1. Explain the following (25%, 5% each)
   (a) The second law of thermodynamics
   (b) Beer's law
   (c) Arrhenius law
   (d) Gibb's free energy
   (e) Henry's Law

2. (a) Balance the complete oxidation of salicylic acid $C_6H_4(OH)(COOH)$ (7%)
   (b) Determine ThOD for 100 ppm salicylic acid. (7%)

3. The dissociation of H_2CO_3 can be described as the followings

   $$H_2CO_3^* \leftrightarrow H^+ + HCO_3^- \qquad pK_{a,1} = 6.3$$
   $$HCO_3^- \leftrightarrow H^+ + CO_3^{2-} \qquad pK_{a,2} = 10.3$$
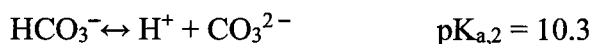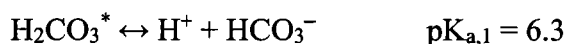
   (a) $[H_2CO_3]_T$ is the total concentration of carbonate species ($[H_2CO_3]_T = [H_2CO_3^*]$ + $[HCO_3^-]$ + $[CO_3^{2-}]$). Determine $[HCO_3^-]/[H_2CO_3]_T$ in terms of K_a and pH. (10%)
   (b) Following (a), calculate $[HCO_3^-]/[H_2CO_3]_T$ when solution pH = 7 (7%)
   (c) If you want to make a buffer solution pH = 6.3, what is the required molar ratio of $[NaHCO_3]/[H_2CO_3]$? (7%)

4. A groundwater analysis gives the followings. $[Ca^{2+}]$ = 60 mg/L, $[Mg^{2+}]$ = 12 mg/L, $[Na^+]$ =10 mg/L, $[HCO_3^-]$ = 180 mg/L; $[Cl^-]$ =10 mg/L, and $[SO_4^{2-}]$ = 109 mg/L. Calculate total hardness, carbonate hardness and non-carbonate hardness。 (15%)　(Ca = 40, Na = 23. Mg = 24, Cl = 35.5, S = 32, O = 16, C = 12)

5. List 3 requirements for BOD analysis during incubation of sample and explain why. (12%)

6. 100 mL of a natural water sample is titrated with 0.01 N HCl and 0.01 N NaOH. It required 4 mL NaOH to titrate to pH 8.3 is and 16 mL HCl to titrate to pH 4.3. Estimate the methyl orange alkalinity and phenolphthalein alkalinity of the original sample in mg/L as $CaCO_3$? (10%)