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1) 1 gram $CaCO_3$ was dissolved in HCl and the solution was made upto 1000ml with distilled water. 50ml of solution required 45ml of EDTA solution for titration. 50 ml of hard water sample required 28ml of EDTA and after boiling and filtering required 15ml of EDTA solution. Calculate the hardness of water.

⇒ Sol': we know, 1 ml solution of standard hard water ⇒ 1mg of $CaCO_3$.
50ml solution ⇒ 50mg of $CaCO_3$.

Since given in question,
45ml of EDTA ⇒ 50ml of standard solution
= 50mg $CaCO_3$

⇒ 1 ml of EDTA ⇒ $\left(\frac{50}{45}\right)$ mg $CaCO_3$.

Again, In 2nd titration,
50 ml of hard water ⇒ 28ml of EDTA
⇒ $\left(\frac{28 \times 50}{45}\right)$ mg $CaCO_3$
1 litre (1000ml) hard water ⇒ $\left(\frac{28 \times 50 \times 1000}{50 \times 45}\right)$ mg $CaCO_3$
⇒ 622.22 mg $CaCO_3$

∴ Hardness of water (total) = 622.22 mg/L of $CaCO_3$ equivalent

Also, to calculate temporary hardness, we need to calculate permanent haldness.
50 ml of hard water ⇒ 15 ml of EDTA
= $\left(\frac{15 \times 50}{45}\right)$ mg $CaCO_3$ equivalent
1 l of hard water ⇒ $\left(\frac{15 \times 50}{45 \times 50} \times 1000\right)$ mg $CaCO_3$
= 333.33 mg/L $CaCO_3$ equivalent
= 333.33 ppm

Then, temporary hardness = Total hardness - permanent hardness
= 622.22 - 333.33
= 288.89

∴ Total hardness = 622.22 ppm
Permanent hardness = 333.33 ppm
Temporary hardness = 288.89 ppm.

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Q2) 0.45 gram $CaCO_3$ was dissolved in HCl and solution was made upto 500 ml with distilled water. 50 ml of solution required 50 ml EDTA solution for titration. 50 ml hard water sample required 18 ml EDTA and after boiling and filtering required 10 ml of EDTA solution. Calculate each type of hardness of water.

Sol^n> 0.45 gram $CaCO_3$ is in 500 ml solution.

In 50 ml solution, there will be $\left(\frac{0.45}{10}\right) = 0.045$ gram $CaCO_3$.

50 ml of EDTA ⇒ 50 ml standard solution

1 ml of EDTA ⇒ $\left(\frac{0.045}{50}\right)$ gram $CaCO_3$.

In 1st titration,

50 ml hard water needed ⇒ 18 ml EDTA

1 ml hard water needed ⇒ $\frac{18}{50}$ ml EDTA

1 l hard water needed ⇒ $\left(\frac{18}{50} \times 1000 \times \frac{0.045}{50}\right)$ gram $CaCO_3$

$= 0.0324$ gram $CaCO_3$.

$= 324$ mg $CaCO_3$

∴ Total hardness = 324 mg/L of $CaCO_3$ equivalent.

After boiling and filtering,

50 ml hard water needed ⇒ 10 ml EDTA solution

1000 ml hard water needed ⇒ $\frac{10}{50} \times \frac{1000}{1} \times \frac{20}{1}$ ml EDTA solution

$= 200$ ml EDTA solution.

$= \left(\frac{200 \times 0.045}{50}\right)$ gram $CaCO_3$

$= 0.18$ gram $CaCO_3$

$= 180$ mg $CaCO_3$

∴ Permanent hardness = 180 mg/L of $CaCO_3$ equivalent

Temporary hardness = Total hardness − permanent hardness

$= 324 - 180$

$= 144$ mg/L of $CaCO_3$ equivalent.

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(3) 1.53 gram $CaCO_3$ was dissolved in HCl and the solution was made upto 1000 ml with distilled water. 50 ml of the solution required 32 ml of EDTA solution for titration. 50 ml of hard water sample required 16 ml of EDTA and after boiling and filtering required 9 ml of EDTA solution. Calculate temporary, permanent and total hardness.

↳ Sol^n.

In standard hard water,

1000 ml contains 1.53 gram $CaCO_3$ equivalent

1 ml contains 0.00153 gram $CaCO_3$ equivalent.

Here, During standardization of EDTA,

32 ml EDTA required 50 ml of standard solution

$= (50 \times 0.00153)$ gram $CaCO_3$ equivalent.

1 ml EDTA required $\left(\frac{50 \times 0.00153}{32}\right)$ gram $CaCO_3$ equivalent.

In 2nd titration,

50 ml hard water required 16 ml EDTA solution

1000 ml hard water required $\frac{16}{50} \times 1000$ ml EDTA solution

$= \left(\frac{16}{50} \times 1000 \times \frac{50 \times 0.00153}{32}\right)$ gram $CaCO_3$ equivalent

$= 0.765$ gram $CaCO_3$ equivalent.

$= 765$ mg $CaCO_3$ equivalent.

∴ Total hardness = 765 mg/L.

In 3rd titration,

50 ml hard water required 9 ml EDTA solution.

1000 ml hard water required $\left(\frac{9}{50} \times 1000\right)$ ml EDTA solution

$= \left(\frac{9}{50} \times 1000 \times \frac{50 \times 0.00153}{32}\right)$ gram $CaCO_3$ equivalent

$= 0.4303$ gram $CaCO_3$ equivalent

$= 430.31$ mg $CaCO_3$ equivalent.

∴ Permanent hardness = 430.31 mg/L.

Temporary hardness = (765 − 430.31) mg/L = 334.69 mg/L

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(4) 20BDSCH105 BIMAL x PARAJULI PAGE NO.

0.3 gram $CaCO_3$ was dissolved in HCl and the solution made upto 1000 ml with distilled water. 50ml of solution required 32 ml of EDTA solution for titration. 50 ml of hard water sample required 16 ml of EDTA and after boiling and filtering required 9 ml of EDTA solution. Calculate the hardness of water.

Ans:- (Total: 350 ppm, Permanent: 120 ppm, Temp. 230 ppm).

In standard solution,

0.3 gram $CaCO_3$ is present in 1l solution.

⇒ 1ml standard hard water contains 0.0003 gram $CaCO_3$ equivalent.

In 1st titration,

32 ml EDTA required 50ml standard solution.

1 ml EDTA required $\frac{50}{32}$ ml standard solution.

⇒ 0.00046875 gram $CaCO_3$ equivalent

In 2nd titration,

50 ml hard water consumed 16 ml EDTA

1000 ml hard would consume $\frac{16}{50} \times 1000$ ml EDTA

$\Rightarrow \left(\frac{16}{50} \times 1000 \times 0.00046875\right)$ g $CaCO_3$ equivalent

⇒ 0.15 g $CaCO_3$ equivalent.

⇒ 150 ppm $CaCO_3$ equivalent.

In 3rd titration,

50 ml hard water required 9 ml EDTA

1000 ml hard water would consume $\frac{1}{50} \times 1000$ ml EDTA

$\Rightarrow \left(\frac{9000}{50} \times 0.00046875\right)$ g $CaCO_3$ equivalent

⇒ 0.084375 g $CaCO_3$ equivalent

⇒ 84 ppm

∴ Total hardness = 150 ppm

Permanent hardness = 84 ppm

Temporary hardness = 66 ppm.

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(5) 0.25 gram $CaCO_3$ was dissolved in HCl and the solution was made upto 250 ml with distilled water. 50ml of the solution required 20ml of EDTA solution for titration. 50ml of hard water sample required 18ml of EDTA and after boiling and filtering required 10ml of EDTA solution. Calculate the hardness of water.

Ans: (Total : 900 ppm, permanent : 500 ppm, Temp : 400 ppm).

Sol: In standard solution,

0.25 gram $CaCO_3$ is present in 250 ml

$\Rightarrow$ 1 ml standard hard water contains 0.001 gram $CaCO_3$ eq.

In 1st titration,

20 ml EDTA required 50 ml solution.

1 ml EDTA would require $\frac{50}{20}$ ml standard solution.

$\Rightarrow$ 0.0025 g $CaCO_3$ equivalent

In 2nd titration,

50 ml hard water sample required 18 ml of EDTA

1000 ml hard water sample required $\left(\frac{18}{50} \times 1000\right)$ ml EDTA

$\Rightarrow \left(\frac{18000}{50} \times 0.0025\right)$ g $CaCO_3$ equivalent

$= 0.9$ g $CaCO_3$ equivalent

$= 900$ mg $CaCO_3$ eq.

In 3rd titration, 50ml hard water sample consumed 10ml EDTA

1000 ml hard water sample consumed $\left(\frac{10}{50} \times 1000\right)$ ml EDTA

$\Rightarrow \left(\frac{10,000}{50} \times 0.0025\right)$ g $CaCO_3$ eq.

$= 500$ mg $CaCO_3$ eq.

$\therefore$ Total hardness = 900 ppm or mg/L

Permanent hardness = 500 ppm or mg/L

Temporary hardness = Total hardness - Permanent hardness

$= 900 - 500$

$= 400$ ppm.

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(6) 20BDS0105 BIMAL PARAJULI x PAGE NO.

20ml of standard hard water containing 1g pure $CaCO_3$ per lit consumed 25 ml of EDTA. 100ml of water sample consumed 18ml of EDTA using EBT as indicator. While same water sample requires 12 ml of EDTA solution. Calculate the carbonate and non-carbonate hardness of water.

(Ans: Permanent: 96 ppm, Temporary: 48 ppm)

Sol

In standard hard water;

1000ml contains 1g $CaCO_3$ equivalent.

1 ml contains 1 mg $CaCO_3$ equivalent.

In 1st titration of EDTA with standard hard water,

25 ml EDTA required 20ml standard hard water

1 ml EDTA required $\left(\frac{20}{25} \times 1\right)$ ml standard hard water

$\Rightarrow \left(\frac{20}{25} \times 1\right)$ mg $CaCO_3$ eq

= 0.800 mg $CaCO_3$ equivalent.

In 2nd titration of EDTA with hard water sample;

100ml of water sample consumed 18ml EDTA

1000 ml of water sample consumed (18x10)ml EDTA

$\Rightarrow (18 \times 10 \times 0.8)$ mg $CaCO_3$ eq

= 144 mg $CaCO_3$ eq.

In 3rd titration of EDTA with boiled water,

100ml water sample consumed 12 ml EDTA.

1000 ml water sample would consume (12x10)ml EDTA

$\Rightarrow (12 \times 10 \times 0.8)$ mg $CaCO_3$ eq.

= 96 mg $CaCO_3$ eq.

∴ Total hardness = 144 ppm or mg/L.

Permanent hardness = 96 ppm or mg/L.

Temporary hardness = Total - Permanent hardness

= 144 - 96 = 48 mg/L or ppm.

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(7) 0.5g $CaCO_3$ was dissolved in dil. HCl and diluted to 500ml using distilled water. 50ml of this solution required 48 ml of EDTA solution for titration. 50ml of hard water sample required 15 ml of EDTA solution for titration. 50 ml of same water sample on boiling and filtering requires 10 ml of EDTA solution. Calculate the hardness of water in ppm. (Ans: Permanent: 208.33 ppm, Temporary: 104.17 ppm).

Sol: In standard hard water,

500ml solution contains 0.5g = 500mg $CaCO_3$

1 ml solution contains 1 mg $CaCO_3$ equivalent.

In 1st titration of EDTA vs. standard solution,

48 ml EDTA required 50ml of standard solution.

1 ml EDTA would require $\left(\frac{50}{48}\right)$ ml of standard solution.

$\Rightarrow \left(\frac{50}{48} \times 1\right)$ mg $CaCO_3$ equivalent.

In 2nd titration of EDTA against sample of hard water,

50ml sample consumed 15ml EDTA

1000ml sample would consume $\left(\frac{15}{50} \times 1000\right)$ ml EDTA

$= \left(\frac{15000}{50} \times \frac{50}{48}\right)$ mg $CaCO_3$ eq.

$= 312.5$ mg $CaCO_3$ eq.

In 3rd titration of EDTA against boiled water,

50ml sample consumed 10ml EDTA.

1000ml sample consumed $\left(\frac{10}{50} \times 1000\right)$ ml EDTA.

$\Rightarrow \left(\frac{10}{50} \times 1000 \times \frac{50}{48}\right)$ mg $CaCO_3$ equivalent.

$= 208.33$ mg $CaCO_3$ eq.

∴ Total hardness = 312.5 ppm.

Permanent hardness = 208.33 ppm.

Temporary hardness = Total hardness − Permanent hardness

= 104.17 ppm.

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(8) Calculate the temporary and permanent hardness of water sample containing $Mg(HCO_3)_2 = 7.3$ mg/L, $Ca(HCO_3)_2 = 16.2$ mg/L, $MgCl_2 = 9.5$ mg/L, $CaSO_4 = 13.6$ mg/L. (Ans:- Temp: 15ppm, permanent: 20ppm).

Solution:

S.N.	Impurities	Concentration	Conversion Ratio	$CaCO_3$ equivalent (ppm).
1	$Mg(HCO_3)_2$	7.3 mg/L	$\frac{100}{146}$	5
2	$Ca(HCO_3)_2$	16.2 mg/L	$\frac{100}{162}$	10
3	$MgCl_2$	9.5 mg/L	$\frac{100}{95}$	10
4	$CaSO_4$	13.6 mg/L	$\frac{100}{136}$	10

Here, Temporary hardness = Concentration of $Mg(HCO_3)_2 + Ca(HCO_3)_2$

$= (5 + 10)$ ppm

$= 15$ ppm.

Permanent hardness = Concentration of $MgCl_2 + CaSO_4$

$= (10 + 10)$ ppm

$= 20$ ppm.

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(9) Calculate the temporary and total hardness of a water sample containing $Mg(HCO_3)_2$ = 73 mg/L, $Ca(HCO_3)_2$ = 162 mg/L, $MgCl_2$ = 95 mg/L, $CaSO_4$ = 136 mg/L. (Ans:- 150 mg/L (temporary) & 350 mg/L (permanent))

Sol'n

S.N.	Impurities	Concentration of Impurities (mg/L)	Conversion Ratio	$CaCO_3$ equivalent (ppm).
1	$Mg(HCO_3)_2$	73	$\frac{100}{146}$	50 ppm
2	$Ca(HCO_3)_2$	162	$\frac{100}{162}$	100 ppm
3	$MgCl_2$	95	$\frac{100}{95}$	100
4	$CaSO_4$	136	$\frac{100}{136}$	100

Now,

Temporary hardness = Sum of $CaCO_3$ eq. of $Mg(HCO_3)_2$ + $Ca(HCO_3)_2$

= (50 + 100) ppm

= 150 ppm

And,

Permanent hardness = Sum of $CaCO_3$ eq. of $MgCl_2$ + $CaSO_4$.

= (100 + 100) ppm

= 200 ppm

Total hardness = temporary hardness + permanent hardness

= (150 + 200) ppm

= 350 ppm.

(b) 50ml of a sample water consumed 15ml of 0.01 M EDTA before boiling and 5ml of same EDTA after boiling. Calculate the degree of hardness, permanent hardness and temporary hardness.

Ans:- 100mg/L (permanent), 200 mg/L (temporary)

So,

Concentration of EDTA = 0.01M $CaCO_3$ eq

= 0.01 mole ~~per litre~~ $CaCO_3$ per litre

$= 0.01 \times \frac{100}{1000}$ gram per litre

= 1 gram per litre.

= 1 mg per ml.

Then,

50ml hard water consumed 15 ml EDTA

1000 ml hard water consumed $\left(\frac{15,000}{50}\right)$ ml EDTA

= 300 ml EDTA

= 300 mg $CaCO_3$ eq. per litre

~~= 300~~

Again, after boiling,

50ml hard water consumed 5 ml EDTA.

1000 ml hard water consumed $\frac{5000}{50}$ ml EDTA

= 100 ml EDTA

= 100 mg $CaCO_3$ eq. per litre

∴ Total hardness = 300 ppm

~~Permanent~~ hardness = 100 ppm.

Temporary hardness = Total − Permanent hardness

= (300 − 100) ppm

= 200 ppm.

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(11) 0.5gram $CaCO_3$ was dissolved in HCl and the solution was made upto 500 ml with distilled water. 50 ml of the solution required 48 ml of EDTA solution for titration. 50 ml of hard water sample required 15 ml of EDTA and after boiling and filtering required 10ml of EDTA solution. Calculate the hardness. (Ans: 312.5 mg $CaCO_3$ eq.).

Sol: 0.5 gram $CaCO_3$ was present in 500ml standard solution.

1ml standard solution would contain 1 mg $CaCO_3$ equivalent.

In 1st titration of EDTA against standard solution,

48 ml EDTA required 50ml standard solution.

1 ml EDTA would require $\left(\frac{50}{48} \times 1\right)$ ml standard solution

$= \frac{50}{48}$ mg $CaCO_3$ equivalent.

In 2nd titration,

50 ml hard water sample required 15 ml EDTA.

1000 ml hard water sample would require $\frac{15 \times 1000}{50}$ ml EDTA

$\Rightarrow \left(\frac{15000}{50} \times \frac{50}{48}\right)$ mg $CaCO_3$ eq.

$= 312.5$ mg $CaCO_3$ eq.

In 3rd titration,

50ml hard water sample consumed 10ml EDTA.

1000 ml hard water sample would consume $\left(\frac{10}{50} \times 1000\right)$ ml EDTA

$\Rightarrow \left(\frac{10000}{50} \times \frac{50}{48}\right)$ mg $CaCO_3$ eq.

$= 208.33$ mg $CaCO_3$ eq.

∴ Temporary hardness $= (312.5 - 208.33)$ ppm

$= 104.17$ ppm

Total hardness = 312.5 ppm

Permanent hardness = 208.33 ppm

A sample of water shows following impurities. Calculate the lime and soda needed for 10^6 liter of water.

Sol'n

S.N.	Impurities	Concentration (in ppm)	Multiplication factor	$CaCO_3$ equivalent	Lime needed	Soda needed
1	$Ca(HCO_3)_2$	220	$\frac{100}{162}$	135.8	135.8	—
2	$Mg(HCO_3)_2$	56	$\frac{100}{146}$	35.36	70.72	—
3	$MgCl_2$	130	$\frac{100}{95}$	136.84	136.84	136.84
4	$MgSO_4$	84	$\frac{100}{120}$	70	70	70
5	$CaSO_4$	98	$\frac{100}{136}$	72.06	—	72.06
					$\Sigma \Rightarrow 413.36$	$\Sigma \Rightarrow 278.9$

Total Lime needed $= \frac{74}{100} \times \Sigma \text{lime} \times \frac{\text{Volume}}{10^6}$ kg

$= \frac{74}{100} \times 413.36 \times \frac{10^6}{10^3}$

$= 305.88$ kg

Total soda needed $= \frac{106}{100} \times \Sigma \text{soda} \times \frac{\text{Volume of water}}{10^6}$ kg

$= \frac{106}{100} \times 278.9 \times \frac{10^6}{10^6}$

$= 295.634$ kg.

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(2) Calculate the amount of lime (88.3% pure) and soda (99.2% pure) needed to soften 24000 litres of water per day for a year containing the following:-

Total volume of water = $24000 \times 365 = 8.76 \times 10^6$ litres

Impurities	Concentration (in ppm)	Conversion factor	$CaCO_3$ equivalent	Lime required	Soda required
$CaCO_3$	1.85	$\frac{100}{100}$	1.85	1.85	—
$MgCO_3$	0.42	$\frac{100}{84}$	0.5	0.5	—
$MgSO_4$	0.9	$\frac{100}{120}$	0.75	0.75	0.75
SiO_2	2.32	—	—	—	—
$CaSO_4$	0.34	$\frac{100}{136}$	0.25	—	0.25
$MgCl_2$	0.76	$\frac{100}{95}$	0.8	0.8	0.8
NaCl	2.34	—	—	—	—

$\Sigma \rightarrow 3.9$ $\Sigma \rightarrow 1.8$

Then,

Total lime needed $= \frac{74}{100} \times \frac{\Sigma \text{ lime} \times 100}{\%\text{purity}} \times \frac{\text{Volume}}{10^6}$ kg

$= \frac{74}{100} \times \frac{100 \times 3.9}{88.3} \times \frac{24000}{10^6}$ kg

$= 0.07844$ kg $= 78.44$ gram

Total Soda Needed $= \frac{106}{100} \times \frac{\Sigma \text{ Soda} \times 100}{\%\text{purity}} \times \frac{\text{Volume}}{10^6}$ kg

$= \frac{74}{100} \times \frac{100 \times 1.8}{99.2} \times \frac{24,000}{10^6}$ kg

$= 0.0461613$ kg

$= 46.16$ grams

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Calculate the quantity of lime and soda required for softening 60,000 litres of water containing following:-

Sol

S.N.	Impurities	Concentration in ppm	Multiplication factor	$CaCO_3$ equivalent	Lime Needed	Soda Needed
1	CO_2	20	$\frac{100}{44}$	45.45	45.45	—
2	$Mg(HCO_3)_2$	25	$\frac{100}{146}$	17.12	34.24	—
3	$Al_2(SO_4)_3$	40	$\frac{100}{342}$	11.69	11.69	11.69
4	$Ca(HCO_3)_2$	20	$\frac{100}{162}$	12.34	12.34	—
5	HCl	8.4	$\frac{100}{36.5}$	23.01	23.01	23.01
6	$MgCl_2$	12	$\frac{100}{95}$	12.63	12.63	12.63
				$\Sigma \rightarrow$	126.73	$\Sigma \rightarrow 47.33$

Total lime needed $= \frac{74}{100} \times \Sigma \text{lime} \times \frac{\text{Volume}}{10^6}$ kg

$= \frac{74}{100} \times 126.73 \times \frac{60,000}{10^6}$ kg

$= 5.62$ kg lime

Total Soda needed $= \frac{106}{100} \times \Sigma \text{Soda} \times \frac{\text{Volume}}{10^6}$ kg

$= \frac{106}{100} \times 47.33 \times \frac{60,000}{10^6}$ kg

$= 3.01$ kg Soda

∴ Total weight of lime needed is 5.62 kg and Soda needed is 3.01 kg.