Constituent	Valence	Form	Solubility Product (Note 5)	Maximum Concentration in equilibrium with this form	Corresponding anion concentration	Remarks
Cd	+2	$CdCO_3$	2.5×10^{-14}	0.197 mg/l	$[CO_3^{=}] = 1.43 \times 10^{-8}$	See Note 1
				41.7 mg/l	$[CO_3^{=}] = 7.48 \times 10^{-10}$	"
				1.79×10^{-3} mg/l	$[CO_3^{=}] = 1.58 \times 10^{-6}$	"
				0.0120 mg/l	$[CO_3^{=}] = 2.34 \times 10^{-7}$	See Note 2
Cd	+2	$CdSO_4$	soluble			
Cd	+2	$Cd(OH)_2$	1.2×10^{-14}	$2.04 \times 10^{+5}$ mg/l	$[OH^-] = 8.13 \times 10^{-8}$	See Note 3, soluble
				34.7 molar, soluble	$[OH^-] = 1.86 \times 10^{-8}$	" "
				1860 mg/l	$[OH^-] = 8.51 \times 10^{-7}$	"
Pb	+2	$PbCO_3$	1.5×10^{-13}	2.18 mg/l	$[CO_3^{=}] = 1.43 \times 10^{-8}$	See Note 1
				41.7 mg/l	$[CO_3^{=}] = 7.45 \times 10^{-10}$	"
				1.98×10^{-2} mg/l	$[CO_3^{=}] = 1.55 \times 10^{-6}$	"
				0.133 mg/l	$[CO_3^{=}] = 2.34 \times 10^{-7}$	See Note 2
Pb	+2	$PbSO_4$	1.8×10^{-8}	2.61 mg/l	$[SO_4^{=}] = 1.43 \times 10^{-3}$	See Note 4
Pb	+2	$Pb(OH)_2$	2.8×10^{-16}	8790 mg/l	$[OH^-] = 8.13 \times 10^{-8}$	See Note 3
				soluble (.809 molar)	$[OH^-] = 1.86 \times 10^{-8}$	"
				80.1 mg/l	$[OH^-] = 8.51 \times 10^{-7}$	"

Constituent	Valence	Form	Solubility Product	in equilibrium with this form	anion concentration	Remark
Ba	+2	$BaCO_3$	8.1×10^{-9}	0.566 Molar (soluble)	$[CO_3^=] = 1.43 \times 10^{-5}$	See Note 1 Soluble
				Soluble	$[CO_3^=] = 7.48 \times 10^{-10}$	"
				706 mg/l	$[CO_3^=] = 1.58 \times 10^{-6}$	"
Ba	+2	$BaSO_4$	1.1×10^{-10}	1.06×10^{-2} mg/l	$[SO_4^=] = 1.43 \times 10^{-3}$	See Note 4
Ba	+2	$Ba(OH)_2$	5.0×10^{-3}	Soluble	$[OH^-] = 8.13 \times 10^{-8}$	See Note 3 Soluble
				Soluble	$[OH^-] = 1.56 \times 10^{-8}$	See Note 3 Soluble
				Soluble	$[OH^-] = 8.51 \times 10^{-7}$	See Note 3 Soluble
Cu	+2	$CuCO_3$	2.5×10^{-10}	1110 mg/l	$[CO_3^=] = 1.43 \times 10^{-8}$	See Note 1
				10.0 mg/l	$[CO_3^=] = 1.58 \times 10^{-6}$	"
		$Cu(OH)_2$	1.6×10^{-19}	29.4 mg/l	$[OH^-] = 1.86 \times 10^{-8}$	See Note 3
				1.40×10^{-7} mg/l	$[OH^-] = 8.51 \times 10^{-7}$	"
		$CuSO_4$	soluble			
Cr	+3	$Cr(OH)_3$	6.7×10^{-31}	5.41×10^{-3} mg/l	$[OH^-] = 1.86 \times 10^{-9}$	See Note 3
				5.65×10^{-8} mg/l	$[OH^-] = 8.51 \times 10^{-7}$	See Note 3
		$Cr_2(CO_3)_3$	unstable			
		$Cr_2(SO_4)_3$	soluble			

Constituent	Valence	Form	Solubility Product	in equilibrium with this form	anion concentration	Remarks
Ni	+2	$NiCO_3$	6.6×10^{-9}	2.71×10^{4} mg/l	$[CO_3^{=}] = 1.43 \times 10^{-5}$	Note 1
				245 mg/l	$[CO_3^{=}] = 1.58 \times 10^{-6}$	"
		$Ni(OH)_2$	2.8×10^{-16}	4.75×10^{4} mg/l	$[OH^-] = 1.86 \times 10^{-5}$	Note 3
				22.7 mg/l	$[OH^-] = 8.51 \times 10^{-7}$	"
		$NiSO_4$	soluble			
Zn	+2	$ZnCO_3$	1.5×10^{-11}	68.6 mg/l	$[CO_3^{=}] = 1.43 \times 10^{-5}$	Note 1
				0.621 mg/l	$[CO_3^{=}] = 1.58 \times 10^{-6}$	"
		$Zn(OH)_2$	4.5×10^{-17}	8.57×10^{3} mg/l	$[OH^-] = 1.86 \times 10^{-8}$	Note 3
				4.06 mg/l	$[OH^-] = 8.51 \times 10^{-7}$	"
		$ZnSO_4$	soluble			
Hg	+2	$HgCO_3$	unstable			
		$Hg(OH)_2$	2.5×10^{-26}	1.45×10^{-5}	$[OH^-] = 1.86 \times 10^{-8}$	Note 3
				6.92×10^{-9}	$[OH^-] = 8.51 \times 10^{-7}$	"
		$HgSO_4$	soluble			

Constituent	Valence	Form	Solubility Product	[illegible] in equilibrium with this form	anion concentration	Remarks
Ag	+1	Ag_2CO_3	8.1×10^{-12}	2.57×10^{3} mg/l	$[CO_3^{=}] = 1.43 \times 10^{-8}$	Note 1
				2.44×10^{2} mg/l	$[CO_3^{=}] = 1.58 \times 10^{-6}$	"
		$AgOH$ (Ag_2O)	2.0×10^{-8}	1.16×10^{5} mg/l	$[OH^-] = 1.86 \times 10^{-8}$	Note 3
				2.54×10^{3} mg/l	$[OH^-] = 8.51 \times 10^{-7}$	"
		Ag_2SO_4	fairly soluble			

Note 1. Calculation of $[CO_3^=]$ with atmospheric CO_2 as the controlling factor.

$[H_2CO_3] = 0.033 \cdot P_{CO_2}$ (Whitten and Gailey, General Chemistry, Saunders, 1981, p. 280)

P_{CO_2}(atmospheric) $= 3.25 \times 10^{-4}$ atm (W and G, p. 683)

So $[H_2CO_3] = .033 \times 3.25 \times 10^{-4} = 1.07 \times 10^{-5}$ M(olar)

The pH of the water samples ranges from 6.27 to 7.93, with an average value of 6.91.

$[H^+] = 10^{-pH}$

$[H^+]_{ave} = 10^{-6.91} = 1.23 \times 10^{-7}$

Similarly $[H^+]_{max} = 5.37 \times 10^{-7}$

$[H^+]_{min} = 1.17 \times 10^{-8}$

Now for H_2CO_3, $K_1 K_2 = \dfrac{[H^+]^2 [CO_3^=]}{[H_2CO_3]}$,

so $[CO_3^=] = \dfrac{K_1 K_2 [H_2CO_3]}{[H^+]^2} = \dfrac{4.2 \times 10^{-7} \times 4.8 \times 10^{-11} \times 1.07 \times 10^{-5}}{[H^+]^2}$

(K_1 and K_2 from W and G). Then

$[CO_3^=]_{ave} = 1.43 \times 10^{-8}$ molar

$[CO_3^=]_{low\ pH} = 7.48 \times 10^{-10}$ "

$[CO_3^=]_{high\ pH} = 1.58 \times 10^{-6}$ "

Note 2. Calculation of $[CO_3^=]$ from the total bicarbonate data on the water samples.

The average value of HCO_3^- as $CaCO_3$ for the ten water samples is $77.46 \frac{mg}{l}$. This gives a total molar CO_3 concentration of $\frac{77.46 \times 10^{-3} gm/l}{100 gm/mole} = 7.75 \times 10^{-4}$ molar.

To determine how much of this is present as $CO_3^=$ we proceed as follows. The average $[H^+]$ is 1.23×10^{-7} molar.

$$K_1 = \frac{[H^+][HCO_3^-]}{[H_2CO_3]} = 4.2 \times 10^{-7}$$

$$K_2 = \frac{[H^+][CO_3^=]}{[HCO_3^-]} = 4.8 \times 10^{-11}$$

$$[CO_3] = 7.75 \times 10^{-4} = [H_2CO_3] + [HCO_3^-] + [CO_3^=]$$

from mass balance.

$$[H_2CO_3] = \frac{[H^+][HCO_3^-]}{K_1}$$

$$[CO_3^=] = \frac{K_2 [HCO_3^-]}{[H^+]}$$

$$\text{So } 7.75 \times 10^{-4} = [HCO_3^-] \cdot \left(\frac{[H^+]}{K_1} + 1 + \frac{K_2}{[H^+]} \right)$$

Substituting in the values for $[H^+]$, K_1, and K_2 then yields $[HCO_3^-] = 5.99 \times 10^{-4} M$, from which we get $[CO_3^=] = \frac{K_2 [HCO_3^-]}{[H^+]} = \underline{2.23 \times 10^{-8} M}$

Note 3. Calculation of $[OH^-]$ from pH.

$$[H^+] = 10^{-pH}$$

$$[H^+][OH^-] = 10^{-14}$$

$$[OH^-] = \frac{10^{-14}}{10^{-pH}} = 10^{pH-14}$$

The minimum $[OH^-]$ is obtained with the smallest pH; this is

$$[OH^-]_{min} = 10^{6.72-14} = 1.86 \times 10^{-8}$$

Similarly, $[OH]_{max} = 10^{7.93-14} = 8.51 \times 10^{-7}$

Note 4. Calculation of $[SO_4^=]$.

The average sulfate concentration for the ten water samples is $137 \frac{mg}{l}$. This gives

$$[SO_4^=] = \frac{137 \times 10^{-3} \frac{gm}{mg}}{96 \, gm/mole} = 1.43 \times 10^{-3} M.$$

Note 5. All solubility products and other equilibrium constants, etc, were taken from Whitten and Gailey, General Chemistry, published by Saunders in 1981.