AP® CHEMISTRY
2009 SCORING GUIDELINES

Question 1 (10 points)

Answer the following questions that relate to the chemistry of halogen oxoacids.

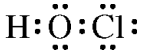
(a) Use the information in the table below to answer part (a)(i).

Acid	K_a at 298 K
HOCl	2.9×10^{-8}
HOBr	2.4×10^{-9}

(i) Which of the two acids is stronger, HOCl or HOBr ? Justify your answer in terms of K_a .

HOCl is the stronger acid because its K_a value is greater than the K_a value of HOBr.	One point is earned for the correct answer with justification.

(ii) Draw a complete Lewis electron-dot diagram for the acid that you identified in part (a)(i).

	One point is earned for a correct diagram.

(iii) Hypoiodous acid has the formula HOI. Predict whether HOI is a stronger acid or a weaker acid than the acid that you identified in part (a)(i). Justify your prediction in terms of chemical bonding.

HOI is a weaker acid than HOCl because the O–H bond in HOI is stronger than the O–H bond in HOCl. The lower electronegativity (electron-drawing ability) of I compared with that of Cl results in an electron density that is higher (hence a bond that is stronger) between the H and O atoms in HOI compared with the electron density between the H and O atoms in HOCl. **OR** The conjugate base OCl^- is more stable than OI^- because Cl, being more electronegative, is better able to accommodate the negative charge.	One point is earned for predicting that HOI is a weaker acid than HOCl and stating that iodine has a lower electronegativity than chlorine **and EITHER** • stating that this results in a stronger O–H bond in HOI **OR** • stating that this decreases the stability of the OI^- ion in solution.

Question 1 (continued)

(b) Write the equation for the reaction that occurs between hypochlorous acid and water.

$HOCl + H_2O \rightleftarrows OCl^- + H_3O^+$ **OR** $HOCl \rightleftarrows OCl^- + H^+$	One point is earned for the correct equation.

(c) A 1.2 *M* NaOCl solution is prepared by dissolving solid NaOCl in distilled water at 298 K. The hydrolysis reaction $OCl^-(aq) + H_2O(l) \rightleftarrows HOCl(aq) + OH^-(aq)$ occurs.

(i) Write the equilibrium-constant expression for the hydrolysis reaction that occurs between $OCl^-(aq)$ and $H_2O(l)$.

$K_b = \dfrac{[HOCl][OH^-]}{[OCl^-]}$	One point is earned for the correct expression.

(ii) Calculate the value of the equilibrium constant at 298 K for the hydrolysis reaction.

$K_b = \dfrac{K_w}{K_a} = \dfrac{1.0 \times 10^{-14}}{2.9 \times 10^{-8}} = \mathbf{3.4 \times 10^{-7}}$	One point is earned for the correct value with supporting work.

(iii) Calculate the value of $[OH^-]$ in the 1.2 *M* NaOCl solution at 298 K .

	$[OCl^-]$	$[HOCl]$	$[OH^-]$
initial value	1.2	0	≈ 0
change	$-x$	x	x
equilibrium value	$1.2 - x$	x	x

One point is earned for the correct setup.

$K_{hyd} = 3.4 \times 10^{-7} = \dfrac{[OH^-][HOCl]}{[OCl^-]} = \dfrac{(x)(x)}{(1.2 - x)} \approx \dfrac{x^2}{1.2}$

$\Rightarrow (1.2)(3.4 \times 10^{-7}) = x^2 \Rightarrow$

$x = [OH^-] = \mathbf{6.4 \times 10^{-4}\ M}$

One point is earned for the correct answer with supporting calculations.

Question 1 (continued)

(d) A buffer solution is prepared by dissolving some solid NaOCl in a solution of HOCl at 298 K. The pH of the buffer solution is determined to be 6.48.

(i) Calculate the value of $[H_3O^+]$ in the buffer solution.

$[H^+] = 10^{-6.48} = \mathbf{3.3 \times 10^{-7}}\ \boldsymbol{M}$	One point is earned for the correct value.

(ii) Indicate which of HOCl(*aq*) or OCl^-(*aq*) is present at the higher concentration in the buffer solution. Support your answer with a calculation.

$[H^+] = 3.3 \times 10^{-7}\ M$ and K_a for HOCl $= 2.9 \times 10^{-8}$ $K_a = \dfrac{[H^+][OCl^-]}{[HOCl]}$ $2.9 \times 10^{-8} = \dfrac{(3.3 \times 10^{-7})[OCl^-]}{[HOCl]}$ $\dfrac{[OCl^-]}{[HOCl]} = \dfrac{2.9 \times 10^{-8}}{3.3 \times 10^{-7}} = 0.088 \quad \Rightarrow \quad [HOCl] > [OCl^-]$	One point is earned for the correct answer with supporting buffer calculations.