Waughter

AKTION CONSULTANCY

Volume 1 : Edition 1 - The Chemistry of Water

Dear Water Warriors,

Reduce, reuse n recycle 3R's in context of water motivated us to apply technology and resulted in disconnect from nature.

Actually, a single R, Respect is something that WATER always needed.

'**Waughter**' is an attempt to bring the dignity to the reborn water produced out of scientific efforts and adding to available WATER.

Urmi Patel

In this inaugural issue we focus on *the "The Chemistry of Water"* and try to make it useful to reader for the day-to-day work with water.

- How much Acid or Alkali to dose to raise /reduce pH?
- Why H_2O with small molecular weight is passing but NaCl with 58 Molecular weight is rejected by RO membranes?
- Buffering of CO_2 & NH_3
- Definitions & Ionic Balance
- Significance of $CaCO_3$

NH_3 does similar buffering by producing NH_4OH and therefore NH_4 rejection on RO requires study of this behavior.

Question 1:

A Typical waste water has pH of 6.7 and your task is to raise the pH to 7.5. That's it? Can you calculate quantity of NaOH needed to raise it to 7.5?

If you think you can, as you know pH = - log [H^+], don't get surprised to know you are wrong. The natural water contains CO_2 that can buffer H^+ (Refer Image 1.1). So, one should use a different equation of pH in this case as hereunder:

pH= 6.3 + log (HCO_3^- as $CaCO_3$ ÷ CO_2 as CO_2) *(Eq.1)*

This brings additional problem to us. How much is HCO_3 in our water? To know that, please visit lab and test two parameters:

Alkalinity

The alkalinity in water indicates the quantities of hydroxide, carbonate and bicarbonate in water. Water may contain either of the 2 never all 3.

The alkalinity of water is determined using two indicators. Phenolphthalein Indicator gives the P Alkalinity (End Point 8.3 pH) and Methyl Orange Indicator yields the M Alkalinity (End Point 4.2 pH).

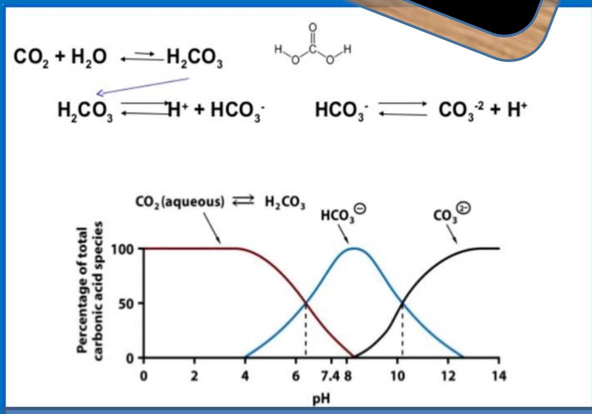

Image 1.1 : The pH and HCO3, CO3 Relation

M alkalinity is also called Total alkalinity.

$M = HCO_3^- + CO_3^{--} + OH^-$

$P = ½\, CO_3^{--} + OH^-$

If we apply modern maths on above we can understand below table:

Alkalinity Relationship			
Relation	Bicarbonate $HCO3^-$	Carbonate $C03^{--}$	Hydroxyl OH^-
P = 0	M	0	0
M = P	0	0	M
M = 2P	0	M	0
M < 2P	0	2 (M-P)	2P-M
M > 2P	M - 2P	2P	0

The Lab technician tests water and reports M as 200 mg/l and P as 0. What it means is HCO_3^- is 200 mg/l.

Now if we put this value in *Eq.1* and solve it for CO_2, we will get:

CO_2 = 79.62 mg/l as CO_2

In the event Acid or Alkali dosing to Reduce or Raise pH, we should understand what's happening to our equation. By Dosing X mg/l (ppm) Alkali.

Alkali : ↑ HCO_3^- , ↓ CO_2
Acid : ↑ CO_2 , ↓ HCO_3^-

pH= 6.3 + log {[(HCO_3^- + X) as $CaCO_3$]÷[(CO_2 -0.88*X) as CO_2)]} *(Eq. 1.1.)*

Sr No	Parameter	Unit	Value
1	pH Actual	-	6.7
2	pH Required	-	7.5
3	M Alkalinity	mg/l as CaCO3	200
4	P Alkalinity	mg/l as CaCO3	0
5	HCO3	mg/l as CaCO3	200
6	CO3	mg/l as CaCO3	0
7	OH	mg/l as CaCO3	0
8	CO2	mg/l as CO2	79.62
11	Dose of NaOH/HCL	mg/l as CaCO3	71.05
12	Dose as Such Alkali	mg/l as NaOH	56.84
13	Dose as Such Acid	mg/l as HCl	-53.28
	Available value		
	Desired		
	Fill after undersatnding M, P Relation		

A quick solution shall suggest that for our case we have to add 28.41 mg/l NaOH to raise pH to 7.5 from 6.7, if M Alkalinity is 200 mg/land P Alkalinity is 0 mg/l.

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Now lets solve what was 0.88.

Question 2:

If you have \$5, ₹10 and €15, how much money you have?

Well, you should know the conversion to bring them to a common unit as the answer shall be in \$, ₹ or €.

Similarly, in water chemistry the addition of impurities shall be done after converting it to a common unit of measurement.

Look at a Material $CaCO_3$

Molecular Weight = 40 + 12 + 3*16
= 100

Valency = 2

Therefore,

Equivalent Weight = Molecular Wt. ÷ Valency
= 100 ÷ 2
= 50

Thus, all the dissolved impurities are converted into equivalent $CaCO_3$ before any further work.

So if CO_2 has a molecular weight of 12 + 2*16 = 44, since valency of gas is considered 1, the equivalent weight is 44.

Thus 0.88 is conversion of $CaCO_3$ (50) into CO_2 (44). CF to CO_2 = 44/55 = 0.88.

On similar lines,

To Convert as such of Ion to equivalent $CaCO_3$, please multiply by:

Chloride	Cl^-	1.41 (50÷35.5)
Sulphate	SO_4^{--}	1.04 (50÷48)
Nitrate	NO_3-	0.81 (50÷62)
Calcium	Ca^{++}	2.50 (50÷20)
Magnesium	Mg^{++}	4.20 (50÷12)

Definitions & Ionic Balance

Let's have a look and image 1.2.

H, OH in centre as Cation & Anion is sign of Acidity or Basicity, if free. If bonded as in H-O-H it's Water.

Water contains some free space, not visible to naked eyes called Inter Molecular space (IMS). Impurities hidden in this space are termed dissolved, soluble.

Floating matter; Wood, plants, fibres, plastic, oil all remain on surface as their specific gravity is < 1.

Gases may be dissolved (in IMS), remember term DO it's the O_2 that is in IMS. Gases out of IMS are bubble and may stick to wall or come out in atmosphere.

Ions with +Ve charge are Cation and -Ve charge Anion.

Hardness

Ca^{++} & Mg^{++} ion and others in same column in periodic table (Be^{++}, Sr^{++}, Ba^{++}) have same characteristics. They tend to precipitate and stick to the surface causing scale.

As per rules of electroneutrality, ions though free entity must have a relation with counter ion to balance it's charge. One of the common most example of a relation is Na^+ & Cl^-.

Hardness that has (M-Alkalinity as balancing ion is Temporary and the one with balancing ion as EMA is termed Permanent. Ca^{++} & Mg^{++} prefer M-Alkalinity and as long as M-alkalinity is available, all hardness would be temporary. Permanent hardness will appear only when Hardness > Alkalinity, here too alkalinity would love Ca^{++} first and Mg^{++} next.

Equivalent Mineral Acidity (EMA)

Cl^-, SO_4^{--} & NO_3^- are anions as they have -Ve Charge. Imagine their balancing ion is Na+ and in that case they all appear like salt. NaCl Na_2SO_4 and $NaNO_3$ respectively.

In case Na^+ is replaced by H^+ ion, they will look like HCl H2SO_4 and HNO_3, the mineral acids. Thus, the anions that have potential to form mineral acids have a family name EMA.

Total Anion, therefore is sum of two differentiating anions 1. EMA & 2. M- Alkalinity.

TA = M-Alkalinity + EMA

Rules of electroneutrality means Total Anion should be equal to Total Anion (in terms of same unit ppm as $CaCO_3$), we say;

Total Cation = Total Anion ; And that means we need to now calculate the balance monovalent ions (Na^+, K^+ etc) by subtraction:

$Na^+ + K^+$ = Total Cation – Total Hardness

Fe^{++}, Cu^{++} and other metallic ions are low in concentrations, and can be oxidized, precipitated and dealt like a suspended matter hence not calculated normally in ionic balance as a matter of simplicity.

Gases : CO2 , O2, H2S	
Floating Matter : Wood Chips, Plants, Oil	
Clay, Silt, Organic Matter, Turbidity	
Colloids	
H^+	OH^-
Na^+ K^+	$HCO3^-$ $CO3^{--}$
Ca^{++} Mg^{++}	Cl^- $SO4^{--}$ $NO3^-$
Fe^{++} Mn^{++} → 3 Val.	$PO4^{---}$
Silica, Sugar, Phenol	
Organics, COD,BOD,TOC etc.	Micro Organisms

Image 1.2 : Definition & Ionic Balance

So, a good engineer will walk 11 steps on the water analysis report before doing anything, to be sure he/she is working in right direction.

Step 1 : Check Adequacy of Data
Step 2 : Convert Impurities to CaCO3, if not reported as CaCO3
Step 3 : Calculate EMA
Step 4 : Calculate Total Anion (= EMA + M-Alkalinity)
Step 5 : Calculate Total Cation (TC = TA, H2O is Electro neutral)
Step 6 : Find $Na^+ + K^+$ = TC – Total Hardness
Step 6A : If you get – Ve Value, it indicates error in report
Step 7 : Observe M and P Value
Step 8 : Report $HCO3^-$, $CO3^{--}$ and OH^-
Step 9 : Observe Total Hardness and M-Alkalinity
Step 10 : Report Temporary and Permanent Hardness
Step 11 : Report Sodium Alkalinity

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Reverse Osmosis & Chemistry:

This subject of salt behaviours needs explanation at fundamental levels.

Look at the table below:

Molecule	Molecular Weight	Size
H_2O	18	~ 2.75 ANGSTROM
Na	23	Ionic Radius 154 pm
Na^+	23	Ionic Radius 102 pm
F^-	35.5	Ionic Radius 133 pm

pm IS peta meter 1 x 10^{-15}

Wonder why the water is filleted across a composite polyamide membrane RO membrane with distributed pore size in the range of 3 – 10 Å, but Na^+ or F^- which is at-least 1000 times smaller in size cannot?

The answer lies in understanding hydration.

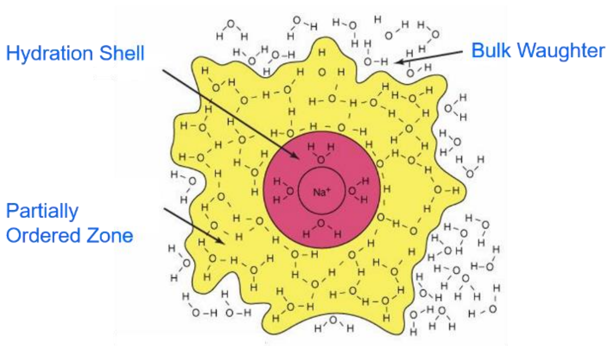

Image 1.3 : Hydration of Na^+ in H2O

The ions that are hydrated cannot move alone; they must take the hydration shell fully as well as little bit of partially ordered zone when they move.

Furthermore, a single Na^+ can not pass alone even if opportunity exists, as we cannot have *Charge* transferring across membrane. Counter charge e.g. Cl^- shall also have the mood to go with Na^+, this is very improbable and thus bulk of NaCl is rejected across RO membrane.

On different lines, find out why NH_4^+, NO_3^- is not rejected well on membranes but pass. Waughter is a wonder material and we consistently learn more.

जल जीवन जननी !!

Vaishali Singh our summer intern, daughter of a farmer and an aspiring Chemical Engineer sow the seeds of this magazine; we wish her good luck !!

Sanjeev Srivastava
Lead Technology at Aktion Consultancy
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'Waughter'

Jal jeevan and Janni.. the word 'waughter' heard many times as water never spelled to souls like daughter.

It's the name of our magazine , the first addition to be published on Jan 26, 2021. Thank you **Vaishali Singh**

You have created a new word WAUGHTER for entire water and waste water afterbirth.

#water #conservation #environment #climatechange #nature #trees #globalwarming #sustainability

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Our world is Waughter

The technical knowledge share attempt of Aktion Consultancy and the contents in the magazine shall be qualified by Sanjeev Srivastava our Technology Lead.

Our next edition focuses on Organic Chemistry : COD

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