SOLVED NUMERICAL: HARDNESS OF WATER

Calculation of equivalents of calcium carbonate

Dissolved Salt/Ion	Molar Mass	Chemical Equivalent	Multiplication factor for converting in to equivalents of $CaCO_3$
$Ca(HCO_3)_2$	162	81	100/162
$Mg(HCO_3)_2$	146	73	100/146
$CaSO_4$	136	68	100/136
$CaCl_2$	111	55.5	100/111
$MgSO_4$	120	60	100/120
$MgCl_2$	95	47.5	100/95
$CaCO_3$	100	50	100/100
$MgCO_3$	84	42	100/84
CO_2	44	22	100/44
$Ca(NO_3)_2$	164	82	100/164
$Mg(NO_3)_2$	148	74	100/148
HCO_3^-	61	61	100/122
OH^-	17	17	100/34
CO_3^{2-}	60	30	100/60
$NaAlO_2$	82	82	100/164
$Al_2(SO_4)_3$	342	57	100/114
$FeSO_4.7H_20$	278	139	100/278
H^+	1	1	100/2
HCl	36.5	1	100/73

$Mg(HCO_{3)2}$ (Temp.Mg) $Mg(HCO_3)_2+2Ca(OH)_2 \rightarrow 2CaCO_3+Mg(OH)_2+ 2H_2O$ =**2L**

HCO_3^- (e.g., $NaHCO_3$) $2HCO_3^- + Ca(OH)2 \rightarrow CaCO_3+H_2O+CO_3^{2-}$ =**L-S**

$NaAlO_2$ $NaAlO_2+2H_2O \rightarrow Al(OH)_3 +NaOH$ = **-L**

Note: Substance like NaCl, KCl, Na_2SO_4, SiO_2, Fe_2O_3 etc.do not impart any hardness and therefore, these do not consume any lime or soda. These should not be taken in to consideration for calculating the lime and soda requirements.

Lime requirement for softening

=74/100 [Temp.Ca^{2+} +2xTemp.Mg^{2+} + Perm. (Mg^{2+} +Fe^{2+} +$Al^{3+)}$ +CO_2+H^+ (HCl or H_2SO_4) +HCO_3^- -$NaAlO_2$: All in terms of $CaCO_3$ eq.]

Soda requirement for softening

=106/100[Perm. (Ca^{2+} +Mg^{2+} +Al^{3+} +$Fe^{2+)}$ x H+ (HCl or H_2SO^4) –HCO_3^- : All in terms of $CaCO_3$ eq.]

Q.1 How many grams of $FeSO_4$ dissolved per litre gives 210.5 ppm of hardness?

Solution: $FeSO_4$ = $CaCO_3$

56+16+64=136 gm=152 gm = 100gm

∴ 100 ppm of hardness = 152 ppm of $FeSO_4$

210.5 ppm of hardness = 152x210.5/100= 319.96 ppm of $FeSO_4$

=319.96 mg/L or 0.31996 gm /L of $FeSO_4$

Q.2.Calculate the temporary and permanent hardness of a sample of water containing:

Mg $(HCO_3)_2$= 7.3mg/L, Ca $(HCO_3)_2$=16.2 mg/L, $MgCl_2$= 9.5mg/L, $CaSO_4$= 13.6 mg/L

(Atomic weight of Mg and Ca are 24 and 40 respectively.)

Solution: Conversion in to $CaCO_3$ equivalents:

Constituents	Multiplication factor	$CaCO_3$ equivalents
Mg $(HCO_3)_2$= 7.3mg/L	100/146	7.3x100/146= 5mg/L
Ca $(HCO_3)_2$=16.2 mg/L	100/162	16.2X100/162=10 mg/L
$MgCl_2$= 9.5mg/L	100/95	9.5X100/95=10 mg/L
$CaSO_4$= 13.6 mg/L	100/136	13.6X100/136=10 mg/L

Temporary hardness, due to Mg $(HCO_3)_2$ and Ca $(HCO_3)_2$

= (5+10) mg/L=15 mg/L or 15 ppm

Permanent hardness due to $MgCl_2$ and $CaSO_4$

= (10+10 mg/L=20 mg/L or 20 ppm

Q.3.Calculate the temporary and total hardness of a sample of water containing:

Mg $(HCO_3)_2$= 73mg/L, Ca $(HCO_3)_2$=162 mg/L, $MgCl_2$= 95mg/L ,$CaSO_4$= 136 mg/L

(Atomic weight of Mg and Ca are 24 and 40 respectively.)

Solution: Conversion in to $CaCO_3$ equivalents:

Constituents	Multiplication factor	$CaCO_3$ equivalent

$Mg(HCO_3)_2$= 73mg/L $Ca(HCO_3)_2$=162 mg/L $MgCl_2$= 95mg/L $CaSO_4$= 136 mg/ L	100/146 100/162 100/95 100/136	73x100/146= 50mg/L 162X100/162=100 mg/L 95X100/95=100 mg/L 136X100/136=100 mg/L

Temporary hardness, due to $Mg(HCO_3)_2$ and $Ca(HCO_3)_2$

= (50+100) mg/L=150 mg/L or 150 ppm

Total hardness =Temporary + permanent

= (150) mg/L+(200) mg/L =350 mg/L or 350 ppm

Q.4.Calculate the quantity of lime and soda required for softening 50,000 litres of water containing following salts per litre: $Ca(HCO_3)_2$=8.1 mg/L, $Mg(HCO_3)_2$= 7.5mg/L, $CaSO_4$= 13.6 mg/L, $MgSO_4$= 12.0 mg/L, $MgCl_2$= 2.0 mg/L and NaCl=4.7 mg/L.

Solution: Conversion in to CaCO3 equivalents:

Constituents	Multiplication factor	$CaCO_3$ equivalent
$Ca(HCO_3)_2$=8.1 mg/L $Mg(HCO_3)_2$= 7.5mg/L $CaSO_4$= 13.6 mg/L $MgSO_4$= 12.0 mg/L $MgCl_2$= 2.0 mg/L	100/162 100/146 100/136 100/120 100/95	8.1X100/162=5.0 mg/L 7.5X100/146=5.14 mg/L 13.6X100/136=5.0 mg/L 12.0X100/120=10.0 mg/L 2.0X100/95=2.11 mg/L

Lime requirement for 50,000 L water:

=74/100[$Ca(HCO_3)_2$+2x$Mg(HCO_3)_2$+ $MgSO_4$+ $MgCl_2$ as $CaCO_3$ equivalent]x vol. of water

=74/100[5.0+2x5.14+10.0+2.11] mg/Lx50,000 L

=74/100[27.39 mg/L]x50,000L=10,13,430 mg

=10,13,430 mgx10-6 kg=1.0134 kg

Soda requirement for 50,000 L water:

=106/100[$CaSO_4$+ $MgSO_4$+ $MgCl_2$ as $CaCO_3$ equivalent]x vol. of water

=106/100[5.0+10.0+2.11] mg/L x50,000 L

=106/100[17.11mg/L]x50,000 L=9,06830 mg

= 9,06830 mg x 10-6 kg =0.9068 kg

Q.5. A water sample on analysis gave the following data:

Ca^{2+}=30 mg/L, Mg^{2+}=24 mg/L, CO_2=24mg/L, HCl=50 mg/L, K^+=10mg/L

Calculate the quantities of lime (90% pure) and soda (94% pure) required to softened one million litres of water sample.

Solution: Conversion in to $CaCO_3$ equivalents:

Constituents	Multiplication factor	$CaCO_3$ equivalent
Ca^{2+} = 30 mg/L	100/40	30x100/40=75.0 mg/L
Mg^{2+} =24 mg/L	100/24	24x100/24=100.0 mg/L
CO_2 =24mg/L	100/44	24x100/44=54.5 mg/L
HCl=50 mg/L	100/73	50x100/73=68.5 mg/L

Lime requirement:

=74/100[Mg^{2+}+CO_2 +HCl as $CaCO_3$ eq.] x Vol.of water x (100% purity)

=74/100[(100+54.5+68.5) mg/L]x 106Lx(100/90)

=74/100[223mg/L]x 106 Lx(100/90)=(74x223x106)/90 mg

=1.834x108 mg =1.834x102kg=183.4 kg

Soda requirement:

=106/100[Ca^{2+}+Mg^{2+}+ HCl as $CaCO_3$ eq.]x Vol.of water x(100% purity)

=106/100[(75+100+68.5) mg/L] x106 Lx (100/94)

=106/100[243.5mg/L]x 106 Lx (100/94)=(106x243.5x106)/94 mg

=2.946x108mg=2.946x102kg=294.6 kg

Q.6. A water sample on analysis gave the following data:

Ca^{2+}=30 mg/L, Mg^{2+}=18mg/L, K^+= 19.5 mg/L, CO_2=11mg/L, HCO_3^- = 122 mg/L, Cl^- =35.5 mg/L, SO_4^{2-} =48mg/L

(i) Calculate the total hardness and alkalinity of water sample

(ii) Calculate lime-soda required for softening one litre of this sample of hard water

Solution: Conversion in to $CaCO_3$ equivalents:

Constituents	Multiplication factor	$CaCO_3$ equivalent
Ca^{2+}=30 mg/L	100/40	30x100/40=75 mg /L
Mg^{2+}=18mg/L	100/24	18x 100/24=75 mg /L
CO_2=11mg/L	100/44	11x 100/44=25 mg/L
HCO_3^- = 122 mg/L	100/122	122x 100/122 = 100 mg /L

(i) Total hardness= (75+75) mg/L=150 mg/L or 150 ppm

Alkalinity present = (HCO_3^- -CO_2) = (100-25) mg/L = 75 mg/L or 75 ppm

(ii) Lime requirement =74 /100[Mg^{2+} + CO_2 +HCO_3^- as $CaCO_3$ eq.]

= 74/100[75+25+100] mg /L = 148 mg/L

Soda requirement = 106/100[Ca^{2+} + Mg^{2+} - HCO_3^- as $CaCO_3$ eq.]

= 106/100[75+75-100] mg /L= 53 mg/L

Q.7. 100 ml of water sample has a hardness equivalent to 12.5 ml of 0.08N $MgSO_4$. What is its hardness in ppm?

Solution: 100 ml of water sample=12.5 ml of 0.08N $MgSO_4$

=12.5X0.08ml of 1N $MgSO_4$

= 1ml of 1N $MgSO_4$=1 ml of 1N $CaCO_3$ eq.

= 0.001 L of 1N $CaCO_3$ eq.

=0.001x50 g $CaCO_3$ eq.

=0.05 g $CaCO_3$ eq. (or 50 mg $CaCO_3$)

Therefore, 1000 ml (or /L) of water sample=50 mg $CaCO_3$ eq.x1000 ml/100 ml

=500 mg $CaCO_3$ eq.

Hence, the hardness of water sample is 500 mg $CaCO_3$ eq. Per litre or 500 ppm.

Q.8. 100 ml of a sample of hard water neutralizes exactly 12 ml of 0.12 N HCl using methyl orange as indicator. What kind of hardness is present? express the same in terms of $CaCO_3$ equivalent.

Solution: Hardness is temporary, since methyl orange does not give the value for permanent hardness.

100 ml of sample = 12 ml of 0.12 N HCl

= 12x0.12 ml of 1N HCl

=1.44 ml of 1 N HCl or 1N $CaCO_3$ eq.

=1.44x10-3 L x 50 g $CaCO_3$ eq. L-1

= 0.072 g $CaCO_3$ eq. or 72 mg $CaCO_3$ eq.

Hence,1000 ml (or 1 L) of water =72 mg CaCO3 eq. x 1000 ml /100 ml=720 mg $CaCO_3$ eq.

Temporary hardness of water is 720 ppm

Q.9. 0.5 g of $CaCO_3$ was dissolved in HCl and the solution 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 10 ml of EDTA solution. Calculate the hardness.

Solution: 500 ml of SHW =0.5 g or 500mg $CaCO_3$ eq.

Hence, 1 ml SHW = 1mg $CaCO_3$

Now 48 ml of EDTA = 50 ml SHW =50 mg $CaCO_3$ eq.

Therefore, 1 ml of EDTA = 50/48 mg $CaCO_3$ eq.

(i) Calculation of the total hardness of water:

50 ml hard water =15 ml EDTA = 15x (50/48) mg $CaCO_3$ eq.

= 15.625 mg $CaCO_3$ eq.

Hence, 1000 ml of hard water = 15.625 x 1000/50 mg $CaCO_3$ eq.

= 312.5 mg /L $CaCO_3$ eq.

Therefore**, total hardness =312.5 mg /L or 312.5 ppm**

(ii) Calculation of non-carbonate hardness:

50 ml boiled hard water = 10 ml EDTA

= 10 x (50/48) mg $CaCO_3$ eq.

= 10.417 mg $CaCO_3$ eq.

Hence, 1000 ml boiled hard water = 10.417 x 1000 /50 mg $CaCO_3$ eq.

= 208.3 mg $CaCO_3$ eq.

Therefore, non-carbonate hardness = 208.3 mg/L or 208.3 ppm

Hence, carbonate hardness = (312.5-208.3) = 104.2 ppm

Q.10. A water sample contains the following impurities: Ca^{2+}=20 ppm, Mg^{2+} =18 ppm, HCO_3^-=183ppm and SO_4^{2-} =24ppm. Calculate the amount of lime and soda needed for softening.

(Atomic weight of Mg and Ca are 24 and 40 respectively.)

Solution: Conversion in to $CaCO_3$ equivalents:

Constituents	Multiplication factor	$CaCO_3$ equivalent
Ca2+ = 20 ppm	100/40	20x100/40=50 ppm
Mg2+ =18 ppm	100/24	18x100/24=75 ppm
HCO3- =183ppm	100/122	183x100/122=150 ppm

Lime requirement:

=74/100[perm. Mg^{2+} +HCO_3^- as $CaCO_3$ equivalent]

=74/100[75+150] ppm=166.5 ppm or mg/L

Soda requirement:

=106/100[perm. Ca^{2+} + Mg^{2+}-HCO_3^- as $CaCO_3$ equivalent]

=106/100[50+75-150] ppm=Negative or Nil