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Acids, Bases, Salts

4.11 pH, pOH and pK Values

a) The pH Scale

i) A logarithmic scale showing strength of acids and bases.

[OH^-]

10^{-14} 10^{-13} 10^{-12}

[H_3O^+]

1 10^{-1} 10^{-2} 10^{-3} 10^{-4} 10^{-5} 10^{-6} 10^{-7} 10^{-8} 10^{-9} 10^{-10} 10^{-11} 10^{-12} 10^{-13} 10^{-14}

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14

pH

14 13 12

pOH

ii) Every decrease in pH of 1 = Increase in [H_3O^+] by 10

b) What is pH?

i) Measure of [H_3O^+] present in a solution

ii) Solution is acidic when pH less than 7 (or when pOH greater than 7)

iii) **pH = -log[H_3O^+]**

iv) What is pH when the [H_3O^+] = 1.2×10^{-3} M?

pH = -log(1.2×10^{-3}) = **2.92**

v) What is pH when the [H_3O^+] = 4.8×10^{-8} M?

pH = -log(4.8×10^{-8}) = **7.32**

vi) What is the [H_3O^+] when the pH is 2.55?

[H_3O^+] = $10^{-2.55}$ *or* [H_3O^+] = antilog(-2.55) = **2.8×10^{-3} M**

vii) What is the [H_3O^+] when the pH is 9.70?

[H_3O^+] = $10^{-9.70}$ = **2.0×10^{-10} M**

c) What is pOH?

i) Measure of $[OH^-]$ present in a solution

ii) Solution is basic when pOH less than 7 *(pH greater than 7)*

iii) **pOH = -log$[OH^-]$**

iv) What is pOH when the $[OH^-] = 1.5 \times 10^{-1}$ M?

$pOH = -\log(1.5 \times 10^{-1}) = 0.82$

v) What is pOH when the $[OH^-] = 4.4 \times 10^{-4}$ M?

$pOH = -\log(4.4 \times 10^{-4}) = 3.36$

vi) What is the $[OH^-]$ when the pOH is 12.65?

$[OH^-] = 10^{-12.65} = 2.2 \times 10^{-13}$ M

vii) What is the $[OH^-]$ when the pOH is 1.70?

$[OH^-] = 10^{-1.70} = 2.0 \times 10^{-2}$ M

d) Relationship Between pH and pOH

i) **pH + pOH = 14**

ii) What is the pH of a solution if the pOH is 10.2?
$pH = 14 – 10.2 =$ **3.8**

iii) What is the $[OH^-]$ if the pH is 3.25?

$pOH = 14 - 3.25 = 10.75$ $[OH^-] = 10^{-10.75} =$ $\mathbf{1.8 \times 10^{-11}}$ **M**

iv) What is the pOH if the $[H_3O^+] = 1.7 \times 10^{-4}$ M?

$pH = -\log(1.7 \times 10^{-4}) = 3.78$ $pOH = 14 - 3.78 =$ **10.22**

v) What is the $[H_3O^+]$ if the $[OH^-] = 3.50 \times 10^{-5}$ M

$pOH = -\log(3.50 \times 10^{-5}) = 4.456$

$pH = 14 – 4.456 = 9.544$

$[H_3O^+] = 10^{-9.544} =$ $\mathbf{2.86 \times 10^{-10}}$ **M**

or

$[H_3O^+][OH^-] = Kw$

$[H_3O^+] = \dfrac{1.00 \times 10^{-14}}{3.50 \times 10^{-5}} = \mathbf{2.86 \times 10^{-10}\ M}$

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e) pK Values

i) pK values are just for convenience!

ii) Observe the Pattern!

pH = -log[H_3O^+] 6 = -log[1.00 x 10^{-6}]

pKw = -log[Kw] 14 = -log[1.00 x 10^{-14}]

ii) **pKw = 14** *(pH + pOH = 14 or pH + pOH = pKw)*

iii) Observe the Pattern!

pKa = -log[Ka] 2.12 = -log[7.5 x 10^{-3}]

pKb = -log[Kb] 4.74 = -log[1.8 x 10^{-5}]

iv) **pKa + pKb = pKw**

f) Significant Figures

i) In a pH (or pOH) value, only the numbers after the decimal are significant

ii) Example:

pH = 2.465 has 3 sig. figs. The “2” give the power of 10….not significant.

iii) Example:

pH = 10.25 has 2 sig. figs.

iv) Example: [H_3O^+] = 1.24 x 10^{-3} M. What is pH?

pH = -log(1.24 x 10^{-3}) = 2.907

v) Example: [H_3O^+] = 1.762 x 10^{-6} M. What is pH?

pH = -log(1.762 x 10^{-6}) = 5.7540

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g) Advanced pH and pOH Calculations

i) Example: 50.0ml of 0.200 M NaOH is reacted with 30.0ml of 0.250 M HCl. What is the pH of the resulting solution?

① NaOH + HCl → NaCl + H_2O

moles of acid or base in ***excess*** will determine the pH

② moles NaOH present = 0.200M x 0.0500L = 0.0100 moles
moles HCl present = 0.250M x 0.0300L = 0.00750 moles

③ NaOH is in excess by: 0.0100 – 0.00750 = 0.00250 moles

④ [NaOH] = [OH^-] = 0.00250 moles / (0.0300L + 0.0500L) = 0.0312 M

⑤ pOH = -log[0.0312M] = 1.506

⑥ pH = 14 – pOH = 14 - 1.506 = **12.494**

ii) Example: Calculate the pH if 1.25 L of 0.300 M KOH is added to 0.500 L of 0.0900 M H_2SO_4.

① 2KOH + H_2SO_4 → K_2SO_4 + $2H_2O$

moles of acid or base in ***excess*** will determine the pH

② moles [OH^-] present = 0.300M x 1.25L = 0.375 moles
moles [H_3O^+] present = 0.0900M x 0.500L **x 2** = 0.0900 moles

↑
cause each H_2SO_4
produces two H_3O^+ 's

③ [OH^-] is in excess by: 0.375 – 0.0900 = 0.285 moles

④ [OH^-] = 0.285 moles / (1.25L + 0.500L) = 0.163 M

⑤ pOH = -log[0.163M] = 0.788

⑥ pH = 14 – 0.788 = **13.212**

iii) Example: Calculate the pOH if 0.0300 L of 0.400 M $Ca(OH)_2$ is added to 0.250 L of 0.125 M HBr.

① $2HBr + Ca(OH)_2 \rightarrow CaBr_2 + 2H_2O$

moles of acid or base in ***excess*** will determine the pH

② moles $[OH^-]$ present = 0.400M x 0.0300L **x 2** = 0.0240 moles
moles $[H_3O^+]$ present = 0.125M x 0.250L = 0.0312 moles

③ $[H_3O^+]$ is in excess by: 0.0312 – 0.0240 = 0.00720 moles

④ $[H_3O^+]$ = 0.00720 moles / (0.250L + 0.0300L) = 0.0257 M

⑤ pH = -log[0.0257M] = 1.590

⑥ pOH = 14 – 1.590 = **12.410**

iv) Example: How many grams of NaOH must be added to 0.800 L of 0.0400 M HBr to change the pH to 7.00? *(Assume no volume change from adding NaOH)*

① $NaOH + HBr \rightarrow NaBr + H_2O$

② want $[H_3O^+] = 10^{-7}$ = 0.0000001 M

③ current $[H_3O^+]$ = 0.0400 M

④ change in $[H_3O^+]$ = 0.0400 – 0.0000001 = 0.0399 M

⑤ $[H_3O^+] = [OH^-]$ = 0.0399 M

⑥ 0.0399 M x 0.800 L = 0.0320 moles NaOH

⑦ 0.0320 moles x 40 g/mol = **1.28 g NaOH**

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