Chemistry 225 Semester 01-2013
Homework for Submission #4 – Answer Key

1) The hydrazinium ion ($N_2H_5^+$) is a weak Brønsted-Lowry acid in water.

   a) Write the equation for the acid dissociation of this ion in water. Label the conjugate base of this acid in the equation. (2)

$$N_2H_5^+(aq) + H_2O(l) \rightleftharpoons \underbrace{N_2H_4(aq)}_{\text{conjugate base}} + H_3O^+(aq)$$

   b) The pK_a of this ion is 8.23 at 25°C.

   i) Calculate the K_a value of the acid. (2)

$$pK_a = -\mathrm{Log}_{10}(K_a)$$

$$\therefore K_a = 10^{-pK_a} = 10^{-8.23} = 5.8884\times10^{-9} \approx \underline{\underline{5.89\times10^{-9}}} \text{ to 2 d.p.}$$

   ii) Calculate the pH of a solution which is made up by dissolving 0.015 mol of hydrazinium nitrate, $N_2H_5^+NO_3^-$, (sometimes used as a rocket fuel) in water to make 2.50 dm^3 of solution. (NB. The nitrate ion has no appreciable acidic nor basic properties and need not be considered.) (8)

	$N_2H_5^+(aq)$	+	$H_2O(l)$	$\rightleftharpoons$	$N_2H_4(aq)$	+	$H_3O^+(aq)$
Initial /M	0.015/2.50 = 6.00×10^{-3}		---		0		~0
Change /M	$-x$				$+x$		$+x$
Equilibrium /M	$6\times10^{-3} - x$				x		x

$$\therefore K_a = \frac{[N_2H_4]}{[N_2H_5^+][H_3O^+]} = \frac{x^2}{6\times10^{-3} - x}$$

Assume x<5% of 6×10^{-3}.

$$\therefore 6\times10^{-3} - x \approx 6\times10^{-3}$$

$$\therefore \frac{x^2}{6\times10^{-3} - x} \approx \frac{x^2}{6\times10^{-3}} = K_a = 5.8884...\times10^{-9}$$

$$\therefore x^2 = 5.8884...\times10^{-9} \times 6\times10^{-3} = 3.5330\times10^{-11}$$

$$\therefore x = \sqrt{3.5330\times10^{-11}} = 5.9439\times10^{-6}$$

$$\therefore pH = -Log_{10}([H_3O^+]) - Log_{10}(5.9439\times10^{-6}) = 5.2259 \approx \underline{\underline{5.23}} \text{ to 2 d.p.}$$

Check assumption:

5% of $6\times10^{-3} = 3\times10^{-4}$ and since $x \approx 5.9\times10^{-6}$,

$x << 5\%$ of 6×10^{-3}
and the assumption is justified.

2) The hypochlorite ion (ClO^-) is a weak base in water. The base dissociation constant for this ion in water is 3.58×10^{-7} at 25°C.

a) Write the equation for the base dissociation of this ion in water. Label the conjugate acid of this base in the equation. (2)

$$ClO^-(aq) + H_2O(l) \rightleftharpoons \underbrace{HClO(aq)}_{\text{conjugate acid}} + OH^-(aq)$$

b) Household bleach is a solution of sodium hypochlorite in water, typically 2.5%. This means that 100 cm^3 of solution contains 2.5 g of sodium hypochlorite, Na^+ClO^-.

i) Calculate the molarity of 2.50% sodium hypochlorite solution. (RAM of Na=22.99, Cl=35.45, O=16.00.) (3)

$$\text{Molar mass of NaClO} = 22.99 + 35.45 + 16.00 = 74.44\,\text{g mol}^{-1}$$

$$\therefore 2.50\,g = \frac{2.50\,g}{74.44\,g\,mol^{-1}} = 0.033584\ldots\text{mol}$$

but 2.50 g is present in $100\,\text{cm}^3$ of solution.

$$\therefore \text{Molarity of 2.50\% sodium hypochlorite} = \frac{0.033584\ldots\text{mol}}{0.1\,\text{dm}^3} = 0.33584\ldots\text{mol dm}^{-3}$$

$$\approx \underline{\underline{0.336}}\,M \text{ to } 3\,s.f.$$

ii) Calculate the pH of 2.50% sodium hypochlorite solution (bleach) at 25°C. (NB. The sodium ion has no appreciable acidic or basic properties and need not be considered.) (8)

	$ClO^-(aq)$	+	$H_2O(l)$	$\rightleftharpoons$	$HClO(aq)$	+	$OH^-(aq)$
Initial /M	0.33584		---		0		~0
Change /M	$-x$				$+x$		$+x$
Equilibrium /M	$0.33584 - x$				x		x

The base dissociation constant of the hypochlorite ion, ClO^- is $K_b = 3.58\times10^{-7}$

$$\therefore K_b = \frac{[HClO]}{[ClO^-][H_3O^-]} = \frac{x^2}{0.33584 - x}$$

and assuming $x < 5\%$ of 0.33584

$$x = \sqrt{0.33584 K_b} = \sqrt{0.33584 \times 3.58 \times 10^{-7}} = 3.46743... \times 10^{-4}$$

$$\therefore pOH = -Log_{10}[OH^-] = Log_{10}(x) = Log_{10}(3.46743... \times 10^{-4}) = 3.4599...$$

But $\mathrm{pH} + \mathrm{pOH} = 14.00$ @ $25^\circ C$

$$\therefore \mathrm{pH} = 14 - 3.459992276... = 10.5400 \approx \underline{\underline{10.54}} \text{ to 2 d.p.}$$

Check assumption:

5% of $0.33584 \approx 1.68 \times 10^{-2}$ and since $x \approx 3.5 \times 10^{-4}$,

$x << 5\%$ of 0.33584

and the assumption is justified.