Introduction to Natural Science

Spring Quarter, Week 5, Chemistry Workshop

Answer Key

(1) H_3O^+, Cl^-, H_2O

CH_3COOH, H_2O, CH_3COO^-, H_3O^+

NH_3, H_2O, NH_4^+, OH^-

Na^+, OH^-; H_2O

H_3PO_4, H_2O, $H_2PO_4^-$, H_3O^+, HPO_4^{2-}, PO_4^{3-}

(2) $[Co(H_2O)_6]^{3+}_{(aq)} + H_2O(l) \rightleftharpoons [Co(H_2O)_5OH]^{2+}_{(aq)} + H_3O^+(aq)$

$$K_a = \frac{[Co(H_2O)_5OH]^{2+}_{eq}\,[H_3O^+]_{eq}}{[Co(H_2O)_6]^{3+}_{eq}}$$

$CH_3NH_2(aq) + H_2O(l) \rightleftharpoons CH_3NH_3^+(aq) + OH^-(aq)$

$$K_b = \frac{[CH_3NH_3^+]_{eq}\,[OH^-]_{eq}}{[CH_3NH_2]_{eq}}$$

(3) $HF(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + F^-(aq)$

Bronsted acid — Bronsted base → conj. acid — conj. base

$HSO_4^-(aq) + H_2O(l) \rightleftharpoons SO_4^{2-}(aq) + H_3O^+(aq)$

Bronsted acid — Bronsted base — Conj. base — Conj. acid

$C_6H_5NH_2(aq) + HOCl(aq) \rightleftharpoons C_6H_5NH_3^+(aq) + OCl^-(aq)$

Bronsted base — Bronsted acid — Conj. acid — Conj. base

(4) $HNO_3(aq) + H_2O(l) \longrightarrow H_3O^+(aq) + NO_3^-(aq)$

$0.250\,M$ $0.250\,M$ $0.250\,M$

$pH = -\log[H_3O^+] = -\log(0.250) = \underline{\underline{0.60}}$

$pOH = 14 - pH = \underline{\underline{13.40}}$

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

initial	$0.250\,M$	0	0
change	$-x$	$+x$	$+x$
equilibrium	$(0.250-x)$	x	x

$$K_a = \frac{[CH_3COO^-][H_3O^+]_{eq}}{[CH_3COOH]_{eq}} = \frac{(x)(x)}{(0.250-x)} = 1.8\times10^{-5}$$

$$x^2 + 1.8\times10^{-5}x - 4.5\times10^{-6} = 0$$

$$x = \frac{-1.8\times10^{-5} \pm \sqrt{(1.8\times10^{-5})^2 + 4(4.5\times10^{-6})}}{2}$$

$$x = 2.11 \times 10^{-3} = [H_3O^+]$$

$$pH = -\log[H_3O^+] = \underline{2.68} \qquad pOH = \underline{11.32}$$

$$H_2NNH_2(aq) + H_2O(l) \rightleftharpoons [H_2NNH_3]^+(aq) + OH^-(aq)$$

initial	2.0 M	0	0
change	$-x$	$+x$	$+x$
equilibrium	$(2.0-x)$	x	x

$$K_b = \frac{[H_2NNH_3^+]_{eq}[OH^-]_{eq}}{[H_2NNH_2]_{eq}} = \frac{x^2}{2.0-x} = 3.0 \times 10^{-6}$$

$$x^2 + 3.0 \times 10^{-6} x - 6.0 \times 10^{-6} = 0$$

$$x = \frac{-3.0 \times 10^{-6} \pm \sqrt{(3.0 \times 10^{-6})^2 + 4(6.0 \times 10^{-6})}}{2}$$

$$x = 2.45 \times 10^{-3} = [OH^-]$$

$$pOH = -\log[OH^-] = \underline{2.61} \qquad pH = \underline{11.39}$$

(5)

	molarity	volume	# of moles of H_3O^+
HCl	5.00M	90.0mL	$\frac{5.00\text{mol}}{\text{L}} \times 90.0\times10^{-3}\text{L}$
			$= 0.450\text{mol}$
HNO_3	8.00M	30.0mL	$\frac{8.00\text{mol}}{\text{L}} \times 30.0\times10^{-3}\text{L}$
			$= 0.240\text{ mol}$
total		120.0mL	0.690 mol

Total $[H_3O^+]$ concentration $= \frac{0.690\text{ mol}}{120.0\text{mL}} \times \frac{10^3\text{mL}}{\text{L}}$

$= 5.75\text{ mol L}^{-1}$

$pH = -\log[H_3O^+] = -0.76$

$pOH = 14.76$

$[H_3O^+] = 5.75\text{ mol L}^{-1}$

$[H_3O^+][OH^-] = 1\times10^{-14}$

$\Rightarrow [OH^-] = 1.74\times10^{-15}$

$H_2O(l) + HCl(aq) \longrightarrow H_3O^+(aq) + Cl^-(aq)$

$HNO_3(aq) + H_2O(l) \longrightarrow H_3O^+(aq) + NO_3^-(aq)$

$2H_2O(l) \rightleftharpoons H_3O^+(aq) + OH^-(aq)$

(6) Exothermic reaction (ΔH is negative)
∴ Low T favors the reaction.

Number of species decrease from 2 to $1\frac{1}{2}$ during the reaction. ∴ High P favors the reaction.

Answer is (C).

(7) (C) Changing the temperature.

(8) $2\,COCl_2(g) \rightleftharpoons C\,(graphite) + CO_2(g) + 2\,Cl_2(g)$

initial	1.0 atm		
change	$-2x$	$+x$	$+2x$
equilibrium	$(1.0-2x)$	x	$2x$

$$K_p = \frac{\left(P_{CO_2(g)}\right)\left(P_{Cl_2(g)}\right)^2}{\left(P_{COCl_2(g)}\right)^2} = \frac{(x)(2x)^2}{(1.0-2x)^2}$$

Answer is (C)