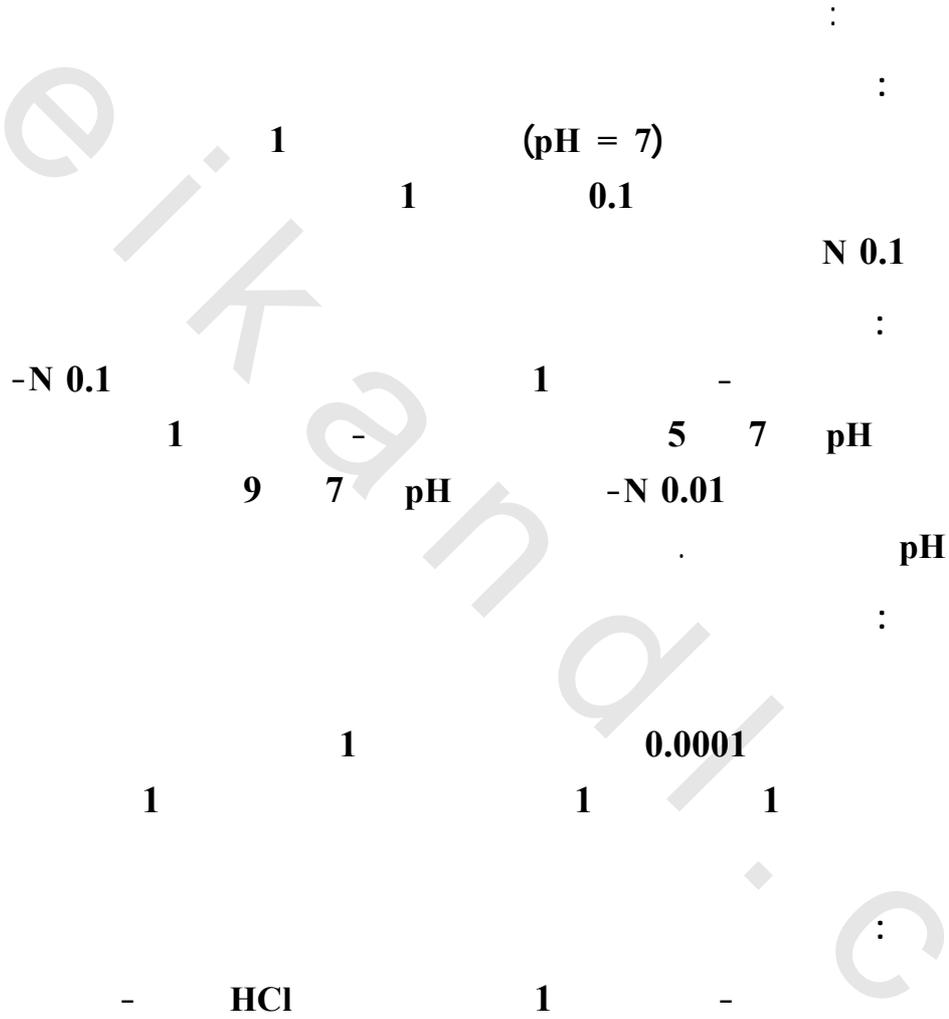


الباب السادس المحائل المنظمة وتطبيقاتها

الباب السادس
المحاليل المنظمة وتطبيقاتها

(pH)



4 pH 3 4 pH
-N NaOH 1 1 -
pH 11

(1)

NaOH HCl

(2)

pH

pH

pH

pH

pH

. (pH)

. (Buffer Capacity)

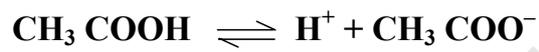
-1

. pH = pka

50

100

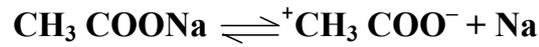
-2



$$\frac{[\text{CH}_3\text{COO}^-][\text{H}^+]}{[\text{CH}_3\text{COOH}]} = K = K_a$$

$$\therefore [H^+] = K_a \times \frac{[CH_3COOH]}{[CH_3COO^-]}$$

:



:

$$[H^+] = K_a \times \frac{[CH_3COOH] - [H^+]}{[CH_3COONa] + [H^+]}$$

$$[H^+] = K_a \times \frac{[CH_3COOH] - [H^+]}{[CH_3COONa] + [H^+]}$$

:

$$[H^+] = K_a \times \frac{[CH_3COOH]}{[CH_3COONa]}$$

$$[H^+] = K_a \times \frac{[\text{حمض}]}{[\text{ملح}]}$$

$$-\log [H^+] = -\log K_a + \log \frac{[\text{حمض}]}{[\text{ملح}]}$$

$$\therefore \text{pH} = \text{pKa} + \log \frac{[\text{حمض}]}{[\text{ملح}]}$$

:

$$\text{pOH} = \text{pK}_b + \log \frac{[\text{حمض}]}{[\text{ملح}]}$$

$$pH = pK_a - pK_b - \log \frac{[\text{حمض}]}{[\text{ملح}]}$$

مقاومة المحلول المنظم للتغير في الـ pH :

pH

HCl

(NaCl)

pH



pH



HCl

pH



pH

تطبيقات المحاليل المنظمة :

pH

pH

pH

pH

0.1

0.05

$$\text{pH} = \text{pK}_a \pm 1$$

10/1

:

1/10

pH

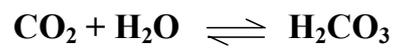
pH

pH

pH

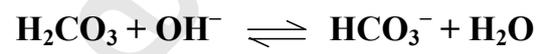
7.4

7

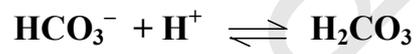


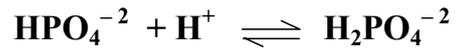
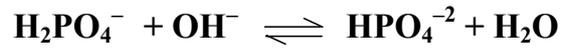
:

-1



-2





pH

0.01

1.5

pH

(Metabolic reactions)

pH

0.1

0.01

$1.8 \times 10^{-5} =$

0.01

0.1

:

:

$$\frac{0.01}{0.1} + 4.74 = \frac{\text{(الـمـلـح)}}{\text{(الـحـامـض)}} + pK_a = \text{pH}$$

$$3.74 = \text{pH} \quad 3.74 = 1 - 4.74 = \text{pH}$$

-

$$\frac{0.01}{0.1} + 4.74 = \frac{\text{(الـمـلـح)}}{\text{(الـقـاعـدة)}} + pK_b = \text{POH}$$

$$\text{pH} = 14 - 3.74 = 10.26 \quad = 4.74 - 1 = 3.74$$

$$10.26 = \text{pH}$$

:

0.5

$$. (4.1 = pK_a) / 10$$

:

$$() \quad 0.007 = \frac{10}{144}$$

$$2.26 = \frac{0.007}{0.5} + 4.1 = \frac{\text{(الـمـلـح)}}{\text{(الـحـامـض)}} + K_a = \text{pH}$$

K_a pH

pH

³ pH
X

³ 10 (+)

pH	³ Y	³ X
3.42	0.5	9.5
3.47	1	9
4.05	2	8
4.27	3	7
4.45	4	6
4.63	5	5
4.80	6	4
4.99	7	3
5.22	8	2
5.23	9	1
5.57	9.5	0.5

$$\text{pH} = \text{pK}_a + \log \frac{[\text{Acid}]}{[\text{Salt}]}$$

pK_a

pH

$$[\text{H}^+] = \frac{[\text{CH}_3\text{COOH}]}{C} \times K_a$$

(activities)

$$a_{\text{H}^+} = \frac{a_{\text{HA}}}{a_{\text{A}^-}} \times K_a$$

a_{H^+} , HA

a_{HA}
 a_{A^-}

:

8.5 pH

$$. 1.3 \times 10^{-9}$$

0.1

HCN

:

HCN

pH

CN^-

$$/ 3.2 \times 10^{-9} = [\text{H}^+] \therefore$$

$$8.5 = \text{pH}$$

:



$$/ 3.2 \times 10^{-9} = [\text{CN}^-] = [\text{H}^+]$$

$$/ 1.3 \times 10^{-9} = [\text{CN}^-][\text{H}^+]$$

$$0.41 = \frac{1.3 \times 10^{-9}}{3.2 \times 10^{-9}} = \frac{[\text{CN}^-]}{[\text{HCN}]}$$

:

$$/ 0.1$$

$$0.41 = \frac{X - 0.1}{X} \frac{[\text{CN}^-]}{[\text{HCN}]}$$

$$X = [\text{CN}^-] \quad X = [\text{HCN}]$$

$$/ \quad 0.071 = [\text{HCN}] = X \therefore$$

HCl

0.1

HCN

0.071

:

$$\frac{C_a}{C_s} - K = \text{pH}$$

$$\frac{C_a}{C_s} - 1.3 \times 10^{-9} = 8.5$$

$$2.43 = \frac{[\text{HCN}]}{[\text{CN}^-]} \therefore$$

$$0.386 = \frac{[\text{HCN}]}{[\text{CN}^-]} = \frac{C_a}{C_s}$$

$$2.43 = \frac{X}{X - 0.1}$$

$$X - 0.1 = [\text{CN}^-] \quad X = [\text{HCN}]$$

$$/ \quad 0.071 = [\text{HCN}] = X$$

:

0.1

25

1.34%

$$5 \cdot 10^{-10} \times 1.8$$

0.2

0.03

0.1

0.1

0.1

0.1

0.2

-

:

-1

(CH₃ COOH)

. 0.1

0.2

$$/ \quad 9 \times 10^{-6} = \frac{0.1 \times 1.8 \times 10^{-5}}{0.2} = \frac{1.8 \times 10^{-5}}{[CH_3COO^-]} = [H^+]$$

0.03

-2

0.03

0.03

$$/ \quad 4 \times 10^{-5} = \frac{(0.03 - 0.1) 1.8 \times 10^{-5}}{0.03} = [H^+]$$

0.1

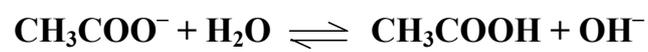
0.1

-3

0.1

-

0.1



$$1.8 \times 10^{-5} = \frac{[\text{NH}_4^+][\text{OH}^-]}{[\text{NH}_3]} = K_b$$

pH
 $3.98 \times 10^{-10} = [\text{H}^+] \therefore$

$[\text{OH}^-]$
 $10 - 0.6 = 9.4 = \text{pH} = [\text{H}^+]$

$$0.25 \times 10^{-4} \frac{1 \times 10^{-14}}{3.98 \times 10^{-10}} = [\text{OH}^-]$$

$$0.3 = \frac{\text{مول } 0.15}{\text{لتر } 0.5} = [\text{NH}_3]$$

0.3

$$0.3 \approx 0.000025 - 0.3 = [\text{OH}^-] - 0.3 = [\text{NH}_3]$$

$$/ \quad 0.216 = [\text{NH}_4^+] \quad 1.8 \times 10^{-5} = \frac{(0.25 \times 10^{-4})[\text{NH}_4^+]}{0.3}$$

$$0.216 = [\text{NH}_4^+] + [\text{OH}^-]$$

$$0.216 \approx 0.000025 - 0.216 = [\text{NH}_4^+]$$

$$0.108 = 0.5 \times 0.216 \quad \text{NH}_4\text{Cl}$$

$$/ \quad 53.5$$

$$0.78 = 0.108 \times 53.5$$

$$/ \quad 0.1$$

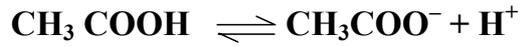
HCl

$$/ \quad 0.05$$

:

HCl

0.05



$$X = [\text{CH}_3\text{COO}^-] \quad X + 0.05 = [\text{H}^+]$$

$$(X - 0.1) = [\text{CH}_3\text{COOH}]$$

$$\frac{(X + 0.05)(X)}{(X - 0.1)} = 1.8 \times 10^{-5}$$

HCl

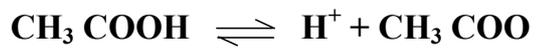
$$1.8 \times 10^{-5} = \frac{(X + 0.05)}{0.1}$$

$$/ \quad 3.6 \times 10^{-5} = [\text{CH}_3\text{COO}^-] = X$$

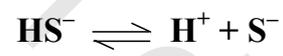
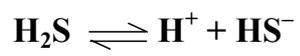
$$3.6 \times 10^{-4} = \frac{5 \cdot 10 \times 3.6}{0.1} =$$

$$1.3 \times 10^{-2}$$

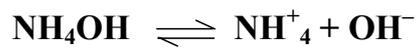
تأثير الأيون المشترك :



:



HCl



NH₄Cl

NH₄⁺

OH⁻

NH₄OH

()

HCl H₂SO₄ HClO₄ :

KOH NaOH

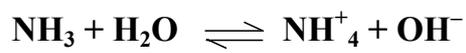
Ba(OH)₂

0.1

9

pH

NH₄Cl



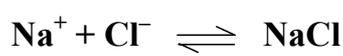
$$\begin{array}{l}
 : \quad \text{pH} \quad \quad \quad [\text{OH}^-] \\
 14 = \text{pOH} + \text{pH} \quad \quad 1 \times 10^{-14} = [\text{OH}^-] = [\text{H}^+] \\
 14 = \text{pOH} + \text{pH} \quad \quad 1 \times 10^{-14} = [\text{OH}^-] = [\text{H}^+] \\
 \quad \quad \quad \quad \quad \quad 5 = 9 - 14 = \text{pOH} \therefore \\
 \quad \quad \quad \approx [\text{NH}_3] \quad \quad / \quad 1 \times 10^{-14} = [\text{OH}^-] \\
 1.8 \times 10^{-5} = \frac{(5 \times 10^{-10})(\text{NH}_4^+)}{0.1} \quad \quad 1.8 \times 10^{-5} = \frac{[\text{OH}^-][\text{NH}_4^+]}{[\text{NH}_3]} \\
 \quad 1.8 \times 10^{-1} = [\text{NH}_4^+] \therefore
 \end{array}$$

$$\begin{array}{l}
 53.5 = \\
 9.63 = 53.5 \times 0.18 \quad \quad \quad \text{NH}_4\text{Cl}
 \end{array}$$

تفاعلات الأحماض والقواعد :

$$\text{pH} = 7$$

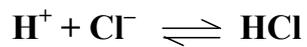
$$-1$$



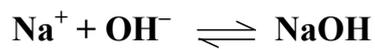
:



:



.



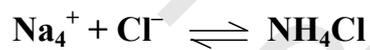
. 7

-2

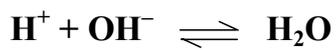
:



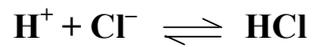
:



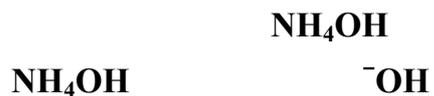
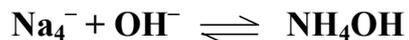
NH_4Cl



:

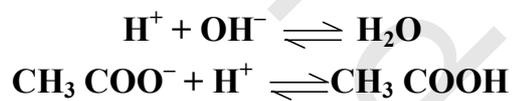
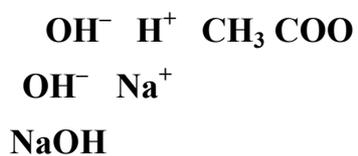


:



(pH < 7) 7

-3



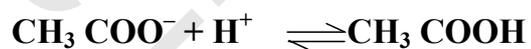
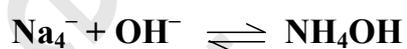
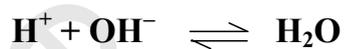
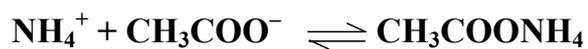


$$[\text{H}^+][\text{OH}^-] = 10^{-14}$$



(pH > 7)

-4



$$[\text{OH}^-][\text{H}^+]$$

- 173 -

$$[\text{H}^+] > [\text{OH}^-] \quad K_a > K_b$$

. (pH < 7)

$$[\text{H}^+] < [\text{OH}^-] \quad K_a < K_b$$

. (pH < 7)

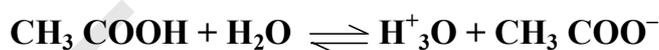
$$K_b = 1.8 \times 10^{-5} \quad ^\circ 25$$

$$1.8 \times 10^{-10} \quad K_a$$

$$[\text{OH}^-] = [\text{H}^+]$$

. (pH = 7)

ثابت التأيين للحامض الضعيف :



$$K = \frac{[\text{H}_3\text{O}^+][\text{CH}_3\text{COO}^-]}{[\text{CH}_3\text{COOH}][\text{H}_2\text{O}]}$$

$$K [\text{H}_2\text{O}] = \frac{[\text{H}_3\text{O}^+][\text{CH}_3\text{COO}^-]}{[\text{CH}_3\text{COOH}]}$$

$$K_a = \frac{[\text{H}_3\text{O}^+][\text{CH}_3\text{COO}^-]}{[\text{CH}_3\text{COOH}]}$$

K_a

ثابت التآين للقاعدة الضعيفة :

()

:



:

$$K = \frac{[\text{NH}_4^+][\text{OH}^-]}{[\text{NH}_3][\text{H}_2\text{O}]}$$

:

$$K_b = \frac{[\text{NH}_4^+][\text{OH}^-]}{[\text{NH}_4\text{OH}]}$$

K_b

الأحماض المتعددة :

()

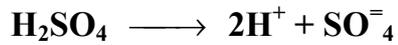
. H_3PO_4

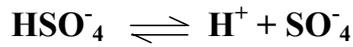
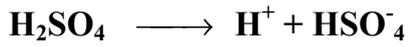
الأحماض القوية المتعددة القاعدية :

:



:





$$K_2 = \frac{[\text{H}^+][\text{SO}_4^{2-}]}{[\text{HSO}_4^-]} = 1.2 \times 10^{-2}$$

$$X = \frac{[\text{HSO}_4^-][\text{H}_3\text{PO}_4]}{[\text{H}_2\text{SO}_4][\text{H}_2\text{SO}_4]} = \frac{[\text{H}^+][\text{HSO}_4^-]}{[\text{H}_2\text{SO}_4]} \cdot \frac{[\text{H}_3\text{PO}_4]}{[\text{H}_2\text{SO}_4]} = \frac{K_1}{K_2} \cdot \frac{[\text{H}_3\text{PO}_4]}{[\text{H}_2\text{SO}_4]}$$

(F) $0.02 \text{ H}_2\text{SO}_4$ $[\text{H}^+]$ $[\text{H}^+]$ $[\text{H}_2\text{SO}_4]$

0.04 $[\text{H}^+]$ $[\text{H}_2\text{SO}_4]$

H_2SO_4 0.02

HSO_4^- $[\text{H}^+]$ HSO_4^-

$X = \frac{[\text{HSO}_4^-]}{[\text{SO}_4^{2-}]}$ $[\text{SO}_4^{2-}]$

$$X - 0.02 = [SO_4^-] \quad X + 0.02 = [H]$$

:

$$K_2 = \frac{[H^+][SO_4^-]}{[HSO_4^-]} = 1.2 \times 10^{-2}$$

$$1.2 \times 10^{-2} = \frac{(X)(X+0.02)}{X-0.02}$$

$$= \frac{10^{-2} \times 2.4 - X^2 + 0.032X}{X-0.02}$$

$$0.00625 = \frac{0.0125}{2} = \frac{\sqrt{4 \times 10^{-2} \times 9.6 + 2 \times 0.032 + 0.032}}{2} = X$$

$$/ \quad 2 \times 10^{-2} \times 2.6 = 0.00625 + 0.02 =$$

الأحماض المتعددة القاعدية الضعيفة :

H₂S :



:



:

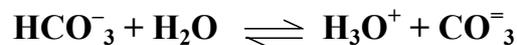


K₁

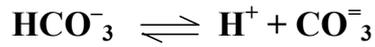
:

$$K_1 = \frac{[H^+][HCO_3^-]}{[H_2CO_3]} = 3.5 \times 10^{-7}$$

:



:



: K_2

$$K_2 = \frac{[\text{H}^+][\text{CO}_3^{2-}]}{[\text{HCO}_3^-]} = 0.6 \times 10^{-11}$$

K_2 K_1

HCO_3^-

. HCO_3^-

الدالة الحامضية pH للأحماض المتعددة القاعدية :

K_1

K_2

100

K_1

()

pH

pH

pH

K_1

HCO_3^-

$[\text{H}^+]$

: $[\text{HCO}_3^-]$

$$3.5 \times 10^{-7} = \frac{[\text{HCO}_3^-][\text{H}^+]}{0.036}$$

$[\text{H}^+]$

$[\text{HCO}_3^-]$

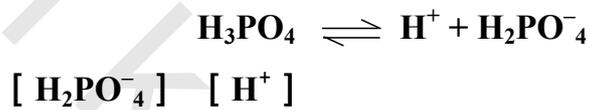
$$3.5 \times 10^{-7} = \frac{[\text{H}^+]^2}{10 \times 3.6} :$$

$$/ \quad 1.12 \times 10^{-4} = \sqrt{3.6 \times 10^{-2} \times 3.5 \times 10^{-7}} = [H^+]$$

$$4 \approx 3.92 = 1.12 - 4 = 1.12 \times 10^{-4} \quad - = \text{pH} \quad \text{pH}$$

$$\begin{array}{ccc} \text{pH} & & \\ 2 \times 10^{-12} & 6.2 \times 10^{-8} & 7.5 \times 10^{-3} \\ K_2 & 100 & K_1 \end{array} \quad \begin{array}{l} H_3PO_4 \\ H_3PO_4 \\ H^+ \end{array}$$

$$\begin{array}{ccc} H_3PO_4 & 0.04 & \text{pH} \\ & & [H^+] \\ K_2 & K_1 & \text{pH} \\ & : H_3PO_4 & . \end{array}$$



$$K_1 = \frac{[H^+][H_2PO_4^-]}{[H_3PO_4]} = 7.5 \times 10^{-3}$$

$$7.5 \times 10^{-3} = \frac{[H^+]^2}{0.04} \quad [H_2PO_4^-] = [H^+]$$

$$1.73 \times 10^{-2} = 0.3 \times 10^{-4} = \sqrt{4 \times 10^{-2} \times 7.5 \times 10^{-3}} = [H^+]$$

$$1.75 = 1.73 - 2 = 2 \times 10^{-2} \times 1.73 \quad - = \text{pH} \therefore$$

$$[H^+]$$

$$[H^+]$$

الدالة الحامضية pH للمحاليل المنظمة :

pH

pH

pH



pH



$$0.06 = [\text{H}_2\text{PO}_4^-]$$



K_3 K_2 K_1

K_1

$$[\text{H}_2\text{PO}_4^-] [\text{H}_3\text{PO}_4]$$

K_1

$$5 \times 10^{-3} = \frac{0.4 \times 10^{-3} \times 7.0}{0.06} [\text{H}^+] \quad 7.0 \times 10^{-3} = \frac{(0.06)(\text{H}^+)}{0.4} = K_1$$

$$2.3 = 5 - 3 = 5 \times 10^{-3} \quad \text{pH}$$

$$7.5 \times 10^{-3} = [H^+] [H_2PO_4^-] = [H_3PO_4]$$

pH pH

$$2.12 = 7.5 - 3 = 7.5 \times 10^{-3} \quad \therefore \text{pH}$$

$$HPO_4^{2-} = 0.1 \quad 0.3 = [H_2PO_4^-]$$

pH

:

K₂

$$6.2 \times 10^{-8} = \frac{0.1 \times (H^+)}{0.30} = K_2$$

$$1.86 \times 10^{-7} = \frac{0.3 \times 6.2 \times 10^{-8}}{0.1} = [H^+] \quad :$$

$$6.72 = 1.86 - 7 = 1.86 \times 10^{-7} \quad \therefore \text{pH} \quad \therefore$$

[HPO₄²⁻], [H₂PO₄⁻]

$$\therefore 7.21 = \text{pH} \quad 6.2 \times 10^{-8} = [H^+] :$$

PO₄³⁻ HPO₄²⁻

pH

. K₃

0.5

pH

(NaHC₄H₄O₄)

0.6 (H₂C₄H₄O₄)

$$. K_1 = 6.4 \times 10^{-5}$$

:

: K_1

$$K_1 = \frac{[H^+][HC_4H_4O_4^-]}{[H_2C_4H_4O_4]} = \frac{(H^+) \times 0.6}{0.5} = 6.4 \times 10^{-5}$$

$$5.34 \times 10^{-5} = \frac{0.5}{0.6} \times 5.34 \times 10^{-5} = [H^+] \therefore$$

$$4.27 = 5.34 - 5 = 5.34 \times 10^{-5} \quad - = \text{pH} \therefore$$

* * *

الأسئلة

pH () -1
 2.8×10^{-3}

pOH ()
 4.17

: pOH pH -2
 6.5×10^{-3} ()
 . / -
 6.5×10^{-3} ()
 . / -
 0.5 ()
 . / -
 0.005 ()
 . / -

-3
 :
 . 3.5 = pH ()
 . 8.5 = pH ()
 . 11.8 = pOH ()
 . 3.8 = pOH ()

: pOH ← pH -4
 . 0.0001 ()
 . () 0.005 ()
 . 0.00002 ()

0.1			pH	pOH	-5
	1.8×10^{-5}	$^{\circ}25$			
	4.3		8.7	pH	-6
	14.11		8.5	pH	-7
50		0.015			-8
pH				100	
	10	0.04			-9
	100	pH			
			150		
			0.02	pH	-10
	1.8×10^{-5}	$^{\circ}25$			
	0.0001				-11
pH			0.01		
10		1			-12
				10	
pH			0.01		
					-13
	(0.1)				
	$^{\circ}25$		$2 \times 10^{-4} =$		
4.6	pH			0.2	-14
	$1.8 \times 10^{-5} =$				$^{\circ}25$

$$7.5 \times 10^{-5} \times 1.85 = 1.3875 \times 10^{-4} \text{ pH } -15$$

$$6.4 \times 10^{-5} \text{ pH } -16$$

$$1.8 \times 10^{-5} \text{ pH } -17$$

$$100 \text{ N } 0.1 \text{ pH } -18$$

$$0.5 \text{ pH } -19$$

$$1.8 \times 10^{-5} \text{ pH } -20$$

$$1.85 \times 10^{-5} = K_a \text{ pH } 4.8$$

$$0.2 = \text{pH } -21$$

$$2 \times 10^{-4} = K_a \text{ pH } -22$$

$$1.8 \times 10^{-5} = K_a \text{ pH } 0.1 =$$

* * *