x(35.5) = 21.48$

$x = \frac{21.48}{35.5} = 0.6$

$= 60\%$

Q A city with the population of 50000 is to be provided disinfected water @ of 250l/c/d. find the amount of 25% pure bleaching powder required for treatment of this water @ does of 20mg/lit.

$$\text{Qty of } CaOCl_2 = \frac{5 \times 10^4 \times 250 \times 20 \times 10^{-6}}{0.25}$$

$= 1000$ kg/day

Foclor effecting efficiency of chlorination

		$\eta(\%)$
(i) Turbidily	↑	↓
(ii) Presence of metallic ion. (Fe, Mn^{2+})	↑	↓
(iii) Presence of amonia (NH_3)	↑	↓
(iv) PH	↑	↓ (optimum pH = 5-7)
(V) Temperature	↑	↑
(vi) Time of contact	↑	↑

Types of chlorination:-

(i) Plain Chlorination.

→ If the only treatment given to water is chlorination it is termed as plain chlorination.

→ It removes taste, colour, odour and micro-organism from water.

→ It is not done if turbidily of water is beyond permissible limit.

→ Normal does of chlorine in this case is 0.5 mg/lit.

(ii) Pre- Chlorination.:-

→ If chlorination is done during coagulation and or during filteration. it is termed as pre-chlorination.

→ It is adopted when quality of water is poor. with respect to organic matter and micro-organism.

→ Pre- chlorination is always succeded by post chlorination but vice-versa not.

→ Does. of chlorine in this case depend upon point of addition of chlorine.

→ In ~~coagulation~~ filleration it is 0.1-0.5mg/lit and in ~~filteration~~ it is 5-10 mg/lit

(iii) Post-chlorination

→ If chlorination is done after filteration or it is the last treatment given to water it is termed as post chlorination.

→ Does of chlorine in ~~such~~ this case such a residual of 0.2mg/lit of free Cl_2 is insured at contact period of 10 min to safeguard the water against future contamination.

(iv) Double-chlorination.

→ If both pre- and post chlorination is done it is termed as double-chlorination.

→ It is adopted when higher efficiency of chlorination is required

(v) Super-chlorination

→ ~~Whenever a~~ para

→ If excess of chlorine is added in the range of 5-15 mg/lit So as to ensure residual of 1-2 mg/lit at contact period of 10 minute during epedamic. It is termed as super-chlorination.

(vi) De-chlorination.

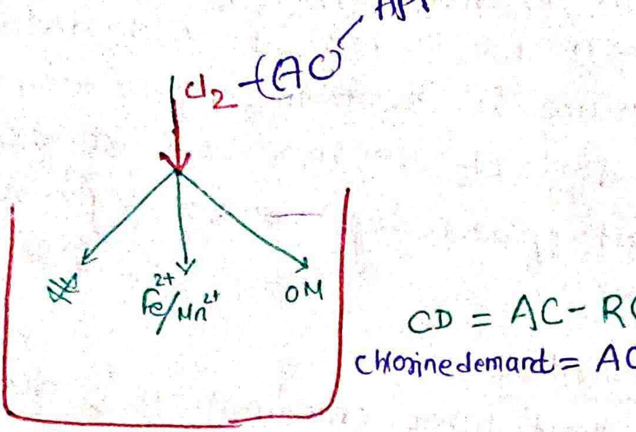
It is process of removal of excess chlorine from the water. It can be achieved by any of following chemicals.

Effective → NaAS
Cheap → $Na_2S_2O_3$
→ NH_4OH
→ Activated carbon
→ SO_2

De-chlorinating Reagent

(190)

(vii) Break Point chlorination.

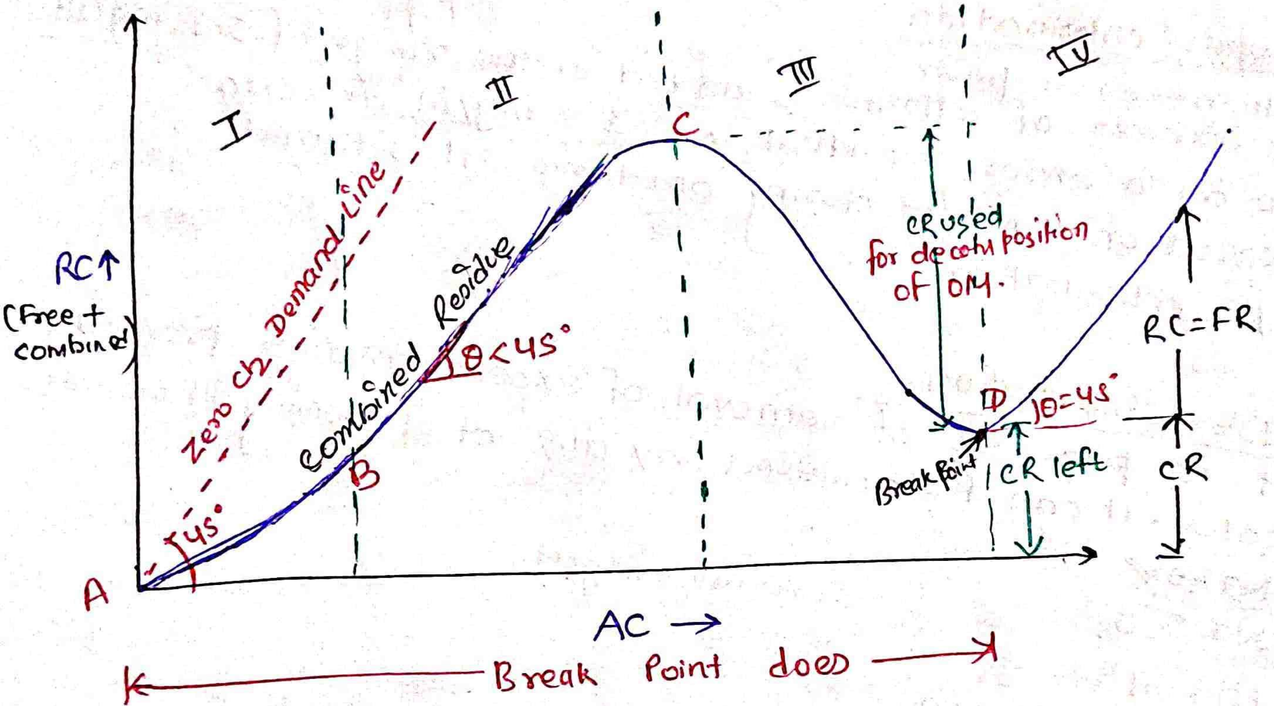


CD = AC − RC

Chlorine demand = AC − RC

RC = FR + CR

Residual chlorine = Free Residual + Combined residual



→ In phase-I, chlorine first performs the function of disinfection and oxidation of minearal in the water resulting in high chlorine demand and leading to lesser residual chlorine in water.

→ As most of the demand for disinfection and oxidation of mineral is satisfied in phase-I, residual chlorine increase in phase-II

→ At no point in phase II, residual chlorine equals applied chlorine as some amount of disinfection still takes place in this phase

→ At the end of this phase ie, at point C, bad smell oxidation of organic matter started by chlorine.

→ As the result of this high chlorine demand, destruction of chloramines and chloroorganic compounds takes place in this phase.

→ At the end of this phase ie, point D, bad smell stop coming out of the water indicate complete decomposition of organic matter.

→ After this point D, whatever chlorine is added breaks free from water ie, appear as a residual chlorine, hence this point is termed as break point & the amount of chlorine required to reach upto thoes point is termed as break point does.

→ Theoretically no chlorine is required to be added in water after this point but practically chlorine is added to ensure the residual of 0.2 mg/lit after the contact period of 10 minutes.

eg

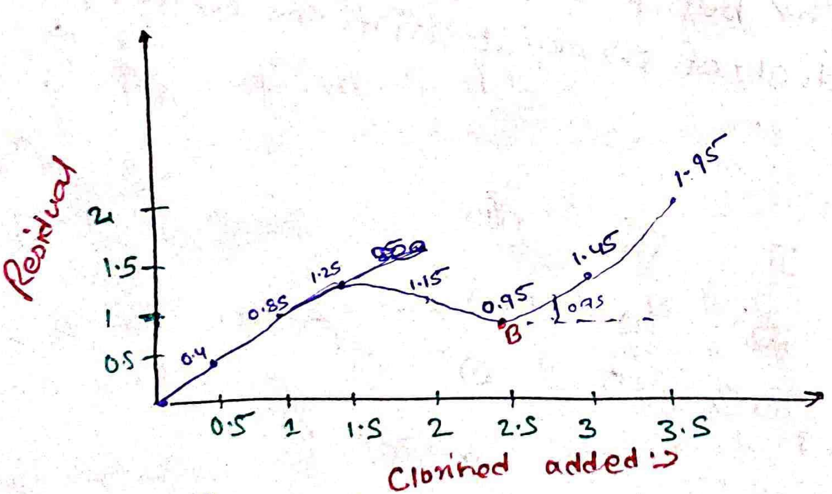
	I	II	III	IV
AC	10	10	10	10
CD	9.8	0.3	85	0
RC	$\underbrace{0.2}_{CR}$	$\underbrace{9.7}_{CR}$	$\underbrace{6.9}_{CR}$	$\underbrace{16.9}_{FR+CR} = 10+6.9$

3CR → 3FR → 75CR.

Q for the given data, Compute (i) CD (ii) Break point Does, (iii) CD at does of 3mg/lit. (iv) Does of chlorine required for free residual of 0.75

AC (mg/lit)		~~RD~~ RC (mg/lit)		CD'	CD
0.5		0.4		0.5-0.4 = 0.1	0.5-0.4 = 0.1
1.0	0.5	0.85	0.45	0.5-0.45 = 0.05	1-0.85 = 0.15
1.5	0.5	1.25	0.4	0.5-0.4 = 0.1	1.5-1.25 = 0.25
2.0	0.5	1.15	-0.10	0.5-(-0.10) = 0.60	2 - 1.15 = 0.85
(ii) 2.5 Breakpoint	0.5	CR 0.95	-0.2	0.5-(-0.2) = 0.7	2.5-0.95 = 1.55 (i)
3.0	0.5	TR 1.45	0.5 FR	0.5 - 0.5 = 0	3 - 1.45 = 1.55 (iii)
3.5	0.5	TR 1.95	0.5 FR	0.5 - 0.5 = 0	3.5-1.95 = 1.55

(iv) ~~Breakpoint~~
~~after~~ = Free residual of 0.75, chlorine demand = 1.55



B = Break point

(i) Chlorine demand = 2.5 - 0.95 = 1.55

(ii) Break point does = 2.5

(iii) Chlorine demand @ 3 mg/lit = it is after Break point
= 1.55 mg/lit.

(iv) Does of chlorine required for free residue of 0.75
= 1.55 + 0.75

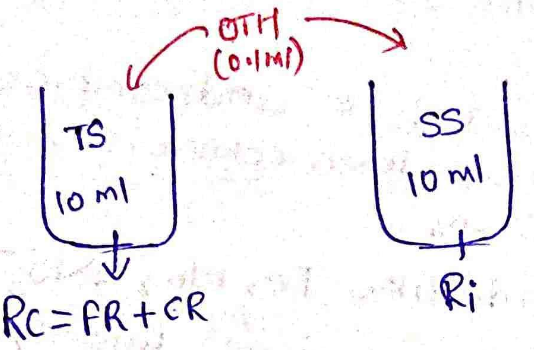
Testing of chlorine Residual.

Testing of chlorine residual can be done by any one of following method:—

① ORTHOTOLIDINE TEST

→ This test is based upon colour matching technique & the colour is induced by addition of orthotolidin.

(i)



5sec

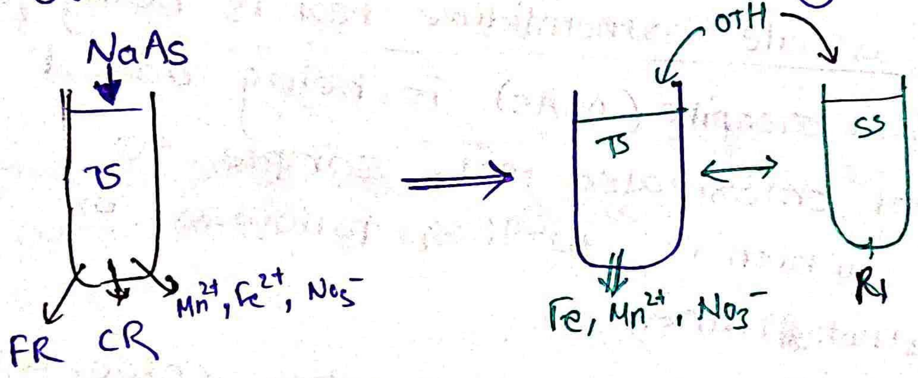
FR = Ri

5min

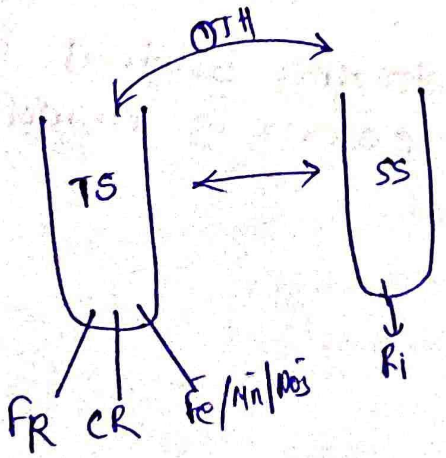
FR + CR = R_2

CR = $R_2 - R_1$

(ii) If colour causing compound (Fe, Mg.) are present in water orthotolidine arsenite test is being performed. (OTA).



Fe^{2+}, Mn^{2+}, NO_3^- = R_1



FR+Fe^{2+}/Mn^{2+}/NO_3^- = R_2

FR = $R_2 - R_1$

5min

FR+CR+ Fe^{2+}/Mg^{2+}/NO_3^- = R_3

CR = $R_3 - R_2$

→ Practically this test obslete now.

Procedure

→ In this test 10ml of chlorinated water sample is mixed with 0.1 ml of orthodidine which gives yellow Colour in it. intensity of which is further matched with that of standard sample. If the intensity of colour of test sample is same with that of the standard sample, then chlorine in standard sample is also same as that of test sample.

→ Orthotodiline or 2-Tolidine is $C_{14}H_{16}N_2$

→ With separate concentration of free and combined chlorine in residual form is desired, then colour is noted after 5s and 5min respectively.

→ If colour causing compounds like Fe, Mn, NO_3^-, are also present in the water, they gives false yellow colour during the test resulting in higher value of residual chlorine than actual.

→ In such case, arsenite orthotolidine test is being performed in which sodium arsenite (NaAs) is being added to the original chlorinated test. sample to dechlorinate it which is further followed by addition of orthotolidine.

→ Intensity of the colour induced by these colour causing compound is matched with that of the standard sample

→ Orthotolidine is also added to the original chlorinated test sample and colour is noted after 5 minute respectively.

In todays time Orthotodine test DPD (Diethyle phenylene diamine and chlorolex test is used which are also based upon colour matching technique. and are more accurate then orthotodidene test but are also comparatively costlier.

→ These to reagent DPD and Chlorolex are also termed as BDH (British Drug house) reagent.

Note:- Orthotolidine test may also be referred as ~~method of~~ SNORT (stabilized neutral-o-tolidine] method

(ii) Starch Iodide Test. (Iodiometric Test)

$$\underset{(Cl_2)}{\overset{(1l)}{\text{Water Sample}}} + \overset{(10ml)}{KI} + \overset{(5ml)}{STARCH} \longrightarrow Cl_2I^- \longrightarrow \text{Blue coloured Complex solution (BCCS)}$$

$$\text{Blue coloured complex solution (BCCS)} \xrightarrow[0.01N\ Na_2S_2O_3]{\text{Titrated}} V\text{ (ml) of } 0.01N\ Na_2SO_3 \text{ (decolourised BCCS)}$$

$$\text{gm. equivalent of } Na_2SO_3 \text{ used} = \frac{0.01}{10^3} \times V = \text{gm. eq. of } Cl_2$$

$$Cl_2\ (mg/lit) = \frac{0.01}{\cancel{10^3}} \times V \times 35.5 \times \cancel{10^3} = 0.355\ V$$

* Starch reacts with complex of halogen gases. [Chlorine, fluorine, bromine]. iodine, astatine].