Answer on Question #59840, Chemistry / General Chemistry

Sodium benzoate, $NaC_7H_5O_2$, is used as a preservative in foods. Consider a 50.0-mL sample of 0.250 M $NaC_7H_5O_2$ 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-a of the HBr solution; (C) at the equivalence point; (D) after the addition of 75.00 mL of the HBr solution. The -10Kb value for the benzoate ion is 1.6 X 10 to the -10th power.

Solution:

A) Sodium benzoate is the salt formed by the strong basis of NAON and weak C6H5COOH acid which in water solution is hydrolyzed on anion:

$C_6H_5COONa + HOH \leftrightarrow NaOH + C_6H_5COOH$

The constant of dissociation of benzoic acid is equal to K = 6,3·10–5, pK = 4.20

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

$pH = 7 + ½·pK + ½(lgC_{salt}) = 7 + ½·4.20 + ½lg(0,250) = 8.980$

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

$C_6H_5COONa + HBr \leftrightarrow NaBr + C_6H_5COOH$

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:

$pH = pK_a – lg(C_{acid}/C_{salt})$

As both concentration pay off in the same volume, in this formula C_acid/C_salt = n_acid/n_salt is possible.

$n_{salt} = M^0_{salt}·V^0_{salt} – M_{HBr}·V_{HBr}.$

Then pH it is possible to calculate on a formula:

$$pH = 4.20 – lg\left(\frac{V_{HBr}·0.200}{0.250V^0_{salt} - 0.200V_{HBr}}\right)$$

After addition of 50 ml of HBr solution:

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

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:

$M^0_{salt} \cdot V^0_{salt} = M_{HBr} \cdot V_{HBr}$,

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

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

$K = \frac{C^2\alpha^2}{C(1-\alpha)} = \frac{C\alpha^2}{(1-\alpha)}$ Since α << 1, then (1 - α) ≈1.

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

Then concentration of ions of hydrogen is equal

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

$pH = -lg [H^+] = 2,58$

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

After addition of 75 ml of HBr solution excess concentration

[HBr] = (75–62.5) *0.2000 / (50+75) = 0.02 M

Then pH = – lg(0.02) = 1.70