COLLEGE
Tanta Engineering

إعدادي 2020

الكيمياء

معالجة المياه

سنتر فيوتشر

سنتر فيوتشر

Subject: كيمياء "اعدادي"

Chapter: معالجة المياه

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⊛ Hardness of Water

هى قدرة الماء على استهلاك الصابون وتكوين رغوة
يسمى بـ عسر الماء

is measure of its capacity to precipitate soap ترسيب الصابون due to the presence of divalent cations of Ca^{+2} & Mg^{+2}

Total hardness (TH) = Ca^{+2} hardness + Mg^{+2} hardness

⊛ Calculation of Ca^{+2} hardness (mg/L as $CaCo_3$)

$$\frac{Ca^{+2}\text{ hardness (mg/L as } CaCo_3)}{\text{eq.wt of } CaCo_3} = \frac{\text{Calcium (mg/L)}}{\text{eq.wt of Calcium}}$$

as equivalent weight = الوزن المكافئ $= \frac{\text{Molecular weight}}{\text{Valence}}$ $\frac{\text{الوزن الجزيئى}}{\text{التكافؤ}}$

$$\therefore \frac{Ca^{+2}\text{ hardness (mg/L as } CaCo_3)}{50.04} = \frac{\text{Calcium(mg/L)}}{20.04} \qquad Ca \rightarrow 40$$

⊛ Calculation of Mg^{+2} hardness (mg/L as $CaCo_3$)

$$\frac{Mg^{+2}\text{ hardness (mg/L as } CaCo_3)}{\text{eq.wt of } CaCo_3} = \frac{\text{Magnesium (mg/L)}}{\text{eq.wt of magnesium}}$$

$$\frac{Mg^{+2}\text{ hardness (mg/L as } CaCo_3)}{50.04} = \frac{\text{Magnesium (mg/L)}}{12.15} \qquad Mg \rightarrow 24$$

$$\therefore \underset{\text{mg/L as } CaCo_3}{\text{Total hardness}} = \underset{\text{mg/L as } CaCo_3}{Ca^{+2}\text{ hardness}} + \underset{\text{mg/L as } CaCo_3}{Mg^{+2}\text{ hardness}}$$

Example:-

A sample of water has Calcium content of 70 mg/L as $CaCo_3$ and magnesium content of 90 mg/L as $CaCo_3$

$\therefore$ Total hardness = 70 + 90 = 160 mg/L as $CaCo_3$

✱ Hardness of Water

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✱ Calculation of Mg^{+2} hardness (mg/L as $CaCo_3$)

$$\frac{Mg^{+2}\text{ hardness (mg/L as } CaCo_3)}{\text{eq.wt of } CaCo_3} = \frac{\text{Magnesium (mg/L)}}{\text{eq.wt of magnesium}}$$

$$\frac{Mg^{+2}\text{ hardness (mg/L as } CaCo_3)}{50.04} = \frac{\text{Magnesium (mg/L)}}{12.15}$$ Mg → 24.3

$$\therefore \underset{\text{mg/L as } CaCo_3}{\text{Total hardness}} = \underset{\text{mg/L as } CaCo_3}{Ca^{+2}\text{ hardness}} + \underset{\text{mg/L as } CaCo_3}{Mg^{+2}\text{ hardness}}$$

Example:-

A sample of water has Calcium Content of 70 mg/L as $CaCo_3$ and magnesium Content of 90 mg/L as $CaCo_3$

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Example 1

Determine the total hardness as $CaCo_3$ of sample of water that has Calcium Content of 28 mg/L and magnesium Content of 9 mg/L

Solution

$$\frac{\text{Calcium hardness (mg/L as } CaCo_3)}{\text{eq.wt of } CaCo_3} = \frac{\text{calcium (mg/L)}}{\text{eq.wt of Calcium}}$$

$$\frac{X}{50.04} = \frac{28 \text{ mg/L}}{20.04}$$

$$X = 69.9 \text{ mg/L as } CaCo_3$$

$$\frac{\text{Magnesium hardness (mg/L as } CaCo_3)}{\text{eq.wt of } CaCo_3} = \frac{\text{Magnesium (mg/L)}}{\text{eq.wt of magnesium}}$$

$$\frac{Y}{50.04} = \frac{9 \text{ mg/L}}{12.15}$$

$$X = 37.1 \text{ mg/L as } CaCo_3$$

Total hardness mg/L as $CaCo_3$ = Ca^{+2} hardness (X) mg/L as $CaCo_3$ + Mg^{+2} hardness (Y) mg/L as $CaCo_3$

$\therefore$ Total hardness = $69.9 + 37.1 = 107$ mg/L as $CaCo_3$

⊛ Carbonate Hardness (CH)°°

Carbonate hardness caused by bicarbonate salts of Ca^{+2} & Mg^{+2} also Ca^{+2} & Mg^{+2} combined with carbonate

$MgCO_3$, $Mg(HCO_3)_2$, $CaCO_3$, $Ca(HCO_3)_2$

⊛ Non-Carbonate Hardness (NCH)°°

Calcium and magnesium salts other than carbonate and bicarbonate salts

$MgCl_2$, $MgSO_4$, $CaCl_2$, $CaSO_4$

Total hardness = Carbonate hardness + Non-Carbonate hardness

↳ If Alkalinty < T.H

∴ Alkalinty = Carbonate hardness

∴ Total hardness = Alkalinty + Non-Carbonate hardness

↳ If Alkalinty ≥ T.H

∴ T.H = Carbonate hardness

∴ Non-Carbonate hardness = Zero

Example| A sample of water has 210 mg/L Alkalinty and 330 mg/L total hardness, Find out Carbonate and non-Carbonate Hardness

T.H > Alkalinty

∴ Carbonate hardness = Alkalinty = 210 mg/L

Non-Carbonate Hardness = T.H − Carbonate hardness

= 330 − 210 = 120 mg/L

⊛ Types of Hardness :-

1- temporary Hardness called Carbonate hardness

Caused by Ca^{+2} & Mg^{+2} Carbonates and bicarbonate

removed by - Boiling
- Addition of Lime

2- Permanent Hardness called non-Carbonate hardness

Caused by sulphates, chlorides and Nitrates of Ca^{+2} & Mg^{+2}

removed by - lime-soda process
- Ion exchange or Zeolite
- Demineralization
- Reverse Osmosis

Water softening mean Removal of Hardness إزالة عسر الماء

There're 3 Basic ways to soften water :-

1- Remove of Ca^{+2} & Mg^{+2} ions from water إزالة الأيونات المسببة لعسر الماء

2- Force insoluble substance (such as $CaCo_3$, $Mg(OH)_2$) to precipitate before enter the system إجبار الأيونات الغير ذائبة على الترسيب

3- prevent Ca^{+2} ions to forming $CaCo_3$ by Complexing them تفاعل Ca^{+2} مع مادة أخرى وتكوين Complex وترك Carbonate ذائبة في الماء

Example] A water sample contains 110 mg/L alkalinty as $CaCo_3$ and 105 mg/L total hardness as $CaCo_3$

What is the Carbonate and non-Carbonate hardness of sample ??

Solution

∵ Alkalinty > total hardness

∴ T.H = Carbonate hardness = 105 mg/L as $CaCo_3$

& Non-Carbonate hardness = Zero

⊛ Hardness Range

Hardness Concentration mg/L	Degreee of Hardness
0 - 60	Soft
60 - 120 ← معتدلة	Moderately Hard
120 - 180	Hard
180 and over ← سوف يتم المعالجة	Very Hard

⊛ problems Caused by Hardness :o

1- Excessive soap is needed for washing استهلاك كميات كبيرة من الصابون as detergents (منظفات) work less efficiently because anions (surfactant المسئولة عن which meant to hold dirt particles will react with Ca^{+2} & Mg^{+2}

2- Soap based on animal fats will react with Ca^{+2} & Mg^{+2} forming ppt on skin and clothes

3- Some food become tough when Cooked in hard water as Ca^{+2} ions Cause cross-linking between molecules of food and prevent water entering, food remain hard

4- Scale clog → pipes and fittings تقلل من كفاءة المعدات and become 90% less efficient

Lime Soda Process

↳ Lime Softening :- chemicals used Lime & Soda Ash

$Ca(OH)_2$ → to remove Carbonate hardness

Na_2CO_3 → to remove non-Carbonate hardness

↳ Lime Addition :-

Hardness + Lime → precipitate

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

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

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

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

$\Rightarrow$ Quick Lime dosage can be calculated with formula :-

$$\text{Quick Lime mg/l as CaO} = \frac{(A+B+C+D) * (\text{Excess \%} + 1)}{\text{purity of lime}}$$

A → Carbon Dioxide in source water
mg/l CO_2 X 1.27

B → Bi Carbonate Alkalinity
mg/l $CaCO_3$ X 0.56

C → Hydroxide Alkalinity
mg/l $CaCO_3$ X 0.56

D → Magnesium removed in softening
mg/l as Mg^{+2} X 2.30

⇒ Soda Ash dosage can be calculated with formula :-

$$\text{Soda Ash mg/l as } Na_2CO_3 = \frac{X * (\text{Excess \%} + 1)}{\text{purity of soda}}$$

$$X \text{ Soda Ash mg/l as } Na_2CO_3 = \text{non Carbonate hardness mg/l as } CaCO_3 \times \frac{106}{100}$$

$$\text{"} = \text{"} \times 1.06$$

(X) non-Carbonate hardness mg/l as $CaCO_3$ → non-Carbonate hardne mg/l as Na_2CO_3

M.wt of $CaCO_3$ → M.wt of Na_2CO_3

Example The following test results were provided by laboratory

CO_2	Concentration	25 mg/l as CO_2
HCO_3	bicarbonate Conc	205 mg/l as $CaCO_3$
Mg	magnesium Conc	9 mg/l as Mg
non-Carbonate hardness Concentration		95 mg/l as $CaCO_3$

Assuming no excess lime is added, find correct dosage for lime (Containing 90% pure CaO) and soda Ash (Containing 99% pure Na_2CO_3) required to remove all hardness

Solution

$CO_2 \rightarrow A = 25 \text{ mg/l} \times 1.27 = 31.75 \text{ mg/l as CaO}$

$HCO_3 \rightarrow B = 205 \text{ mg/l} \times 0.56 = 114.8 \text{ mg/l as CaO}$

$Mg \rightarrow D = 9 \text{ mg/l} \times 2.30 = 20.79 \text{ mg/l as CaO}$

$$\therefore \text{Quick lime dosage mg/l as CaO} = \frac{(31.75 + 114.8 + 20.79) * 1}{0.9} = 185.9 \text{ mg/l as CaO}$$

$Y = 95\ mg/l * 1.06 = 100.7\ mg/l$ as Na_2CO_3

Soda Ash dosage mg/l as $Na_2CO_3 = \frac{100.7 * 1}{0.99} = 101.7\ mg/l$ as Na_2CO_3

Example

A water sample has Carbon dioxide Content of 4 mg/l as CO_2, total Alkalinity of 130 mg/l as $CaCO_3$ and magnesium Content of 26 mg/l as Mg^{+2}, **How much quick Lime will be required for softening?** if purity of Lime is 90% and use 15% excess of Lime

Solution

$CO_2 \rightarrow A = 4\ mg/l \times 1.27 = 5\ mg/l$ as CaO

Alkalinity $\rightarrow B = 130\ mg/l \times 0.56 = 73\ mg/l$ as CaO

$C =$ Zero

Magnesium $\rightarrow D = 26\ mg/l \times 2.30 = 60\ mg/l$ as CaO

$\therefore$ Quick Lime dosage mg/l as $CaO = \frac{(A+B+C+D) * \text{Excess \%}}{\text{purity of Lime}}$

" $= \frac{(5+73+60\ mg/l) * 1.15}{0.9} = 176\ mg/l$ as CaO

⊛ Alkalinity of Water قاعدية الماء

CO_3^{--}, HCO_3^-, OH^-

- the alkalinty of water is primarily due to carbonate, bicarbonate and hydroxide Content

- Alkalinty measure the acid-neutralizing capacity of water

كمية الحمض المستهلك للتعادل مع Alkalinty

- Higher alkalinty, the greater capacity of water to neutralize acids

$$\text{phenolphthalein Alkalinity at pH=8.3 mg/L as } CaCO_3 = \frac{A * N * 50,000}{\text{ml of sample}}$$

$$\text{Total Alkalinity at pH=4.5 mg/L as } CaCO_3 = \frac{B * N * 50,000}{\text{ml of sample}}$$

where, A → titrant used to pH = 8.3

B → titrant used to pH = 4.5

N → Normality of Acid (Ex:- 0.02 N H_2SO_4)

50,000 → factor

⊛ Determination Bicarbonate, Carbonate and hydroxide Alkalinity

	Bicarbonate Alkalinity	Carbonate Alkalinity	Hydroxide Alkalinity
① $P=0$	T	0	0
② $P<\frac{1}{2}T$	$T-2P$	$2P$	0
③ $P=\frac{1}{2}T$	0	$2P$	0
④ $P>\frac{1}{2}T$	0	$2T-2P$	$2P-T$
⑤ $P=T$	0	0	T

Example) Results of Alkalinity titrations on water sample as follow :— Sample was 100 ml

- 1.4 ml titrant was used to pH 8.3
- 2.4 ml titrant was used to pH 4.5
- Acid normality was 0.02 N H_2SO_4

what is phenolphthalein, total Alkalinity ??
BiCarbonate, Carbonate and hydroxide Alkalinity ??

Solution

$$\text{Ph.ph Alkalinity } (mg/l \text{ as } CaCo_3) = \frac{1.4 \text{ ml} * 0.02N * 50,000}{100 \text{ ml}}$$

$$= 14 \text{ mg/l as } CaCo_3$$

$$\text{Total Alkalinity } (mg/l \text{ as } CaCo_3) = \frac{2.4 \text{ ml} * 0.02N * 50,000}{100 \text{ ml}}$$

$$= 24 \text{ mg/l as } CaCo_3$$

From table $P > \frac{1}{2}T$

∴ BiCarbonate Alkalinity = Zero

Carbonate Alkalinity = $2T - 2P$

$= 2(24) - 2(14) = 20 \text{ mg/l as } CaCo_3$

Hydroxide Alkalinity = $2P - T$

$= 2(14) - 24 = 4 \text{ mg/l as } CaCo_3$

كلية الهندسة السنة الأعدادية

جدول الكشف عن الشقوق الحامضية للاملأح

الفرقه		الاسم	
الرقم		التاريخ	
		رقم المادة	
		الشق الحامضي	

الخواص الطبيعيه 1- الحاله 2- اللون 3- الذوبان

1- الملح الجاف + حامض هيدروكلوريك مخفف

تفاعل مصحوب بتولد غاز ـــــ مجموعة أ موجودة ـــــ

لا تفاعل ـ مجموعة ب أو ج موجودة

2- الملح الجاف + حامض كبريتيك مركز

تفاعل مصحوب بتولد غاز مجموعة ب موجودة

غاز عديم اللون والرائحه يعكر ماء الجير (CO_2) فوران	غاز عديم اللون وعند إضافة ثاني كرومات البوتاسيوم المحمضة تتحول الى اللون الاخضر(SO_2)	غاز عديم اللون عفن الرائحه يسود ورق خلات الرصاص(H_2S)	غاز بني خانق (NO^2+NO) بني محمر عند فوهة الانبوبة	غاز عديم اللون يدخن مع النشادر (HCl) سحب بيضاء مع النشادر	غاز بني يدخن مع النشادر HBr+Br2 (ابخره برتقالية)	أبخرة بنفسجية (I2)	أبخرة بنية (HNO_3+NO_2) عند فوهة الانبوبه
محلول الملح +محلول كبريتات الماغنسيوم	**محلول الملح + محلول خلات الرصاص**		محلول الملح +محلول نيترات الفضة	**محلول الملح +محلول نيترات الفضة**			
راسب ابيض بالتسخين — راسب ابيض	راسب ابيض يذوب في حامض النيتريك المخفف وعند الغليان راسب ابيض — راسب ابيض يذوب في حامض النيتريك المخفف وعند الغليان يصير الراسب رماديا — اسب أسود	راسب أبيض لا يذوب في حامض النيتريك المخفف ويذوب في محلول النشادر	راسب أصفر فاتح لا يذوب في حامض النيتريك شحيح الذوبان في محلول النشادر المخفف ويذوب في محلول النشادر المركز	راسب ابيض لا يذوب في حامض النيتريك المخفف أو محلول النشادر	لا راسب		
كربونات — بيكربونات	كبريتيت — ثيو كبريتات — كبريتيد	راسب أبيض يذوب بالتسخين ويعود بالتبريد — كلوريد	راسب أبيض يذوب بالتسخين — بروميد	راسب أصفر يذوب بالتسخين — يوديد	محلول الملح +محلول كبريتات الحديدوز يعطى حلقة سمراء — نيترات		

لا تفاعل مجموعه جـ موجودة	
محلول الملح +محلول كلوريد الحديديك	
لا راسب — راسب ابيض مصفر	
.....	
محلول الملح + كلوريد الباريوم	
راسب ابيض لا يذوب في حامض الهيدروكلوريك المخفف — راسب ابيض يذوب في حامض الهيدروكلوريك المخفف	
كبريتات — فوسفات	