

Worksheet 7.4: Solutions

Acid equilibria – an extension

No.	Answer
1	<p>a i $[\text{H}_3\text{O}^+] = 1.0 \text{ mol L}^{-1} = 1 \times 10^0 \text{ mol L}^{-1}$ $\text{pH} = -\log_{10}[\text{H}_3\text{O}^+] = -\log_{10}(1 \times 10^0) = 0$</p> <p>ii As HCl is a strong, monoprotic acid: $[\text{H}_3\text{O}^+] = [\text{HCl}] = 9.05 \times 10^{-8} \text{ mol L}^{-1}$ $\text{pH} = -\log_{10}[\text{H}_3\text{O}^+] = -\log_{10}(9.05 \times 10^{-8}) = 7.04$ Of course this answer does not make sense as a solution of an acid cannot have a $\text{pH} > 7$ at 25°C. In this situation, the self-ionisation of water already produces a solution with a pH of 7, so a solution that contains this small amount of additional HCl would have a pH slightly below 7.</p> <p>b i $[\text{OH}^-] = 0.0700 \text{ mol L}^{-1}$ $K_w = [\text{H}_3\text{O}^+][\text{OH}^-] = 1 \times 10^{-14}$ $\therefore [\text{H}_3\text{O}^+] = \frac{1 \times 10^{-14}}{[\text{OH}^-]} = \frac{1 \times 10^{-14}}{0.0700} = 1.43 \times 10^{-13} \text{ mol L}^{-1}$ $\text{pH} = -\log_{10}[\text{H}_3\text{O}^+] = -\log_{10}(1.43 \times 10^{-13}) = 12.8$</p> <p>ii $[\text{NaOH}] = [\text{OH}^-] = 4.00 \times 10^{-12} \text{ mol L}^{-1}$ $K_w = [\text{H}_3\text{O}^+][\text{OH}^-] = 1 \times 10^{-14}$ $\therefore [\text{H}_3\text{O}^+] = \frac{1 \times 10^{-14}}{[\text{OH}^-]} = \frac{1 \times 10^{-14}}{4.00 \times 10^{-12}} = 2.50 \times 10^{-3} \text{ mol L}^{-1}$ $\text{pH} = -\log_{10}[\text{H}_3\text{O}^+] = -\log_{10}(2.50 \times 10^{-3}) = 2.60$</p> <p>iii $[\text{OH}^-] = 2 \times [\text{Ba}(\text{OH})_2] = 0.0124 \text{ mol L}^{-1}$ $K_w = [\text{H}_3\text{O}^+][\text{OH}^-] = 1 \times 10^{-14}$ $\therefore [\text{H}_3\text{O}^+] = \frac{1 \times 10^{-14}}{[\text{OH}^-]} = \frac{1 \times 10^{-14}}{0.0124} = 8.06 \times 10^{-13} \text{ mol L}^{-1}$ $\text{pH} = -\log_{10}[\text{H}_3\text{O}^+] = -\log_{10}(8.06 \times 10^{-13}) = 12.1$</p> <p>c i $[\text{H}_3\text{O}^+] = 10^{-\text{pH}} = 10^{-1.07} = 0.085 \text{ mol L}^{-1}$ ii $[\text{H}_3\text{O}^+] = 10^{-\text{pH}} = 10^{-14.7} = 2.0 \times 10^{-15} \text{ mol L}^{-1}$</p>
2	<p>$c_1 \times V_1 = c_2 \times V_2$ $\therefore 3.55 \times 45.0 = c_2 \times 295$ $\therefore c_2 = 0.542 \text{ mol L}^{-1}$ As HNO_3 is a strong, monoprotic acid: $[\text{H}_3\text{O}^+] = [\text{HNO}_3] = 0.542 \text{ mol L}^{-1}$ $\text{pH} = -\log_{10}[\text{H}_3\text{O}^+] = -\log_{10}0.542 = 0.266$</p>

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3	$n(\text{NaOH}) = \frac{m}{M} = \frac{9.35}{39.998} = 0.234 \text{ mol}$ $[\text{NaOH}] = \frac{n}{V} = \frac{0.234}{0.400} = 0.584 \text{ mol L}^{-1}$ $[\text{OH}^-] = [\text{NaOH}] = 0.584 \text{ mol L}^{-1}$ $K_w = [\text{H}_3\text{O}^+][\text{OH}^-] = 1 \times 10^{-14}$ $\therefore [\text{H}_3\text{O}^+] = \frac{1 \times 10^{-14}}{[\text{OH}^-]} = \frac{1 \times 10^{-14}}{0.584} = 1.71 \times 10^{-14} \text{ mol L}^{-1}$ $\text{pH} = -\log_{10}[\text{H}_3\text{O}^+] = -\log_{10}(1.71 \times 10^{-14}) = 13.8$
4	$K_{\text{st}} = [\text{Ag}^+][\text{OH}^-] = 2.0 \times 10^{-8}$ <p>From the equation, $[\text{Ag}^+] = [\text{OH}^-]$</p> $\therefore [\text{OH}^-] = \sqrt{2.0 \times 10^{-8}} = 1.41 \times 10^{-4} \text{ mol L}^{-1}$ $K_w = [\text{H}_3\text{O}^+][\text{OH}^-] = 1 \times 10^{-14}$ $\therefore [\text{H}_3\text{O}^+] = \frac{1 \times 10^{-14}}{[\text{OH}^-]} = \frac{1 \times 10^{-14}}{1.41 \times 10^{-4}} = 7.07 \times 10^{-11} \text{ mol L}^{-1}$ $\text{pH} = -\log_{10}[\text{H}_3\text{O}^+] = -\log_{10}(7.07 \times 10^{-11}) = 10.2$
5	<p>a $\text{C}_6\text{H}_5\text{OH}(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{C}_6\text{H}_5\text{O}^-(\text{aq}) + \text{H}_3\text{O}^+(\text{aq})$</p> $\therefore K_a = \frac{[\text{C}_6\text{H}_5\text{O}^-][\text{H}_3\text{O}^+]}{[\text{C}_6\text{H}_5\text{OH}]}$ <p>b $\text{HN}_3(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{N}_3^-(\text{aq}) + \text{H}_3\text{O}^+(\text{aq})$</p> $\therefore K_a = \frac{[\text{N}_3^-][\text{H}_3\text{O}^+]}{[\text{HN}_3]}$ <p>c $\text{HPO}_3^{2-}(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{PO}_3^{3-}(\text{aq}) + \text{H}_3\text{O}^+(\text{aq})$</p> $\therefore K_a = \frac{[\text{PO}_3^{3-}][\text{H}_3\text{O}^+]}{[\text{HPO}_3^{2-}]}$
6	<p>a $K_{a1} = \frac{[\text{C}_2\text{HO}_4^-][\text{H}_3\text{O}^+]}{[\text{C}_2\text{H}_2\text{O}_4]}$</p> $K_{a2} = \frac{[\text{C}_2\text{O}_4^{2-}][\text{H}_3\text{O}^+]}{[\text{C}_2\text{HO}_4^-]}$ <p>b $K_{a1} > K_{a2}$</p>

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7	$K_a = \frac{[\text{H}_2\text{AsO}_3^-][\text{H}_3\text{O}^+]}{[\text{H}_3\text{AsO}_3]} = 5.13 \times 10^{-10}$ <p>From the equation, $[\text{H}_2\text{AsO}_3^-] = [\text{H}_3\text{O}^+]$ at equilibrium, and also, for a weak acid, $[\text{H}_3\text{AsO}_3]_i \approx [\text{H}_3\text{AsO}_3]_{\text{eq}} = 0.882 \text{ mol L}^{-1}$</p> $\therefore \frac{[\text{H}_2\text{AsO}_3^-][\text{H}_3\text{O}^+]}{[\text{H}_3\text{AsO}_3]} = \frac{[\text{H}_3\text{O}^+]^2}{0.882} = 5.13 \times 10^{-10}$ $\therefore [\text{H}_3\text{O}^+] = 2.13 \times 10^{-5} \text{ mol L}^{-1}$ $\text{pH} = -\log_{10}[\text{H}_3\text{O}^+] = -\log_{10}(2.13 \times 10^{-5}) = 4.67$
8	$K_a = \frac{[\text{CH}_3\text{CH}_2\text{COO}^-][\text{H}_3\text{O}^+]}{[\text{CH}_3\text{CH}_2\text{COOH}]}$ $[\text{H}_3\text{O}^+] = 10^{-\text{pH}} = 10^{-2.80} = 0.00158 \text{ mol L}^{-1}$ <p>From the equation, $[\text{CH}_3\text{CH}_2\text{COO}^-]_{\text{eq}} = [\text{H}_3\text{O}^+]_{\text{eq}} = 0.00158 \text{ mol L}^{-1}$ and also, for a weak acid, $[\text{CH}_3\text{CH}_2\text{COOH}]_i \approx [\text{CH}_3\text{CH}_2\text{COOH}]_{\text{eq}} = 0.184 \text{ mol L}^{-1}$</p> $\therefore K_a = \frac{[\text{CH}_3\text{CH}_2\text{COO}^-][\text{H}_3\text{O}^+]}{[\text{CH}_3\text{CH}_2\text{COOH}]} = \frac{(0.00158)^2}{0.184} = 1.37 \times 10^{-5}$
9	$\% \text{ hydrolysis} = \frac{[\text{OBr}^-]}{[\text{HOBr}]} \times \frac{100}{1} = 0.00828\%$ <p>For a weak acid: $[\text{HOBr}]_i \approx [\text{HOBr}]_{\text{eq}} = 0.350 \text{ mol L}^{-1}$</p> $\therefore \frac{[\text{OBr}^-]}{0.350} \times \frac{100}{1} = 0.00828 \therefore [\text{OBr}^-] = 2.90 \times 10^{-5} \text{ mol L}^{-1}$ <p>From the equation:</p> $[\text{OBr}^-]_{\text{eq}} = [\text{H}_3\text{O}^+]_{\text{eq}} = 2.90 \times 10^{-5} \text{ mol L}^{-1}$ $\text{pH} = -\log_{10}[\text{H}_3\text{O}^+] = -\log_{10}(2.90 \times 10^{-5}) = 4.54$ $K_a = \frac{[\text{OBr}^-][\text{H}_3\text{O}^+]}{[\text{HOBr}]} = \frac{(2.9 \times 10^{-5})^2}{0.350} = 2.40 \times 10^{-9}$
10	<p>a</p> $K_a = \frac{[\text{HO}_2^-][\text{H}_3\text{O}^+]}{[\text{H}_2\text{O}_2]} = 2.27 \times 10^{-12}$ <p>b</p> $[\text{H}_3\text{O}^+] = 10^{-\text{pH}} = 1 \times 10^{-6}$ <p>From the equation, $[\text{HO}_2^-]_{\text{eq}} = [\text{H}_3\text{O}^+]_{\text{eq}}$ and also, for a weak acid, $[\text{H}_2\text{O}_2]_i \approx [\text{H}_2\text{O}_2]_{\text{eq}} = 0.44 \text{ mol L}^{-1}$</p> $\% \text{ ionisation} = \frac{[\text{HO}_2^-]}{[\text{H}_2\text{O}_2]} \times \frac{100}{1} = \frac{1 \times 10^{-6}}{0.44} \times \frac{100}{1} = 2.3 \times 10^{-4}$