

Homeworks: Acids, bases, hydrolysis

Exercise 1

- ◆ Which is the pH of a solution 0.01M of ammonia?
($K_b=1.8 \cdot 10^{-5}$ M at 25°C)



Ammonia is a weak base, hence we can calculate [OH]:

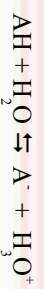
$$[\text{OH}] = \sqrt{(K_b \cdot C_b)} = \sqrt{(1.8 \cdot 10^{-5} \cdot 0.01)} = 4.24 \cdot 10^{-4}$$

$$\text{pOH} = -\log(4.24 \cdot 10^{-4}) = 3.37$$

$$\text{pH} = 14 - 3.37 = 10.63$$

Exercise 2

Calculate the K_a of a weak monoprotic acid whose 0.1 M solution has $\text{pH}=3.0$.



$$[\text{H}_3\text{O}^+] = 10^{\text{pH}} = 10^{-3} \text{ M}$$

$$K_a = \frac{[\text{H}_3\text{O}^+]^2}{C_a} = 10^{-6} / 10^{-1} = 10^{-5}$$

Exercise 3

Calculate the molar concentration of a solution of ammonia ($K_b=1.8 \cdot 10^{-5}$ M at 25°C) and the concentration of hydroxyls, given that $\alpha=1.3 \cdot 10^{-2}$.



$$K_b = C_b \cdot \alpha^2 / (1-\alpha)$$

$$\rightarrow C_b = K_b \cdot (1-\alpha) / \alpha^2 = 1.8 \cdot 10^{-5} \cdot 0.987 / 1.69 \cdot 10^{-4} = 0.105 \text{ M}$$

$$[\text{OH}] = C_b \cdot \alpha = 0.105 \cdot 1.3 \cdot 10^{-2} = 1.36 \cdot 10^{-3} \text{ M}$$

Exercise 4

Calculate the pH of a solution made by mixing 25ml of KOH 0.01 N with 75ml of HNO₃ 0.01 N.



$$n_{\text{eq base}} = N \cdot V = 10^{-2} \cdot 25 \cdot 10^{-3} = 2.5 \cdot 10^{-4} \text{ eq}$$

$$n_{\text{eq acid}} = N \cdot V = 10^{-2} \cdot 75 \cdot 10^{-3} = 7.5 \cdot 10^{-4} \text{ eq}$$

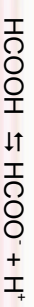
There is an excess of acid, therefore the pH will be <7

$$n_{\text{eq acid}} - n_{\text{eq base}} = 7.5 \cdot 10^{-4} - 2.5 \cdot 10^{-4} = 5 \cdot 10^{-4} \text{ eq}$$

$$\text{pH} = -\log(5 \cdot 10^{-4}) = 3.3$$

Exercise 5

Calculate the dissociation coefficient of a methanoic acid solution 5 · 10⁻³ M (K_a = 2 · 10⁻⁴ M).



$$K_a = \text{Ca} \cdot \alpha^2 / (1 - \alpha) \rightarrow \text{Ca} \cdot \alpha^2 - \text{Ka}(1 - \alpha) = 0$$

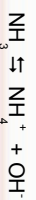
$$5 \cdot 10^{-3} \alpha^2 + 2 \cdot 10^{-4} \alpha - 2 \cdot 10^{-4} = 0$$

$$5 \alpha^2 + 0.2 \alpha - 0.2 = 0$$

$$\alpha = \frac{-0.2 \pm \sqrt{(0.04 + 4)}}{10} = 0.18$$

Exercise 6 = 3

K_b of ammonia is 1.8 · 10⁻⁵ M at 25°C. Calculate the molar concentration of ammonia and of hydroxide anions in a solution in which ammonia is 1.3% dissociated.



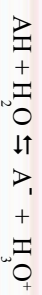
$$K_b = \text{Cb} \cdot \alpha^2 / (1 - \alpha)$$

$$\rightarrow \text{Cb} = K_b \cdot (1 - \alpha) / \alpha^2 = 1.8 \cdot 10^{-5} \cdot 0.987 / 1.69 \cdot 10^{-4} = 0.105 \text{ M}$$

$$[\text{OH}^-] = \text{Cb} \cdot \alpha = 0.105 \cdot 1.3 \cdot 10^{-2} = 1.36 \cdot 10^{-3} \text{ M}$$

Exercise 7

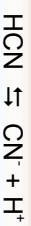
Calculate the concentration of a solution of a weak acid knowing that it is 0.1% dissociated and its pH is 5.0.



$$[\text{H}_3\text{O}^+] = \text{Ca} \cdot \alpha \rightarrow \text{Ca} = [\text{H}_3\text{O}^+] / \alpha = 10^{-5} / 10^{-3} = 10^{-2} \text{ M}$$

Exercise 8

K_a of HCN is $4 \cdot 10^{-10}$ M at 25°C . Calculate the molar concentration of the undissociated acid and the pH of the solution in which 0.01% of HCN is dissociated.



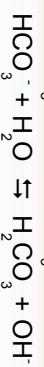
$$K_a = \text{Ca} \cdot \alpha^2 / (1 - \alpha)$$

$$\rightarrow \text{Ca} = K_a \cdot (1 - \alpha) / \alpha^2 = 4 \cdot 10^{-4} \cdot (1 - 10^{-4}) / 10^{-8} = 0.0399 = 0.04 \text{ M}$$

$$[\text{H}_3\text{O}^+] = \text{Ca} \cdot \alpha = 4 \cdot 10^{-6} \quad \rightarrow \text{pH} = 5.39$$

Exercise 10

A solution of Lithium hydrogen carbonate, made by dissolving 7.6 mg of salt in 1 L of water, has $\text{pH}=8.2$. Calculate the values of K_i and K_a .



$$\text{Cs} = g / (\text{FW} \cdot V) = 7.6 \cdot 10^{-3} / 6.9 \cdot 1 = 1.1 \text{ mM}$$

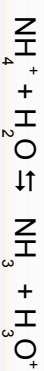
$$\text{pOH} = 14 - \text{pH} = 14 - 8.2 = 5.8 \quad \rightarrow [\text{OH}] = 10^{-5.8} = 1.58 \cdot 10^{-6} \text{ M}$$

$$K_i = K_w / K_a = [\text{OH}]^2 / \text{Cs} = (1.58 \cdot 10^{-6})^2 / 1.1 \cdot 10^{-3} = 1.44 \cdot 10^{-9}$$

$$K_a = K_w / K_i = 10^{-14} / 1.44 \cdot 10^{-9} = 6.94 \cdot 10^{-6}$$

Exercise 9

A solution of ammonium chloride has $\text{pH}=5.3$. Calculate the concentration of the salt in solution. ($K_b=1.8 \cdot 10^{-5}$ M at 25°C)

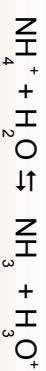


$$K_f = \frac{K_w}{K_b} = \frac{[\text{H}_3\text{O}^+]^2}{\text{Cs}}$$

$$\text{Cs} = [\text{H}_3\text{O}^+]^2 \cdot \frac{K_b}{K_w} = \frac{(5 \cdot 10^{-6})^2 \cdot 1.8 \cdot 10^{-5}}{10^{-14}} = 0.045 \text{ M}$$

Exercise 11

Calculate the pH of a solution of ammonium chloride made by 10^{-4} mol of NH_4^+ in 100 ml of solution. ($K_b=1.8 \cdot 10^{-5}$ M at 25°C)



$$[\text{H}_3\text{O}^+] = \sqrt{K_i \cdot \text{Cs}} = \sqrt{\frac{K_w \cdot \text{Cs}}{K_b}} = \sqrt{\frac{10^{-14} \cdot 10^{-3}}{1.8 \cdot 10^{-5}}} = \sqrt{5.5 \cdot 10^{-13}} = 7.4 \cdot 10^{-7}$$

$$\text{pH} = -\log 7.4 \cdot 10^{-7} = 6.13$$