2. Answer the following questions about ascorbic acid (vitamin C).

A. A student combusts a sample of ascorbic acid, $C_xH_yO_x$, to determine its chemical composition. The only products of the reaction are 0.2400 mol of CO_2 and 2.883 g of H_2O.

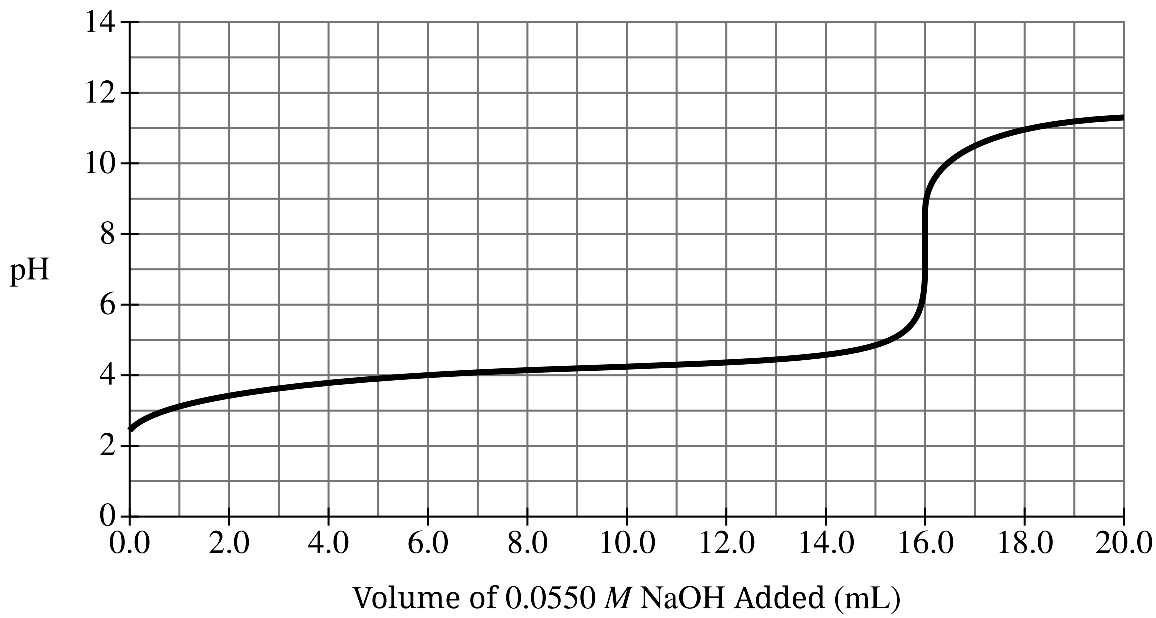
i. Calculate the number of moles of H_2O produced.

ii. The mole ratio of carbon (C) to oxygen (O) is 1:1 in ascorbic acid. Based on this information and your answer to part A (i), determine the empirical formula of ascorbic acid.

B. Ascorbic acid, $\text{HAsc}(aq)$, acts as a weak acid, as shown in the equation.

$$\text{HAsc}(aq) + \text{H}_2\text{O}(l) \rightleftarrows \text{H}_3\text{O}^+(aq) + \text{Asc}^-(aq)$$

The following titration curve was produced when a 10.0 mL sample of $\text{HAsc}(aq)$ was titrated using 0.0550 M $\text{NaOH}(aq)$.



i. Calculate the molar concentration of the ascorbic acid solution.

ii. From the titration curve, determine the approximate $\text{p}K_a$ of ascorbic acid.

iii. What is the value of the ratio $\dfrac{[\text{Asc}^-]}{[\text{HAsc}]}$ when the pH of the solution is 4.7?

C. Dehydroascorbic acid (DHAsc) can be produced by reacting ascorbic acid with the triiodide ion, I_3^-, as represented by the following equation.

$$\text{HAsc} + I_3^- \rightarrow \text{DHAsc} + 3\ I^- + 2\ H^+$$

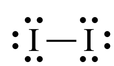
The student runs three trials of the reaction with different initial concentrations of HAsc and I_3^-, producing the following data.

Trial	[HAsc] (M)	$[I_3^-]$ (M)	Initial Rate of DHAsc Formation (M/s)
1	0.450	1.200	2.457×10^{-4}
2	0.450	0.600	1.229×10^{-4}
3	0.900	1.200	4.914×10^{-4}

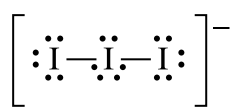
i. The rate law for the reaction is $rate = k[\text{HAsc}][I_3^-]$. Explain how the data in the table support the conclusion that the reaction is first order with respect to $[\text{HAsc}]$.

ii. Calculate the value of the rate constant, k, for the reaction. Include units with your answer.

D. The triiodide ion, I_3^-, is significantly more soluble in water than elemental iodine, I_2, is. Identify an intermolecular force between I_3^- and water that is **not** present between I_2 and water, which could explain the difference in solubility. Lewis diagrams for I_2 and I_3^- are provided.



I_2



I_3^-

Question 2: Long Answer — 10 points

A (i) For the correct calculated value: **Point 01**

$$2.883 \text{ g } H_2O \times \frac{1 \text{ mol } H_2O}{18.02 \text{ g } H_2O} = 0.1600 \text{ mol } H_2O$$

(ii) For the correct calculated number of moles of H (may be implicit): **Point 02**

$$0.1600 \text{ mol } H_2O \times \frac{2 \text{ mol H}}{1 \text{ mol } H_2O} = 0.3200 \text{ mol H}$$

For the correct empirical formula. **Point 03**

Examples of acceptable responses may include the following:

- $x : y : z$ = (moles of C):(moles of H):(moles of O)

  $x : y : z = 0.2400 : 0.3200 : 0.2400 = 3 : 4 : 3$

  Therefore, the empirical formula of ascorbic acid is $C_3H_4O_3$.

- $$0.2400 \text{ mol } CO_2 \times \frac{1 \text{ mol C}}{1 \text{ mol } CO_2} = 0.2400 \text{ mol C}$$

  $$\frac{0.3200 \text{ mol H}}{0.2400 \text{ mol C}} = \frac{4 \text{ H}}{3 \text{ C}}$$

  Given that the ratio of C:O *is* 1:1, *the empirical formula of ascorbic acid is* $C_3H_4O_3$.

B (i) For the correct calculated value: **Point 04**

$$0.0160 \text{ L NaOH} \times \frac{0.0550 \text{ mol NaOH}}{1 \text{ L NaOH}} \times \frac{1 \text{ mol HAsc}}{1 \text{ mol NaOH}} = 8.80 \times 10^{-4} \text{ mol HAsc}$$

$$\frac{8.80 \times 10^{-4} \text{ mol HAsc}}{0.0100 \text{ L}} = 0.0880\ M \text{ HAsc}$$

(ii) For the correct pK_a: **Point 05**

4.1 (*acceptable range:* 4.0 – 4.3)

(iii) For the correct ratio, consistent with part B (ii): **Point 06**

Using the Henderson-Hasselbalch equation:

$$pH = pK_a + \log\left(\frac{[Asc^-]}{[HAsc]}\right)$$

$$4.7 = 4.1 + \log\left(\frac{[Asc^-]}{[HAsc]}\right)$$

$$\frac{[Asc^-]}{[HAsc]} = 10^{0.6} = 4.0$$