Question 1
(10 points)

A 1.22 g sample of a pure monoprotic acid, HA, was dissolved in distilled water. The HA solution was then titrated with 0.250 *M* NaOH. The pH was measured throughout the titration, and the equivalence point was reached when 40.0 mL of the NaOH solution had been added. The data from the titration are recorded in the table below.

Volume of 0.250 *M* NaOH Added (mL)	pH of Titrated Solution
0.00	?
10.0	3.72
20.0	4.20
30.0	?
40.0	8.62
50.0	12.40

(a) Explain how the data in the table above provide evidence that HA is a weak acid rather than a strong acid.

The pH at the equivalence point is above 7, which indicates that HA is a weak acid.	1 point is earned for the correct explanation.

(b) Write the balanced net-ionic equation for the reaction that occurs when the solution of NaOH is added to the solution of HA .

$HA(aq) + OH^{-}(aq) \rightarrow A^{-}(aq) + H_2O(l)$	1 point is earned for writing the net-ionic equation balanced for mass and charge.

(c) Calculate the number of moles of HA that were titrated.

At the equivalence point, the number of moles of base added equals the number of moles of acid initially present. $0.0400 \text{ L} \times \frac{0.250 \text{ mol NaOH}}{\text{L}} \times \frac{1 \text{ mol HA}}{1 \text{ mol NaOH}} = 0.0100 \text{ mol HA}$	1 point is earned for the correct number of moles.

Question 1 (continued)

(d) Calculate the molar mass of HA .

$MM = \frac{\text{mass of acid}}{\text{moles of acid}} = \frac{1.22\text{ g}}{0.0100\text{ mol}} = 122\text{ g/mol}$	1 point is earned for the correct molar mass.

The equation for the dissociation reaction of HA in water is shown below.

$$HA(aq) + H_2O(l) \rightleftarrows H_3O^+(aq) + A^-(aq) \qquad K_a = 6.3 \times 10^{-5}$$

(e) Assume that the initial concentration of the HA solution (before any NaOH solution was added) is 0.200 *M*. Determine the pH of the initial HA solution.

$K_a = \frac{[H_3O^+][A^-]}{[HA]}$ $6.3\times10^{-5} = \frac{(x)(x)}{(0.200-x)}$; assume that $x << 0.200\ M$. $x = [H_3O^+] = 3.5\times10^{-3}\ M$ $pH = -\log[H_3O^+] = -\log(3.5\times10^{-3}) = 2.45$	1 point is earned for the appropriate substitution into the K_a expression. 1 point is earned for the correct $[H_3O^+]$. 1 point is earned for the calculation of pH.

(f) Calculate the value of $[H_3O^+]$ in the solution after 30.0 mL of NaOH solution is added and the total volume of the solution is 80.0 mL.

$HA + OH^- \rightarrow A^- + H_2O$ mol before rxn: 0.0100 0.00750 0.00000 mol after rxn: 0.00250 0.00000 0.00750	1 point is earned for the correct calculation of moles of A^- and HA after the reaction.
$[HA] = \frac{0.00250\text{ mol}}{0.0800\text{ L}} = 3.13\times10^{-2}\ M$ $[A^-] = \frac{0.00750\text{ mol}}{0.0800\text{ L}} = 9.38\times10^{-2}\ M$ $K_a = \frac{[H_3O^+][A^-]}{[HA]}$ $6.3\times10^{-5} = \frac{(x)(9.38\times10^{-2}+x)}{(3.13\times10^{-2}-x)}$	1 point is earned for the appropriate substitution into the equilibrium expression.
Assume that $x << 9.38\times10^{-2}\ M$ and $3.13\times10^{-2}\ M$, then $6.3\times10^{-5} = \frac{(x)(9.38\times10^{-2})}{(3.13\times10^{-2})}$ $x = [H_3O^+] = 2.10\times10^{-5}\ M$.	1 point is earned for the correct calculation of $[H_3O^+]$.