# ACID-BASE REVIEW KEY

Part I & II

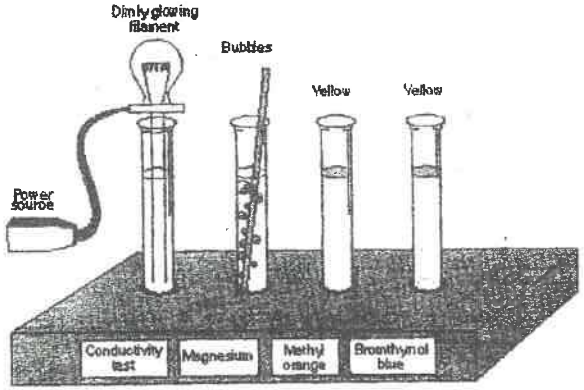
29. Calculate the mass of NaOH which is required to neutralize 25.00 mL of 0.500 M $H_2SO_4$. (3 marks)

$2NaOH + H_2SO_4 \longrightarrow Na_2SO_4 + 2H_2O$

$\frac{0.500\ mol}{1\ L} \times 0.02500\ L = 0.0125\ mol \times \frac{2\ mol\ NaOH}{1\ mol}$

$0.025\ mol\ NaOH \times \frac{40.0\ g}{1\ mol} = \boxed{1.00\ g\ NaOH}$

30. A 1.0 M unknown solution was analyzed and the following was observed:




Classify the unknown as an acid or base indicating whether it is weak or strong. Justify your answer using the data provided. (2 marks)

This is a weak acid. It is an acid because bubbles are produced with magnesium. It is weak because the light is dimly glowing.



31. Calculate the pH of 2.0 M nitrous acid. (4 marks)

| | $HNO_2 + H_2O \rightleftharpoons$ | $NO_2^-$ | $+ H_3O^+$ |
|---|---|---|---|
| I | 2.0 | ∅ | ∅ |
| C | $-x$ | $+x$ | $+x$ |
| E | $2.0-x$ | $x$ | $x$ |

"assume $2.0-x \approx 2.0$"

$K_a = \left(\frac{x^2}{2.0} = 4.6 \times 10^{-4}\right) 2.0 \rightarrow \sqrt{9.2 \times 10^{-4}} = \sqrt{x^2}$

$x = 3.0 \times 10^{-2} \therefore [H_3O^+] = 3.0 \times 10^{-2}$

$pH = -\log(3.0 \times 10^{-2})$

$\boxed{pH = 1.52}$

32. A 2.0 L solution contains one mole of the weak acid, $H_3PO_4$, in equilibrium with one mole of the salt, $NaH_2PO_4$.

a) Write an equation that represents this equilibrium. (2 marks)

$H_3PO_4 + H_2O \rightleftharpoons H_2PO_4^- + H_3O^+$

b) Explain why the pH of this solution does not change significantly when 10.0 mL of 1.0 M KOH is added. (1 mark)

This is a buffer solution, when KOH is added it causes $[H_3O^+] \downarrow$ ∴ shifts the equilibrium to the Products but there is little change in pH!

33. Lactic acid, $HC_3H_5O_3$, is a compound that accumulates in muscle tissue during exertion. Write the equation and the $K_a$ expression for the ionization of lactic acid in water. (2 marks)

$HC_3H_5O_3 + H_2O \rightleftharpoons C_3H_5O_3^- + H_3O^+$

$K_a = \frac{[C_3H_5O_3^-][H_3O^+]}{[HC_3H_5O_3]}$

34. The ionization constant for water, $K_w$, is $9.6 \times 10^{-14}$ at 60°C.

a) Write an equation including the heat term representing the ionization of water. (2 marks)

$2H_2O(l) + 59kJ \rightarrow H_3O^+ + OH^-$

b) Calculate the pH for water at 60°C. (2 marks)

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

$\sqrt{9.6 \times 10^{-14}} = \sqrt{x^2}$

$3.09 \times 10^{-7} \doteq x$

$\therefore [H_3O^+] \doteq 3.09 \times 10^{-7}$

$pH = -\log(3.09 \times 10^{-7})$

$\boxed{pH = 6.51}$

35. Four monoprotic acids of the same concentration are labelled as follows:

| SOLUTION | LABEL |
|---|---|
| A | $[OH^-] = 5.0 \times 10^{-11}$ M |
| B | $[H^+] = 0.20$ M |
| C | pOH = 11.30 |
| D | pH = 1.20 |

List the four solutions in order of decreasing acidity. Use calculations to support your answer. (4 marks)

(A) $pOH = -\log(5.0 \times 10^{-11})$

$= 10.30$

$\therefore pH = 14.000 - 10.30$

$\boxed{pH = 3.70}$

(B) $pH = -\log(0.20)$

$\boxed{pH = 0.70}$

(C) $pOH = 11.30$ ; $pH = 14.000 - 11.30$

$\boxed{pH = 2.7}$

(D) $\boxed{pH = 1.20}$

$\boxed{B > D > C > A}$

(most acidic to least)



36. a) Write two equations showing the amphiprotic nature of water as it reacts with $HCO_3^-$. (2 marks)

$HCO_3^- + H_2O \rightleftharpoons CO_3^{2-} + H_3O^+$

$HCO_3^- + H_2O \rightleftharpoons H_2CO_3 + OH^-$

b) Calculate the $K_b$ for $HCO_3^-$ (1 mark)

$K_b(HCO_3^-) = \frac{1.00 \times 10^{-14}}{K_a(H_2CO_3)} = \frac{1.00 \times 10^{-14}}{4.3 \times 10^{-7}} =$

$\boxed{K_b = 2.3 \times 10^{-8}}$

37. Calculate the $[H_3O^+]$ in 0.550 M $C_6H_5COOH$. (3 marks)

$C_6H_5COOH + H_2O \rightleftharpoons C_6H_5COO^- + H_3O^+$

| | | | |
|---|---|---|---|
| I | 0.550 | ~~0~~ | ~~0~~ |
| C | $-x$ | $+x$ | $+x$ |
| E | $0.550 - x$ | $+x$ | $+x$ |

"assume $0.550 - x \doteq 0.550$"

$K_a = \left(\frac{x^2}{0.550} = 6.5 \times 10^{-5}\right) 0.550 \rightarrow \sqrt{3.6 \times 10^{-5}} = \sqrt{x^2}$

$6.0 \times 10^{-3} = x \quad \therefore \boxed{[H_3O^+] = 6.0 \times 10^{-3}}$

# ACID-BASE REVIEW KEY

38. Calculate the pH of the solution formed by mixing 20.0 mL of 0.500 M HCl with 30.0 mL 0.300 NaOH. (4 marks)

$HCl + NaOH \rightarrow NaCl + H_2O$

$[HCl]_{xs} = \frac{0.500\ M \times 0.0200\ L}{0.0500\ L} = 0.200\ M\ HCl$

$[NaOH] = \frac{0.300\ M \times 0.0300\ L}{0.0500\ L} = 0.180\ M\ NaOH.$

$[H_3O^+]_{xs} = 0.200\ M - 0.180\ M$

$= 0.020\ M$

$pH = -\log(0.020)$

$\boxed{pH = 1.70}$

39. a) Write the balanced equation representing the reaction of HF with $H_2O$. (1 mark)

$HF + H_2O \rightleftharpoons F^- + H_3O^+$

b) Identify the Brönsted-Lowry bases in the above equation. (1 mark)

$H_2O$ and $F^-$

40. Consider the following data:

| CHEMICAL SPECIES | FORMULA | IONIZATION CONSTANT |
|---|---|---|
| barbituric acid | $HC_4H_3N_2O_3$ | $K_a = 9.8 \times 10^{-5}$ |
| sodium propanoate | $NaC_3H_5O_2$ | $K_b = 7.5 \times 10^{-10}$ |
| propanoic acid | $HC_3H_5O_2$ | ? |

Which is the stronger acid, propanoic acid or barbituric acid? Explain, using appropriate calculation. (2 marks)

$K_a(propanoic) = \frac{1.00 \times 10^{-14}}{7.5 \times 10^{-10}} = 1.3 \times 10^{-5}$

B/C $K_a$ barbituric acid is $> K_a$ propanoic

$9.5 \cdot 10^{-5}$ $1.3 \cdot 10^{-5}$

Barbituric acid is the stronger acid



41. A solution of 0.100 M HOCN has a pH of 2.24. Calculate the $K_a$ value for this acid. (4 marks)

| | $HOCN + H_2O \rightleftharpoons$ | $OCN^- + H_3O^+$ |
|---|---|---|
| I | 0.100 | ∅ ∅ |
| C | 0.0058 | $+5.8 \times 10^{-3}$ $+5.8 \times 10^{-3}$ |
| E | 0.0942 | $+5.8 \times 10^{-3}$ $+5.8 \times 10^{-3}$ |

$pH = 2.24 \rightarrow [H_3O^+] = \text{antilog}(-2.24) = 5.8 \times 10^{-3}$

$K_a = \frac{(5.8 \times 10^{-3})^2}{0.094} = \boxed{3.5 \times 10^{-4}}$

42. Calculate the pH of a 25.0 mL solution formed by mixing 0.0300 mol $HNO_3$ and 0.0280 mol NaOH. (2 marks)

$HNO_3 + NaOH \rightarrow NaNO_3 + H_2O$

$[H_3O^+] = \frac{0.0300\ mol}{0.0250\ L} = 1.20 M$

$[OH^-] = \frac{0.0280\ mol}{0.0250\ L} = 1.12 M$

$[H_3O^+]_{xs} = 1.20 - 1.12 = 0.08\ M$

$pH = -\log(0.08)$

$\boxed{pH = 1.1}$

43. a) Write the net ionic equation for the predominant reaction between $NaHSO_3$ and $NaHC_2O_4$. (2 marks)

$HSO_3^- + HC_2O_4^- \rightleftharpoons C_2O_4^{2-} + H_2SO_3$

Base Acid Base Acid

b) Explain why the reactants are favoured in the above reaction. (1 mark)

B/C $H_2SO_3$ is a stronger acid than $HC_2O_4^-$ and rxn favours the REACTANTS

? $K_{eq} = \frac{6.4 \cdot 10^{-5}}{1.5 \cdot 10^{-2}} = 4.3 \cdot 10^{-3}$

$K_{eq} < 1$

44. What is the $[H_3O^+]$ in a solution formed by adding 60.0 mL of water to 40.0 mL of 0.040 M KOH? **(2 marks)**

$[KOH] = \frac{0.040\,M \times 0.0400\,L}{0.100\,L} = 0.016\,M\ KOH$

$[OH^-] = 0.016\,M$

$\therefore [H_3O^+] = \frac{1.00\times10^{-14}}{0.016\,M} = \boxed{6.3\times10^{-13}}$

45. Calculate the pH in 100.0 mL of 0.400 M $H_3BO_3$. **(4 marks)**

| | $H_3BO_3$ | + $H_2O$ ⇌ | $H_2BO_3^-$ | + $H_3O^+$ |
|---|---|---|---|---|
| I | 0.400 | | ~~0~~ | ~~0~~ |
| C | $-x$ | | $+x$ | $+x$ |
| E | $0.400-x$ | | $+x$ | $+x$ |

"assume $0.400-x \cong 0.400$"

$K_a = \left(\frac{x^2}{0.400} = 7.3\times10^{-10}\right)0.400 \rightarrow \sqrt{2.92\times10^{-10}} = \sqrt{x^2}$

$x = 1.7\times10^{-5} \therefore [H_3O^+] = 1.7\times10^{-5}$

$pH = -\log(1.7\times10^{-5})$

$\boxed{pH = 4.77}$

46. State two tests that could be safely performed to determine whether an unknown solution is acidic. Predict the results if the solution is acidic. → blue or neutral **(2 marks)**

Test 1: Test with litmus paper

Result should turn Red

Test 2: Test with magnesium or zinc

Result should produce bubbles of $H_2(g)$



47. An aqueous solution of $Na_2CO_3$ undergoes hydrolysis.

a) Write the equation for the hydrolysis. **(1 mark)**

$Na_2CO_3 \rightarrow 2Na^+ + CO_3^{2-}$

$CO_3^{2-} + H_2O \rightleftharpoons HCO_3^- + OH^-$

b) Calculate $K_b$ for the hydrolysis in a). **(1 mark)**

$K_b = \frac{1.00\times10^{-14}}{K_a(HCO_3^-)} = \frac{1.00\times10^{-14}}{5.6\times10^{-11}} = \boxed{1.8\times10^{-4}}$

48. A solution of 0.0100 M lactic acid, $HC_3H_5O_3$, has a pH of 2.95. Calculate the $K_a$ value. **(3 marks)**

| | $HC_3H_5O_3$ | + $H_2O$ ⇌ | $C_3H_5O_3^-$ | + $H_3O^+$ |
|---|---|---|---|---|
| I | 0.0100 | | ~~0~~ | ~~0~~ |
| C | $-1.1\times10^{-3}$ | | $+1.1\times10^{-3}$ | $+1.1\times10^{-3}$ |
| E | $8.9\times10^{-3}$ | | $1.1\times10^{-3}$ | $1.1\times10^{-3}$ |

$pH = 2.95 \therefore [H_3O^+] = \text{antilog}(-2.95) = 1.1\times10^{-3}$

$K_a = \frac{(1.1\times10^{-3})^2}{8.9\times10^{-3}} = \boxed{1.4\times10^{-4}}$

49. Calculate the pH of a solution prepared by adding 40.0 mL of 0.440 M NaOH to 60.0 mL of 0.320 M HCl. **(3 marks)**

$NaOH + HCl \rightarrow NaCl + H_2O$

$[HCl] = \frac{0.320\,M \times 0.0600\,L}{0.100\,L} = 0.192\,M\ H_3O^+$

$[NaOH] = \frac{0.440\,M \times 0.0400\,L}{0.100\,L} = 0.176\,M\ OH^-$

$[H_3O^+]_{XS} = 0.192\,M - 0.176\,M$

$[H_3O^+]_{XS} = 0.016\,M$

$pH = -\log(0.016)$

$\boxed{pH = 1.80}$