PROBLEM #4 - 25 points **USE UNITS of METERS SECONDS and GRAMS**

WRITE ANSWERS TO THE FOLLOWING QUESTIONS ON THE NEXT PAGE, SHOW YOUR WORK. These questions are repeated on the next page for your convenience.

NOTE: THIS IS THE SAME WATER ANALYSIS THAT YOU EVALUATED IN PROBLEM #3

a) **(5pts) All of the alkalinity is comprised of HCO_3. Why does the value for alkalinity differ from the concentration of HCO_3? Provide calculations to support your answer.**

b) **(12pts) Is the water saturated with calcium sulfate ($CaSO_4$)? Provide calculations to support your answer.**

c) **(5pts) Will calcium carbonate ($CaCO_3$) precipitate from this sample? Provide calculations to support your answer.**

d) **(3pts) Will this water cause corrosion? Provide calculations to support your answer.**

TEMP	15	C
HCO_3^-	198.4	mg/L
Cl^-	114.9	mg/L
K^+	9.9	mg/L
Ca^{+2}	74.4	mg/L
Mg^{+2}	18.1	mg/L
Na^+	130	mg/L
SO_4^{-2}	227.1	mg/L
Total Dissolved Solids	733	mg/L
Alkalinity as $CaCO_3$	162.6	mg/L
pH	7.37	units

PROVIDE CALCULATIONS AND ANSWERS TO PROBLEM 4 HERE

a) (5pts) All of the alkalinity is comprised of HCO_3. Why does the value for alkalinity differ from the concentration of HCO_3? Provide calculations to support your answer.

alkalinity expressed as equivalents of $CaCO_3$ $= [HCO_3] \frac{\frac{g}{eq} CaCO_3}{\frac{g}{eq} HCO_3} = 198.4 \frac{mg}{L} \frac{\frac{50 g}{eq}}{\frac{61 g}{eq}} = 163 \frac{mg}{L}$

b) (12pts) Is the water saturated with calcium sulfate ($CaSO_4$)? Provide calculations to support your answer.

Ionic strength $= 2.5\times10^{-5}(TDS) = 2.5\times10^{-5}(773 \frac{mg}{L}) = 0.0183$

divalent $\log \gamma = \frac{-0.5\, z^2 \sqrt{I}}{1+\sqrt{I}} = \frac{-0.5\,(2)^2\sqrt{0.0185}}{1+\sqrt{0.0185}} = -0.238 \quad \gamma = 0.58$

$IAP = (\text{activity } Ca^{+2})(\text{activity } SO_4) = 0.58\ 1.86\times10^{-3} \frac{m}{L}\ 0.58\ 2.37\times10^{-3} \frac{M}{L} = 1.5\times10^{-6}$

$\Delta G = \Delta fG Ca_2 + \Delta fG SO_4 - \Delta fG CaSO_4 = 553.6 \frac{KJ}{M} + 744 \frac{KJ}{M} - 1321.8 \frac{KJ}{M} = -24.2 \frac{KJ}{M}$

$\log K_{sp} = \frac{-\Delta rG}{2.303\,RT} = \frac{-23670\ J/M}{2.303\ \ 8.314 \frac{J}{KM}\ 288.15K} = -4.29 \quad K_{sp} = 4\times10^{-5}$

$IAP < K_{sp}$

$SI < 0 = \log \frac{IAP}{K_{SP}} = -1.45$ } so water is not saturated with Ca

c) (5pts) Will calcium carbonate ($CaCO_3$) precipitate from this sample? Provide calculations to support your answer.

univalent $\log \gamma = \frac{-0.5\,(1)\sqrt{0.0183}}{1+\sqrt{0.0183}} \quad \gamma = 0.87$

$pH_S = -\log\left(\frac{K_2\, \gamma_{Ca}[Ca]\gamma_{HCO_3}[HCO_3]}{K_{SP}}\right) = -\log\left(\frac{3.7\times10^{-11}(0.58)\,1.86\times10^{-3}(0.87)\,3.75\times10^{-3}}{6.03\times10^{-9}}\right)$

$= -\log \frac{1.13\times10^{-16}}{6.03\times10^{-9}} = -\log 1.87\times10^{-8} \quad pH_S = 7.73$

$LI = pH - pH_S = 7.37 - 7.73 = -0.36$ < 0 so scale is not expected

d) (3pts) Will this water cause corrosion? Provide calculations to support your answer.

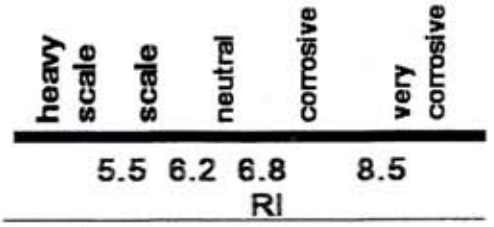
Ryzner Index $= 2pH_S - pH = 2(7.73) - 7.37 = 8.08$

somewhat corrosive

NAME _____

Substance (form)	Gibbs $\Delta_f G$ (kJ)mol^{-1}
Al (s)	0
Al_2SiO_5 (kyanite)	-2443.88
Al_2SiO_5 (andalusite)	-2442.66
Al_2SiO_5 (sillimanite)	-2440.99
Ar (g)	0
C (graphite)	0
C (diamond)	2.9
CH_4 (g)	-50.72
C_2H_6 (g)	-32.82
C_3H_8 (g)	-23.49
C_2H_5OH (l)	-174.78
$C_6H_{12}O_6$ (glucose)	-910
CO (g)	-137.17
CO_2 (g)	-394.36
CO_3^{-2} (aq)	-527.81
H_2CO_3 (aq)	-623.08
HCO_3^- (aq)	-586.77
Ca^{2+} (aq)	-553.58
$CaCO_3$ (calcite)	-1128.8
$CaSO^4$ (anhydrite)	-1321.8
$CaCO_3$ (aragonite)	-1127.8
$CaCl_2$ (s)	-748.1
Cl_2 (g)	0
Cl^- (aq)	-131.23
Cu (s)	0
Fe (s)	0
H_2 (g)	0
H (g)	203.25
H^+ (aq)	0
H_2O (l)	-237.13
H_2O (g)	-228.57
He (g)	0
Hg (l)	0
N_2 (g)	0
NH_3 (g)	-16.45
Na^+(aq)	-261.91
NaCl (s)	-384.14
$NaAlSi_3O_8$ (albite)	-3711.5
$NaAlSi_2O_6$ (jadeite)	-2852.1
Ne (g)	0
O_2 (g)	0
O_2 (aq)	16.4
OH^- (aq)	-157.24
Pb (s)	0
PbO_2(s)	-217.33
$PbSO_4$(s)	-813
SO_4^{2-} (aq)	-744.53
HSO_4^- (aq)	-755.91
SiO_2 (α quartz)	-856.64
H_4SiO_4(aq)	-1307.67

Values of *R*	Units $(V \cdot P \cdot T^{-1} \cdot n^{-1})$
8.314472	$J \cdot K^{-1} \cdot mol^{-1}$
0.0820574587	$L \cdot atm \cdot K^{-1} \cdot mol^{-1}$
83.14472	$cm^3 \cdot bar \cdot mol^{-1} \cdot K^{-1}$
$8.20574587 \times 10^{-5}$	$m^3 \cdot atm \cdot K^{-1} \cdot mol^{-1}$
8.314472	$cm^3 \cdot MPa \cdot K^{-1} \cdot mol^{-1}$
8.314472	$L \cdot kPa \cdot K^{-1} \cdot mol^{-1}$
8.314472	$m^3 \cdot Pa \cdot K^{-1} \cdot mol^{-1}$
62.36367	$L \cdot mmHg \cdot K^{-1} \cdot mol^{-1}$
62.36367	$L \cdot Torr \cdot K^{-1} \cdot mol^{-1}$
83.14472	$L \cdot mbar \cdot K^{-1} \cdot mol^{-1}$
0.08314472	$L \cdot bar \cdot K^{-1} \cdot mol^{-1}$
1.987	$cal \cdot K^{-1} \cdot mol^{-1}$
6.132440	$lbf \cdot ft \cdot K^{-1} \cdot g\text{-}mol^{-1}$
10.73159	$ft^3 \cdot psi \cdot {}^\circ R^{-1} \cdot lb\text{-}mol^{-1}$
0.7302413	$ft^3 \cdot atm \cdot {}^\circ R^{-1} \cdot lb\text{-}mol^{-1}$
998.9701	$ft^3 \cdot mmHg \cdot K^{-1} \cdot lb\text{-}mol^{-1}$
8.314472×10^7	$erg \cdot K^{-1} \cdot mol^{-1}$



Carbonate Equilibrium Constants as a Function of Temperature

T, °C	K_m	K_1	K_2	K_{sp}
5		3.02×10^{-7}	2.75×10^{-11}	8.13×10^{-9}
10		3.46×10^{-7}	3.24×10^{-11}	7.08×10^{-9}
15		3.80×10^{-7}	3.72×10^{-11}	6.03×10^{-9}
20		4.17×10^{-7}	4.17×10^{-11}	5.25×10^{-9}
25	1.58×10^{-3}	4.47×10^{-7}	4.68×10^{-11}	4.57×10^{-9}
40		5.07×10^{-7}	6.03×10^{-11}	3.09×10^{-9}
60		5.07×10^{-7}	7.24×10^{-11}	1.82×10^{-9}

$$K_m = \frac{[H_2CO_3]}{[CO_2]_{aq}} \qquad K_1 = \frac{[H^+][HCO_3^-]}{[H_2CO_3]} \qquad K_2 = \frac{[H^+][CO_3^{-2}]}{[HCO_3^-]}$$

K_{sp} = Solubility product for $CaCO_3$