HL Answers to Acid & base calculations questions

1. i. $-\log_{10}[H^+] = -\log_{10}(1.00 \times 10^{-2}) = 2.0$

ii. 2.0 (pH depends on the hydrogen ion concentration not on the volume present).

iii. 3.7

iv. 12.0

v. 2.7 (H_2SO_4 is diprotic so $[H^+(aq)] = 2.00 \times 10^{-3}$ mol dm^{-3} and pH = $-\log_{10}(2.00 \times 10^{--3})$

vi. 11.3 ($[OH^-(aq)] = 2.00 \times 10^{-3}$ mol dm^{-3} so pOH = 2.7 and pH = 14.0 – 2.7)

2. i. $[H^+(aq)] = 10^{-3.6} = 2.51 \times 10^{-4}$ mol dm^{-3}

ii. Since $[H^+(aq)] \times [OH^-(aq)] = K_w = 1.00 \times 10^{-14}$

$[OH^-(aq)] = (1.00 \times 10^{-14}) / (2.51 \times 10^{-4}) = 3.98 \times 10^{--11}$ mol dm^{-3}

or Since pH = 3.60, pOH = 10.40 so $[OH^-(aq)] = 10^{-10.40} = 3.98 \times 10^{-11}$ mol dm^{-3}

iii. 4.60

3. i. $CH_3COOH(aq) + H_2O(l) \rightleftharpoons CH_3COO^-(aq) + H_3O^+(aq)$

or $CH_3COOH(aq) \rightleftharpoons CH_3COO^-(aq) + H^+(aq)$

ii. $NH_3(aq) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$

4. i. $K_a = 1.8 \times 10^{-5} = \dfrac{[CH_3COO^-(aq)] \times [H^+(aq)]}{[CH_3COOH(aq)]} \approx \dfrac{[H^+(aq)]^2}{1.00 \times 10^{-3}}$

$[H^+(aq)] = (1.8 \times 10^{-8})^{1/2} = 1.34 \times 10^{-4}$ mol dm^{-3}

pH = $-\log_{10}(1.34 \times 10^{--4}) = 3.87$

ii. $K_b = 1.8 \times 10^{-5} = \dfrac{[NH_4^+(aq)] \times [OH^-(aq)]}{[NH_3(aq)]} \approx \dfrac{[OH^-(aq)]^2}{3.00 \times 10^{-2}}$

$[OH^-(aq)] = (5.4 \times 10^{-7})^{1/2} = 7.35 \times 10^{-4}$ mol dm^{-3}

pOH = $-\log_{10}(7.35 \times 10^{-4}) = 3.13$, so pH = 14.00 – 3.13 = 10.87

5. i. $K_a = 10^{-4.87}$ so $[H^+(aq)] = (4.00 \times 10^{-4} \times 10^{-4.87})^{1/2} = 7.35 \times 10^{-5}$ mol dm^{-3}

pH = $-\log_{10}(7.35 \times 10^{-5}) = 4.13$

ii. $K_b = 10^{-3.35}$ so $[OH^-(aq)] = (1.00 \times 10^{-5} \times 10^{-3.35})^{1/2} = 6.68 \times 10^{-5}$ mol dm^{-3}

pOH = $-\log_{10}(6.68 \times 10^{--5}) = 4.18$, so pH = 14.00 – 4.18 = 9.82

6. chloroethanoic acid (pK_a: 2.87) > benzoic acid (pK_a: 4.20) > ethanoic acid (pK_a: 4.76) > propanoic acid (pK_a: 4.87) > phenol (pK_a: 9.99) > water (pK_w: 14.00) > ethanol (pK_a: 15.5)

7. i. 2.2×10^{-13} (note that equilibrium constants do not have units)

ii. $K_w = 1.6 \times 10^{-13}$; so $[H^+(aq)] = (1.6 \times 10^{-13})^{1/2} = 4.0 \times 10^{-7}$ mol dm^{-3}

iii. $[OH^-(aq)] = (1.6 \times 10^{-13})^{1/2} = 4.0 \times 10^{-7}$ mol dm^{-3}

iv. $K_w = 7.0 \times 10^{-14}$ so $[H^+(aq)] = (7.0 \times 10^{-14})^{1/2} = 2.65 \times 10^{-7}$ mol dm^{-3} so pH = 6.6

v. $[OH^-(aq)] = (2.2 \times 10^{-13})^{1/2} = 4.69 \times 10^{-7}$ mol dm^{-3} so pOH = 6.3