ME485 SS Di Julio

SOLUTIONS FOR CHAPTER 6

6.1 Hardness in meq/L:

$$Ca^{2+} = \frac{150 mg/L}{20.05 mg/meq} = 7.5 meq/L$$

$$Mg^{2+} = \frac{60 mg/L}{12.15 mg/meq} = 4.9 meq/L$$

Total hardness = 7.5 + 4.9 = 12.4 meq/L

Hardness as $CaCO_3$:

$$\text{Hardness} = 12.4 \frac{meq}{L} \times 50 \frac{mg \text{ as } CaCO_3}{meq} = 622 mg/L \text{ as } CaCO_3$$

Table 6.5 would classify this as *very hard* water.

6.2 pH = 9,

$$[H^+] = 10^{-pH} = 1 \times 10^{-9} mol/L$$

$$(H^+) = \frac{1 \times 10^{-9} mol}{L} \times \frac{1 g}{mol} \times \frac{10^3 mg}{g} \times \frac{meq}{1 mg} = 1 \times 10^{-6} meq/L$$

$$= 10^{-6} \frac{meq}{L} \times 50 \frac{mg\ CaCO_3}{meq} = 5 \times 10^{-5} mg/L \text{ as } CaCO_3$$

$$[OH^-] = \frac{10^{-14}}{[H^+]} = \frac{10^{-14}}{10^{-9}} = 10^{-5} mol/L$$

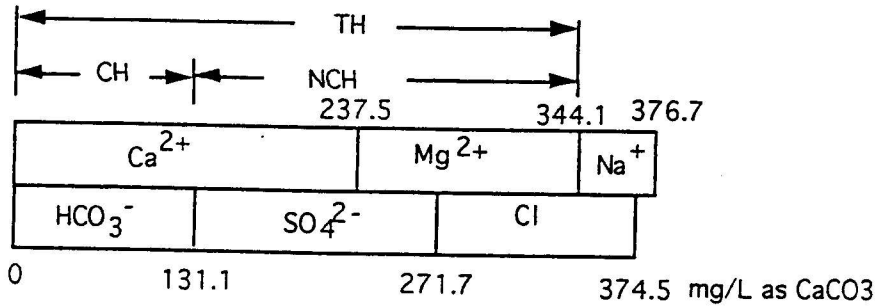
$$(OH^-) = \frac{10^{-5} mol}{L} \times \frac{17 g}{mol} \times \frac{10^3 mg}{g} \times \frac{meq}{17 mg} = 10^{-2} meq/L$$

$$= 10^{-2} \frac{meq}{L} \times 50 \frac{mg\ CaCO_3}{meq} = 0.5 mg/L \text{ as } CaCO_3$$

6.3 First, ignoring the contribution of H^+ and OH^-, with pH=10.5, 39.0mg/L of CO_3^{2-} and 24.5 mg/L of HCO_3^-,

a. $$CO_3^{2-} = \frac{(12 + 3 \times 16)}{2} = 30.0 \frac{mg}{meq}$$

$$(CO_3^{2-}) = \frac{39.0 mg/L}{30 mg/meq} \times \frac{50 mg \text{ of } CaCO_3}{meq} = 65 mg/L \text{ as } CaCO_3$$



6.7 Water analysis:

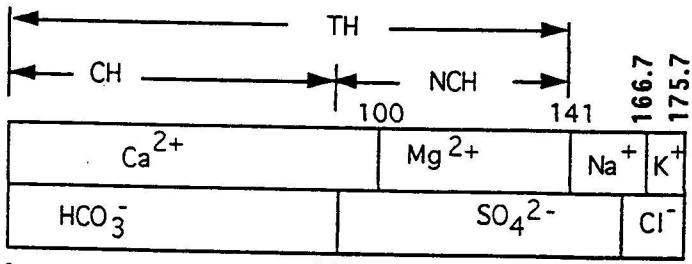
Ion	mg/L	mg/meq	meq/L	mg/L as $CaCO_3$
Ca^{2+}	40.0	20.0	2.0	100.0
Mg^{2+}	10.0	12.2	0.82	41.0
Na^{+}	X?	23.0	Y?	Z?
K^{+}	7.0	39.1	0.18	9.0
HCO_3^{-}	110.0	61.0	1.8	90.2
SO_4^{2-}	67.2	48.0	1.4	70.0
Cl^{-}	11.0	35.5	0.31	15.5

a. Equivalents balance to find Na concentration:

$$100 + 41 + Z + 9 = 90.2 + 70 + 15.5 \qquad Z = 25.7 \text{ mg/L as } CaCO_3$$

$$\text{or, } \frac{25.7 \text{mg/L as } CaCO_3}{50 \text{mg/meq}} \times 23.0 \text{ mg/meq} = 11.8 \text{ mg/L}$$

b. $TH = (Ca^{2+}) + (Mg^{2+}) = 100.0 + 41.0 = 141$ mg/L as $CaCO_3$



c.

6.5 Questionable Cl^-

Ions	mg/L	mg/meq	meq/L
Ca^{2+}	90	20.0	4.5
Mg^{2+}	30	12.2	2.46
Na^+	72	23.0	3.13
K^+	6	39.1	0.15
		Total =	10.24
Cl^-	(Cl^-)	35.5	(Cl^-)/35.5
SO_4^{2-}	225	48.0	4.69
HCO_3^-	165	61.0	2.70
		Total =	7.39 + (Cl^-)/35.5

to balance, $10.24 = 7.39 + (Cl^-)/35.5$

$Cl^- = 101$ mg/L so there probably was an error.

6.6 Water analysis:

Ion	mg/L	mg/meq	meq/L	mg/L as $CaCO_3$
Ca^{2+}	95	20.0	4.75	237.5
Mg^{2+}	26	12.2	2.13	106.6
Na^+	15	23.0	0.65	32.6
HCO_3^-	160	61.0	2.63	131.1
SO_4^{2-}	135	48.0	2.81	140.6
Cl^-	73	35.5	2.06	102.8

a. total hardness (TH) = $(Ca^{2+}) + (Mg^{2+}) = 237.5 + 106.6 = 344.1$ mg/L as $CaCO_3$

b. carbonate hardness (CH) = $(HCO_3^-) = 131.1$ mg/L as $CaCO_3$

c. noncarbonate hardness (NCH) = 344.1 - 131.1 = 213 mg/L as $CaCO_3$

d. alkalinity = $(HCO_3^-) = 131.1$ mg/L as $CaCO_3$ (since pH near neutral)

e. TDS = 95 + 26 + 15 + 160 + 135 + 73 = 504 mg/L

$$HCO_3^- = \frac{(1+12+3x16)}{1} = 61.0\frac{mg}{meq}$$

$$(HCO_3^-) = \frac{24.5mg/L}{61.0mg/meq} x \frac{50mg\ of\ CaCO_3}{meq} = 20.1mg/L\ as\ CaCO_3$$

Ignoring H^+ and OH^-, alkalinity = $(HCO3^-) + (CO3^{2-})$

= 20.1 + 65.0 = 85.1 mg/L as CaCO3

b. Including H^+ and OH^-,

$$pH = 10.5,\ [H^+] = 10^{-10.5} = 3.16x10^{-11} mol/L$$

$$(H^+) = \frac{3.16x10^{-11}mol}{L} x \frac{1\ g}{mol} x \frac{10^3 mg}{g} x \frac{1meq}{mg} x \frac{50mg\ CaCO_3}{meq}$$

$$= 1.5x10^{-6} mg/L\ as\ CaCO_3$$

$$pH = 10.5,\ [OH^-] = \frac{10^{-14}}{10^{-10.5}} = 3.16x10^{-4} mol/L$$

$$(OH^-) = \frac{3.16x10^{-4}\ mol}{L} x \frac{17\ g}{mol} x \frac{10^3 mg}{g} x \frac{meq}{17mg} x \frac{50mg\ CaCO_3}{meq}$$

$$= 15.8\ mg/L\ as\ CaCO_3$$

alkalinity = $(HCO3^-) + (CO3^{2-}) + (OH^-) - (H^+)$

= 20.1 + 65.0 + 15.8 - $1.5x10^{-6}$ = 100.9 mg/L as CaCO3

6.4 a. alkalinity = $(HCO3^-) + (CO3^{2-}) + (OH^-) - (H^+)$,

but pH near neutral so (H^+), (OH^-), and $(CO3^{2-})$ are negligible,

$$(HCO_3^-) = \frac{165mg/L}{61.0mg/meq} x \frac{50mg\ of\ CaCO_3}{meq} = 135.2mg/L\ as\ CaCO_3$$

alkalinity = 135.2 mg/L as CaCO3

b. hardness = $(Ca^{2+}) + (Mg^{2+})$

$$= \left(\frac{90mg}{L} x \frac{meq}{20mg} + \frac{30mg}{L} x \frac{meq}{12.2mg}\right) x \frac{50mg\ of\ CaCO_3}{meq} = 348mg/L\ as\ CaCO$$

c. total dissolved solids (TDS):

TDS = 90 + 30 + 72 + 6 + 120 + 225 + 165 = 708 mg/L