Water Chemistry Homework 2.

Remember: NEAT and orderly.

Organize problems so they are presented in the same order as the problem numbers. Do not rewrite the problems, but do number the answers (use the a's and b's too!). Show work as appropriate.

$K_w = 1.0 \times 10^{-14}$

$pK_w = 14.00$

1. Complete the following table. Do not show work. Use this page.

$[H^+]$ (M)	$[OH^-]$ (M)	pH	pOH
3.6×10^{-9}	2.8×10^{-6}	8.44	5.56
1.7×10^{-13}	0.0582	12.76	1.245
7.6×10^{-3}	1.3×10^{-12}	2.12	11.88
1.9×10^{-7}	5.2×10^{-8}	6.72	7.28

2. Write the answers for question 2 on this page.
   At 50°C, $K_w = 1.85 \times 10^{-13}$. $pK_w = 12.733$

   a. What is the pH of pure water at 50°C? (Show formulas used!)

$K_w = [H^+][OH^-] = 1.85 \times 10^{-13}$

in pure water $[H^+] = [OH^-]$ so

$[H^+]^2 = 1.85 \times 10^{-13}$ $[H^+] = 4.3 \times 10^{-7}$ $pH = 6.366$

   b. Fill in the table below for water at 50°C.

$[H^+]$ (M)	$[OH^-]$ (M)	pH	pOH
1.9×10^{-5}	9.6×10^{-9}	4.72	8.02
1.3×10^{-5}	1.3×10^{-8}	4.87	7.86

3. Fill in the blank with "increase", "decrease" or "stay the same".

a. When pH is increased, the concentration of most metal ions will decrease.
ppt w. OH^-

b. When pH is increased, the solubility of hydrogen sulfide will either.
more S^{2-} ppt
H_2S is volatile, less likely to dissolve

c. When pH is increased, the toxicity of cyanide will decrease.
CN^- less toxic than HCN
more likely to ppt

d. When pH is increased, the concentration of carbonate ion will increases.
removing H^+
$HCO_3^- \rightarrow CO_3^{2-}$

e. When pH is increased, the volatility of ammonia will increase.
$NH_4^+ \rightarrow NH_3$

f. When pH is increased, the total phosphate concentration will same.
changes form not amount

4. Classify the following as "oxidizing agent", "reducing agent" or "neither"

Bromine (Br_2) – oxidizing

Sodium hypochlorite (NaOCl) – oxidizing

Oxygen gas (O_2) – oxidizing

Zinc metal (Zn) – reducing

Carbon dioxide (CO_2) – neither, very stable as is

5. Classify the following reactions as "oxidation" or "reduction"

$MnO_4^- + 8\,H^+ + 5\,e^- \rightarrow Mn^{2+} + 4\,H_2O$ gain of e- is reduction

$C_2O_4^{2-} \rightarrow 2\,CO_2 + 2\,e^-$ loss of e- is oxidation

Converting nitrogen into ammonia reduction (gaining H is typical)

Converting ammonia into nitrate oxidation (gaining O is typical)

Converting organic matter into CO_2 and water oxidation (combustion is a classic example)

6. Use the Deffeyes diagrams (Figs 3.3 and 3.4) in your text to answer the following questions:

a. At a pH = 7.0 and total carbonate = 2 mmol/L, what is the alkalinity? ~1.75 meq/L

b. At pH = 8.0 and alkalinity = 3 meq/L, what is the total carbonate concentration? 3 mmol/L

$2.5\ \frac{meq}{L} \times \frac{1\ mmol}{2\ meq} = 1.25\ \frac{mmol}{L}\ CO_3^{2-}$ 0.003 mol/L

c. If the alkalinity is 1.5 meq/L and total carbonate is 2.5 meq/L, what is the pH? 2.5 mmol/L ⇒ pH ~ 6.45 → ~9.6

d. If 1 meq of NaOH was added to the solution in "a" what is the new pH? 9.3

e. If the solution was diluted so that the alkalinity of solution "b" became 2 meq/L, what is the new pH? 8.0

f. If sodium carbonate was added to the solution in "c" so that the total carbonate was 3.5 mmol/L, what is the new pH? 10.0 if used 2.5 mmol/L instead = ~7.2

7. What is the most dominant species

a. of carbonate at pH 7.0? HCO_3^-

b. of sulfur under highly oxidizing conditions? SO_4^{2-}

c. of nitrogen under highly reducing conditions? NH_3

d. of phosphate at pH 3.0? $H_2PO_4^-$

e. of hydrogen sulfide at pH = 9.0? HS^-

8. DO = dissolved oxygen
the concentration of O_2 dissolved in water

BOD = biological oxygen demand
the amount of O_2 needed to biologically degrade organic material

COD = chemical oxygen demand
amt of O_2 to completely degrade all organic material

comparing BOD + COD to DO allows you to determine how sustainable the system is: what you have versus what you need.

9. Sources of nitrates primarily: animal waste, fertilizer
both in abundance across the street. These would soak through the soil and end up in the ground water accessed by a shallow well.

10. total carbonate = 2.50 mmol/L
at pH 9.5, primary forms are HCO_3^- and CO_3^{2-}
$pKa_1 = 6.35$; $pKa_2 = 10.33$
so total carbonate = $[HCO_3^-] + [CO_3^{-2}]$

ratio @ 9.5 use H-H

$pH = pKa + \log \frac{[base]}{[acid]}$

$9.5 = 10.33 + \log \frac{[CO_3^{2-}]}{[HCO_3^-]}$

$-0.83 = \log \frac{[CO_3^{2-}]}{[HCO_3^-]}$

$0.15 = [CO_3^{2-}]/[HCO_3^{2-}]$

$0.15[HCO_3^-] = [CO_3^{2-}]$

plug into total carbonate

$2.5 = [HCO_3^-] + 0.15[HCO_3^-]$

$[HCO_3^-] = 2.17$

$[CO_3^{2-}] = 0.33$ mmol/L

11. $pH = pKa + \log \frac{[base]}{[acid]}$

K_b of $NH_3 = 1.8 \times 10^{-5}$

K_a of $NH_4^+ = 5.6 \times 10^{-10}$

pK_a of $NH_4^+ = 9.25$

$$pH = 9.25 + \log \frac{[NH_3]}{[NH_4^+]}$$

$$9.0 = 9.25 + \log [NH_3]/[NH_4^+]$$

$$-0.25 = \log [NH_3]/[NH_4^+]$$

$$0.56 = [NH_3]/[NH_4^+]$$

12. $CH_2O + O_2 \longrightarrow CO_2 + H_2O$

CH_2O is approx empirical formula of biological organics

$$\frac{37.1\ mg\ organic\ (0.15\ biodegradable)}{1.5\ L} \times \frac{1\ mmol\ CH_2O}{30.0\ mg} \times \frac{1\ mmol\ O_2}{1\ mmol\ CH_2O} \times \frac{32.0\ mg}{1\ mmol\ O_2} = 3.95\ \frac{mg}{L}$$

DO at 25°C = 8.3ppm

sufficient DO to degrade

13. Bayou/Swamp characterized by high amt of decaying organics and still water

Decay removes O_2 and stillness limits replenishment, so there are reducing conditions (S^{2-} is most reduced form of sulfur)

Organic matter also a source of sulfur

Heat vaporizes sulfide into its smellable $H_2S(g)$ form

14. forms of phosphate with pH

$$H_3PO_4 \rightleftharpoons H_2PO_4^- \rightleftharpoons HPO_4^{2-} \rightleftharpoons PO_4^{3-}$$

more basic →

Phosphates are generally insoluble. Solubility decreases with higher charge as the ionic bonds are stronger because they are created by electrostatic attraction. More acidic (low pH) conditions make phosphates more soluble

15. Eutrophication ≡ from the greek "well-nourished"
condition where excess algae growth leads to deterioration of body of water through accumulation of organic matter and decrease of available O_2

In general it is undesirable as the ultimate end is that body of water disappears

Caused by a excess of nutrients (nitrates and phosphates) that allow extreme algae growth, death, decay, repeat....