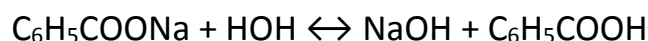


### Answer on Question #59840, Chemistry / General Chemistry

Sodium benzoate,  $\text{NaC}_6\text{H}_5\text{O}_2$ , is used as a preservative in foods. Consider a 50.0-mL sample of 0.250 M  $\text{NaC}_6\text{H}_5\text{O}_2$  being titrated by 0.200 M HBr. Calculate the pH of the solution: (A) when no HBr has been added; (B) after the addition of 50.0 ml of the HBr solution; (C) at the equivalence point; (D) after the addition of 75.00 mL of the HBr solution. The  $K_b$  value for the benzoate ion is  $1.6 \times 10^{-10}$ .

#### Solution:

A) Sodium benzoate is the salt formed by the strong basis of NaOH and weak  $\text{C}_6\text{H}_5\text{COOH}$  acid which in water solution is hydrolyzed on anion:

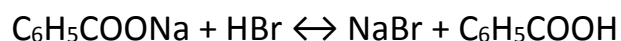


The constant of dissociation of benzoic acid is equal to  $K = 6,3 \cdot 10^{-5}$ ,  $\text{p}K = 4.20$

pH of initial solution of sodium benzoate we will calculate on a formula:

$$\text{pH} = 7 + \frac{1}{2} \cdot \text{p}K + \frac{1}{2}(\lg C_{\text{salt}}) = 7 + \frac{1}{2} \cdot 4.20 + \frac{1}{2} \lg(0,250) = 8.980$$

B) Titration of benzoate of sodium happens on the equation:



Thus, in titrable solution there is a buffer solution – mix of weak, benzoic acid with her salt. pH such buffer mix we will calculate value on a formula:

$$\text{pH} = \text{p}K_a - \lg\left(\frac{C_{\text{acid}}}{C_{\text{salt}}}\right)$$

As both concentration pay off in the same volume, in this formula  $C_{\text{acid}}/C_{\text{salt}} = n_{\text{acid}}/n_{\text{salt}}$  is possible.

$$n_{\text{salt}} = M_{\text{salt}}^0 \cdot V_{\text{salt}}^0 - M_{\text{HBr}} \cdot V_{\text{HBr}}$$

Then pH it is possible to calculate on a formula:

$$\text{pH} = 4.20 - \lg\left(\frac{V_{\text{HBr}} \cdot 0.200}{0.250V_{\text{salt}}^0 - 0.200V_{\text{HBr}}}\right)$$

After addition of 50 ml of HBr solution:

$$\text{pH} = \text{pK}_a - \lg\left(\frac{50 \cdot 0.200}{50 \cdot 0.250 - 50 \cdot 0.200}\right) = 4.20 - (-1,10) = 5,30$$

C) In an equivalence point all sodium benzoate has already passed into benzoic acid. We will calculate the volume of the added solution of acid on a formula:

$$M_{\text{salt}}^0 \cdot V_{\text{salt}}^0 = M_{\text{HBr}} \cdot V_{\text{HBr}},$$

$$\text{Then } V_{\text{HBr}} = M_{\text{salt}}^0 \cdot V_{\text{salt}}^0 / M_{\text{HBr}} = 0,250 \cdot 50 / 0,200 = 62,5 \text{ ml}$$

Solution volume is equal in a point of equivalence  $50 + 62,5 = 112,5$  ml therefore concentration of benzoic acid is equal  $0,200 \cdot 62,5 / 112,5 = 0,111\text{M}$ . We will calculate dissociation degree

$$K = \frac{c^2 \alpha^2}{c(1-\alpha)} = \frac{c \alpha^2}{(1-\alpha)} \text{ Since } \alpha \ll 1, \text{ then } (1 - \alpha) \approx 1.$$

$$\text{then } \alpha = \sqrt{\frac{K}{c}} = \sqrt{\frac{6.3 \cdot 10^{-5}}{0,111}} = 2.38 \cdot 10^{-2}$$

Then concentration of ions of hydrogen is equal

$$[\text{H}^+] = 0.111 \cdot 2.38 \cdot 10^{-2} = 2.64 \cdot 10^{-3}$$

$$\text{pH} = -\lg [\text{H}^+] = 2,58$$

D) After an equivalence point pH solution will be defined by excess concentration of HBr . As Br – strong acid, then  $\text{pH} = -\lg[\text{HBr}]$

After addition of 75 ml of HBr solution excess concentration

$$[\text{HBr}] = (75 - 62.5) \cdot 0.2000 / (50 + 75) = 0.02 \text{ M}$$

$$\text{Then } \text{pH} = -\lg(0.02) = 1.70$$