Question 1

$$K_a = \frac{[H_3O^+][OCl^-]}{[HOCl]} = 3.2 \times 10^{-8}$$

Hypochlorous acid, HOCl, is a weak acid in water. The K_a expression for HOCl is shown above.

(a) Write a chemical equation showing how HOCl behaves as an acid in water.

$HOCl(aq) + H_2O(l) \rightarrow OCl^-(aq) + H_3O^+(aq)$	One point is earned for the correct chemical equation.

(b) Calculate the pH of a 0.175 *M* solution of HOCl.

$HOCl(aq) + H_2O(l) \rightleftarrows OCl^-(aq) + H_3O^+(aq)$ I: 0.175, –, 0, ~0 C: $-x$, –, $+x$, $+x$ E: $0.175 - x$, –, $+x$, $+x$ $K_a = \frac{[H_3O^+][OCl^-]}{[HOCl]} = \frac{(x)(x)}{(0.175 - x)}$ Assume that $0.175 - x \approx 0.175$ $3.2 \times 10^{-8} = \frac{x^2}{0.175}$ $x^2 = (3.2 \times 10^{-8})(0.175) = 5.6 \times 10^{-9}$ $x = [H_3O^+] = 7.5 \times 10^{-5}\ M$ $pH = -\log[H_3O^+] = -\log(7.5 \times 10^{-5}) = 4.13$	One point is earned for calculating the value of $[H_3O^+]$. One point is earned for calculating the pH.

(c) Write the net ionic equation for the reaction between the weak acid HOCl(*aq*) and the strong base NaOH(*aq*).

$HOCl(aq) + OH^-(aq) \rightarrow OCl^-(aq) + H_2O(l)$	One point is earned for both of the correct reactants. One point is earned for both of the correct products.

(d) In an experiment, 20.00 mL of 0.175 *M* HOCl(*aq*) is placed in a flask and titrated with 6.55 mL of 0.435 *M* NaOH(*aq*).

(i) Calculate the number of moles of NaOH(*aq*) added.

or: (Molarity)(Volume) = moles

$mol_{NaOH} = 6.55\ mL \times \frac{1\ L}{1{,}000\ mL} \times \frac{0.435\ mol\ NaOH}{1\ L}$ $mol_{NaOH} = 2.85 \times 10^{-3}\ mol\ NaOH$	One point is earned for the correct number of moles of NaOH.

Question 1 (continued)

(ii) Calculate $[H_3O^+]$ in the flask after the $NaOH(aq)$ has been added.

$mol_{HOCl} = 20.00 \text{ mL} \times \frac{1 \text{ L}}{1{,}000 \text{ mL}} \times \frac{0.175 \text{ mol NaOH}}{1 \text{ L}} = 3.50 \times 10^{-3}$ mol $OH^-(aq)$ is the limiting reactant, therefore all of it reacts	One point is earned for calculating the initial number of moles of HOCl.
$HOCl(aq) + OH^-(aq) \rightarrow OCl^-(aq) + H_2O(l)$ I: 0.00350, 0.00285, 0, – C: −0.00285, −0.00285, +0.00285, – E: 0.00065, 0, 0.00285, – $M_{HOCl} = \frac{0.00065 \text{ mol}}{0.02655 \text{ L}} = 0.0245\ M$ $M_{OCl^-} = \frac{0.00285 \text{ mol}}{0.02655 \text{ L}} = 0.107\ M$	This is the behavior equation for HOCl + OCl⁻ to set up their equilibrium. It is NOT needed to work the problem. One point is earned for the concentration or number of moles of HOCl and OCl^- after the neutralization reaction.
$HOCl(aq) + H_2O(l) \rightarrow H_3O^+(aq) + OCl^-(aq)$ I: 0.0245, –, ~0, 0.107 C: $-x$, –, $+x$, $+x$ E: $0.0245 - x$, –, $+x$, $0.107 + x$ $K_a = \frac{[H_3O^+][OCl^-]}{[HOCl]} = \frac{(x)(0.107 + x)}{(0.0245 - x)}$ Assume that $0.107 + x \approx 0.107$ and that $0.0245 - x \approx 0.0245$ $3.2 \times 10^{-8} = \frac{(x)(0.107)}{(0.0245)}$ $x = [H_3O^+] = 7.3 \times 10^{-9}\ M$	One point is earned for the correct $[H_3O^+]$.

substitute into K_a

(iii) Calculate $[OH^-]$ in the flask after the $NaOH(aq)$ has been added.

$[H_3O^+][OH^-] = 1.0 \times 10^{-14} = K_w$ $[OH^-] = \frac{1.0 \times 10^{-14}}{[H_3O^+]} = \frac{1.0 \times 10^{-14}}{7.3 \times 10^{-9}} = 1.4 \times 10^{-6}\ M$	One point is earned for the correct concentration of OH^-.

This is NOT the OH⁻ that came from the buret. (That's all gone)
It is the tiny amount of OH⁻ that's present in any acid solution with a water solvent.

Question 1 (10 points)

A pure 14.85 g sample of the weak base ethylamine, $C_2H_5NH_2$, is dissolved in enough distilled water to make 500. mL of solution.

(a) Calculate the molar concentration of the $C_2H_5NH_2$ in the solution.

$n_{C_2H_5NH_2} = 14.85 \text{ g } C_2H_5NH_2 \times \frac{1 \text{ mol } C_2H_5NH_2}{45.09 \text{ g } C_2H_5NH_2}$ $= 0.3293 \text{ mol } C_2H_5NH_2$	One point is earned for the correct number of moles.
$M_{C_2H_5NH_2} = \frac{0.3293 \text{ mol } C_2H_5NH_2}{0.500 \text{ L}} = \mathbf{0.659}\ \boldsymbol{M}$	One point is earned for the correct concentration.

The aqueous ethylamine reacts with water according to the equation below.

$$C_2H_5NH_2(aq) + H_2O(l) \rightleftarrows C_2H_5NH_3^+(aq) + OH^-(aq)$$

(b) Write the equilibrium-constant expression for the reaction between $C_2H_5NH_2(aq)$ and water.

$K_b = \frac{[C_2H_5NH_3^+][OH^-]}{[C_2H_5NH_2]}$	One point is earned for the correct expression.

(c) Of $C_2H_5NH_2(aq)$ and $C_2H_5NH_3^+(aq)$, which is present in the solution at the higher concentration at equilibrium? Justify your answer.

$C_2H_5NH_2$ is present in the solution at the higher concentration at equilibrium. Ethylamine is a weak base, and thus it has a small K_b value. Therefore only partial dissociation of $C_2H_5NH_2$ occurs in water, and $[C_2H_5NH_3^+]$ is thus less than $[C_2H_5NH_2]$.	One point is earned for the correct answer with justification.

Question 1 (continued)

(d) A different solution is made by mixing 500. mL of 0.500 *M* $C_2H_5NH_2$ with 500. mL of 0.200 *M* HCl. Assume that volumes are additive. The pH of the resulting solution is found to be 10.93.

(i) Calculate the concentration of $OH^-(aq)$ in the solution.

$pH = -\log[H^+]$ $[H^+] = 10^{-10.93} = 1.17 \times 10^{-11}$ $[OH^-] = \frac{K_w}{[H^+]} = \frac{1.00 \times 10^{-14}}{1.17 \times 10^{-11}} = \mathbf{8.5 \times 10^{-4}}\ M$ **OR** $pOH = 14 - pH = 14 - 10.93 = 3.07$ $pOH = -\log[OH^-]$ $[OH^-] = 10^{-3.07} = \mathbf{8.5 \times 10^{-4}}\ M$	One point is earned for the correct concentration.

(ii) Write the net-ionic equation that represents the reaction that occurs when the $C_2H_5NH_2$ solution is mixed with the HCl solution. weak base/strong acid

$C_2H_5NH_2 + H_3O^+ \rightarrow C_2H_5NH_3^+ + H_2O$	One point is earned for the correct equation.

OR $C_2H_5NH_2 + H^+ \longrightarrow C_2H_5NH_3^+$

(iii) Calculate the molar concentration of the $C_2H_5NH_3^+(aq)$ that is formed in the reaction.

moles of $C_2H_5NH_2 = 0.500\text{ L} \times \frac{0.500\text{ mol}}{1.00\text{ L}} = \mathbf{0.250\ mol}$

moles of $H_3O^+ = 0.500\text{ L} \times \frac{0.200\text{ mol}}{1.00\text{ L}} = \mathbf{0.100\ mol}$

One point is earned for the correct number of moles of $C_2H_5NH_2$ and H_3O^+.

	$[C_2H_5NH_2]$	$[H_3O^+]$	$[C_2H_5NH_3^+]$
initial value	0.250	0.100	~ 0
change	−0.100	−0.100	+0.100
final value	0.150	~ 0	0.100

$[C_2H_5NH_3^+] = \frac{0.100\text{ mol } C_2H_5NH_3^+}{1.00\text{ L}} = \mathbf{0.100}\ M$

One point is earned for the correct concentration.

Question 1 (continued)

(iv) Calculate the value of K_b for $C_2H_5NH_2$.

use into from ICE table

$[C_2H_5NH_2] = \frac{0.150 \text{ mol } C_2H_5NH_2}{1.00 \text{ L}} = \mathbf{0.150}\ \boldsymbol{M}$ [OH⁻] from (i) $K_b = \frac{[C_2H_5NH_3^+][OH^-]}{[C_2H_5NH_2]} = \frac{(0.100)(8.5 \times 10^{-4})}{0.150} = \mathbf{5.67 \times 10^{-4}}$	One point is earned for the correct calculation of the molarity of $C_2H_5NH_2$ after neutralization. One point is earned for the correct value.