Quadrant II – Transcript and Related Materials

Programme: Bachelor of Science (First Year)

Subject: Chemistry

Paper Code: CHC 102

Paper Title: Physical Chemistry and Organic Chemistry

Unit: Ionic Equilibria

Module Name: Problems on degree of dissociation, ionization constant, ionic product

Module No: 17

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DEGREE OF IONISATION OR DISSOCIATION

The fraction of the total number of molecules of the electrolyte that dissociates into ions is called the degree of ionization or dissociation.

- It is usually denoted by α
- *Degree of dissociation (α)* = $\frac{No.\ of\ molecules\ dissociated}{Total\ no.\ of\ molecules\ taken}$

IONISATION CONSTANT

- Ionisation and dissociation constant of the acid

$$K_a = \frac{C\alpha^2}{(1 - \alpha)}$$

- Ionisation and dissociation constant of the base

$$K_b = \frac{C\alpha^2}{(1 - \alpha)}$$

C is the initial concentration of the acid or base & α is the degree of dissociation.

IONIC PRODUCT OF WATER

- It is denoted by K_w
- K_w = $[H^+]$ $[OH^-]$

RELATION BETWEEN K_a and K_b

For conjugate ACID-BASE PAIR,

$$K_w = K_a \times K_b$$

PROBLEMS

1. The degree of ionisation of a 0.1 M bromoacetic acid solution is 0.132. Calculate the pK_a of bromoacetic acid.

Solution:

Given: α = 0.132, C = 0.1 M

pK_a = ??? K_a = ?

Degree of ionization is given by, $K_b = \frac{C\alpha^2}{(1-\alpha)} = \frac{0.1 \times (0.132)^2}{(1 - 0.132)}$

$$K_b = 2 \times 10^{(-3)}$$

pK_a and K_a are related as,

$$pK_a = - \log K_a$$

$$= - \log (2 \times 10^{(-3)})$$

$$pK_a = 2.6974$$

2. The ionization constant of 0.001 M aniline is $4.27 \times 10^{(-10)}$. Calculate the degree of ionization of aniline in the solution. Also calculate the ionization constant of the conjugate acid of aniline.

Solution: $C_6H_5NH_2 + H_2O \rightleftharpoons C_6H_5NH_3^+ + OH^-$

Degree of ionization is given by, $K_b = \frac{C\alpha^2}{(1-\alpha)}$

Given: C = 0.001 M

$K_b = 4.27 \times 10^{(-10)}$

α = ?

$K_b = \frac{C\alpha^2}{(1-\alpha)}$

$K_b = C\alpha^2$ (Assuming that degree of dissociation is very small)

$$\alpha = \sqrt{\frac{K_b}{C}}$$

$$= \sqrt{\frac{4.27 \times 10\,(-10)}{0.001}} = 6.53 \times 10^{(-4)}$$

For a pair of conjugate acid and base,

$$pK_a + pK_b = 14$$

pK_b = - log K_b

pK_b = - log ($4.27 \times 10^{(-10)}$)

we get, $\boldsymbol{pK_b = 9.38}$

Substituting pK_b = 9.38 in equation $pK_a + pK_b = 14$

We get, pK_a + 9.38 = 14

pK_a = 4.62

we know that, K_a = Antilog (- pK_a)

K_a = Antilog (- *4.62)* = **$2.399 \times 10^{(-5)}$**

3. The ionisation constant of dimethylamine is 5.4×10^{-4}. Calculate its degree of ionisation in its 0.02 M solution. What percentage of dimethylamine is ionised if the solution is also having 0.1 M in NaOH?

Solution:

Using: $K_b = \frac{C\alpha^2}{(1-\alpha)} = C\alpha^2$ (Assuming that degree of dissociation is very small)

Given: $K_b = 5.4 \times 10^{-4}$

C = 0.02 M

$$\alpha = \sqrt{\frac{K_b}{C}} = \sqrt{\frac{5.4 \times 10\,(-4)}{0.02}} = 0.164$$

Suppose if x is the amount of dimethyl aniline dissociated in presence of 0.1 M NaOH then,

$$(CH_3)_2NH + H_2O \rightleftharpoons (CH_3)_2NH^+OH^- + OH^-$$

Initially	*0.02 M*		
After dissociation	*0.02 – x*	*x*	*0.1 + x*
	= 0.02		= 0.1

$$K_b = \frac{[(CH_3)_2NH^+OH^-][OH^-]}{(CH_3)_2NH} = \frac{x\,(0.1)}{0.02}$$

Degree of dissociation can also be expressed as, $\alpha = \frac{Amount\ dissociated}{Initial\ concentration}$

$$\alpha = \frac{x}{0.02}$$

$$K_b = \frac{x\,(0.1)}{0.02}$$

substituting $\alpha = \frac{x}{0.02}$ in the above equation, we get

$$K_b = \alpha \times 0.1$$

$$\alpha = \frac{K_b}{0.1} = \frac{5.4 \times 10^{-4}}{0.1}$$

$$\alpha = 5.4 \times 10^{-3}$$

% of dimethylamine ionized if the solution is also having 0.1 M in NaOH, will be therefore $5.4 \times 10^{-3} \times 100$ i.e. 0.54 %.

4. The ionization constant of HF is 6.8×10^{-4}. Calculate the ionization constant of the corresponding conjugate base.

Solution:

For conjugate ACID-BASE PAIR,

$$K_w = K_a \times K_b$$

Given: $K_a = 6.8 \times 10^{-4}$

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

$$K_b = \frac{K_w}{K_a} = \frac{1.0 \times 10\text{-}14}{6.8 \times 10\text{-}4} = 1.5 \times 10^{(-11)}$$