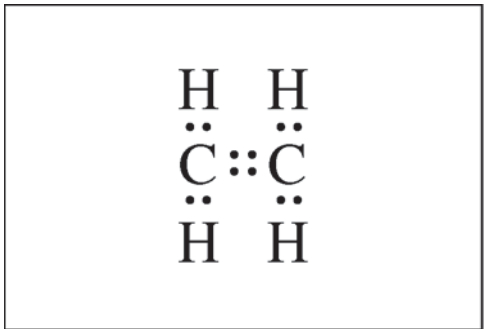
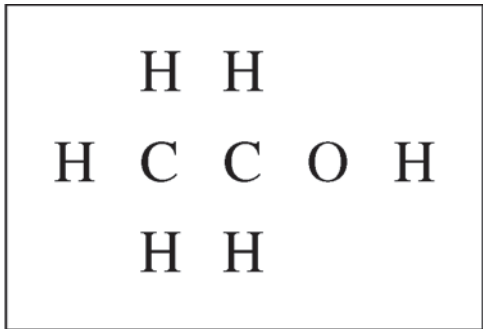
(d) The Lewis electron-dot diagram for C_2H_4 is shown below in the box on the left. In the box on the right, complete the Lewis electron-dot diagram for C_2H_5OH by drawing in all of the electron pairs.





(e) What is the approximate value of the C–O–H bond angle in the ethanol molecule?

(f) During the dehydration experiment, $C_2H_4(g)$ and unreacted $C_2H_5OH(g)$ passed through the tube into the water. The C_2H_4 was quantitatively collected as a gas, but the unreacted C_2H_5OH was not. Explain this observation in terms of the intermolecular forces between water and each of the two gases.

3. Potassium sorbate, $KC_6H_7O_2$ (molar mass 150. g/mol) is commonly added to diet soft drinks as a preservative. A stock solution of $KC_6H_7O_2(aq)$ of known concentration must be prepared. A student titrates 45.00 mL of the stock solution with 1.25 *M* HCl(*aq*) using both an indicator and a pH meter. The value of K_a for sorbic acid, $HC_6H_7O_2$, is 1.7×10^{-5}.

(a) Write the net-ionic equation for the reaction between $KC_6H_7O_2(aq)$ and HCl(*aq*).

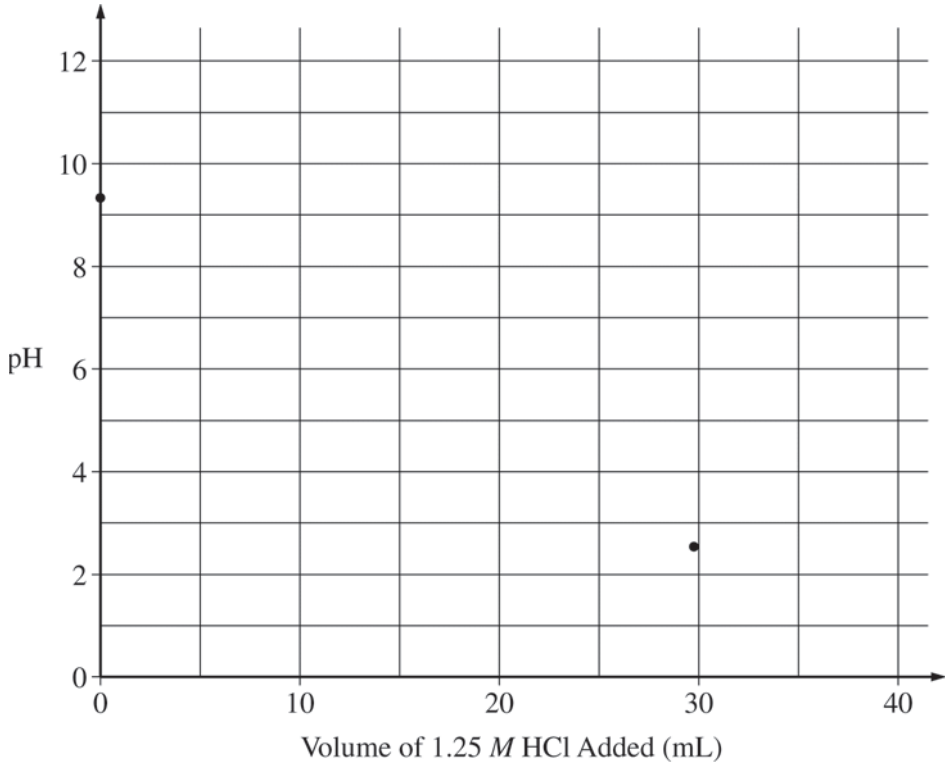
(b) A total of 29.95 mL of 1.25 *M* HCl(*aq*) is required to reach the equivalence point. Calculate $[KC_6H_7O_2]$ in the stock solution.

(c) The pH at the equivalence point of the titration is measured to be 2.54 Which of the following indicators would be the best choice for determining the end point of the titration? Justify your answer.

Indicator	pK_a
Phenolphthalein	9.3
Bromothymol blue	7.0
Methyl red	5.0
Thymol blue	2.0
Methyl violet	0.80

(d) Calculate the pH at the half-equivalence point.

(e) The initial pH and the equivalence point are plotted on the graph below. Accurately sketch the titration curve on the graph below. Mark the position of the half-equivalence point on the curve with an X.



(f) The pH of the soft drink is 3.37 after the addition of the $KC_6H_7O_2(aq)$. Which species, $HC_6H_7O_2$ or $C_6H_7O_2^-$, has a higher concentration in the soft drink? Justify your answer.

AP® CHEMISTRY
2015 SCORING GUIDELINES

Question 3

Potassium sorbate, $KC_6H_7O_2$ (molar mass 150. g/mol) is commonly added to diet soft drinks as a preservative. A stock solution of $KC_6H_7O_2(aq)$ of known concentration must be prepared. A student titrates 45.00 mL of the stock solution with 1.25 *M* HCl(*aq*) using both an indicator and a pH meter. The value of K_a for sorbic acid, $HC_6H_7O_2$, is 1.7×10^{-5}.

(a) Write the net-ionic equation for the reaction between $KC_6H_7O_2(aq)$ and HCl(*aq*).

$H^+ + C_6H_7O_2^- \rightleftarrows HC_6H_7O_2$	1 point is earned the net-ionic equation.

(b) A total of 29.95 mL of 1.25 *M* HCl(*aq*) is required to reach the equivalence point. Calculate $[KC_6H_7O_2]$ in the stock solution.

$\frac{1.25 \text{ mol HCl}}{1000 \text{ mL}} = \frac{x \text{ mol HCl}}{29.95 \text{ mL}}$ $x = 0.0374$ mol HCl $\frac{0.0374 \text{ mol } C_6H_7O_2^-}{45.0 \text{ mL}} = \frac{x \text{ mol } C_6H_7O_2^-}{1000 \text{ mL}} \Rightarrow 0.832\ M$	1 point is earned for the moles of HCl at the equivalence point. 1 point is earned for the correct answer.

(c) The pH at the equivalence point of the titration is measured to be 2.54. Which of the following indicators would be the best choice for determining the end point of the titration? Justify your answer.

Indicator	pK_a
Phenolphthalein	9.3
Bromothymol blue	7.0
Methyl red	5.0
Thymol blue	2.0
Methyl violet	0.80

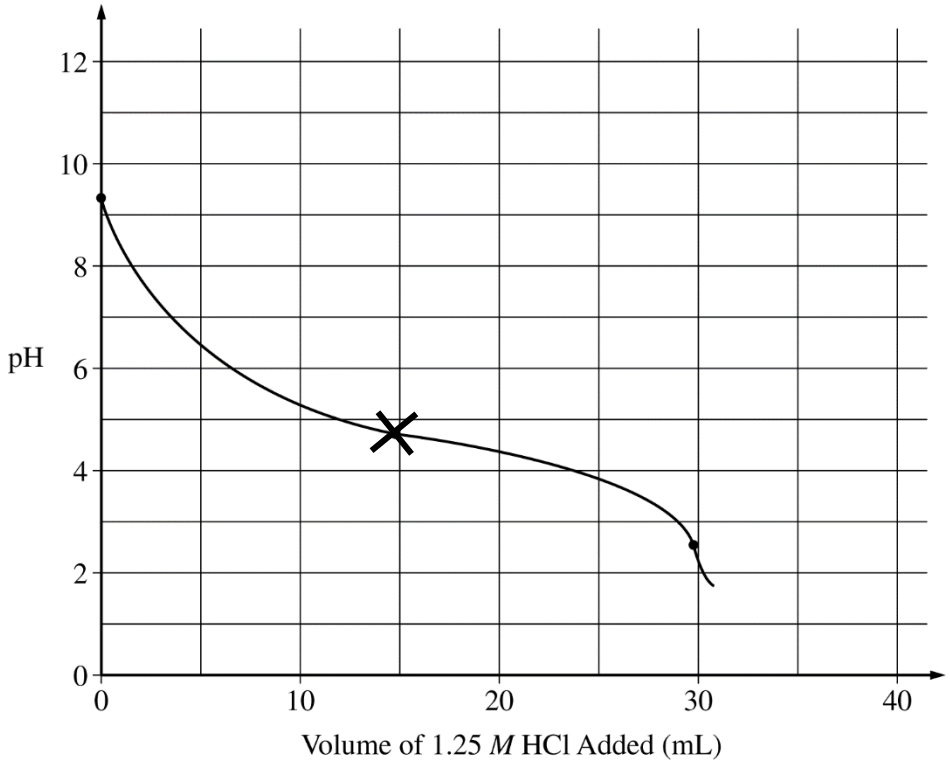
Thymol blue; it has a pK_a close to the pH at the equivalence point, so it will change color near the equivalence point.	1 point is earned for the correct indicator. 1 point is earned for correct justification.

(d) Calculate the pH at the half-equivalence point.

pH = pK_a = –log (1.7×10^{-5}) = 4.77	1 point is earned for the correct pH.

Question 3 (continued)

(e) The initial pH and the equivalence point are plotted on the graph below. Accurately sketch the titration curve on the graph below. Mark the position of the half-equivalence point on the curve with an X.



[The pH curve should have the correct shape.]	1 point is earned for a half-equivalence point consistent with the answer to part (d) and at the correct volume. 1 point is earned for a curve that levels off to a relatively horizontal slope through the half-equivalence point. 1 point is earned for a relatively steep negative slope through the equivalence point.

Question 3 (continued)

(f) The pH of the soft drink is 3.37 after the addition of the $KC_6H_7O_2(aq)$. Which species, $HC_6H_7O_2$ or $C_6H_7O_2^-$, has a higher concentration in the soft drink? Justify your answer.

For sorbic acid, $K_a = \frac{[H^+][C_6H_7O_2^-]}{[HC_6H_7O_2]}$, thus $\frac{[C_6H_7O_2^-]}{[HC_6H_7O_2]} = \frac{K_a}{[H^+]} = \frac{1.7 \times 10^{-5}}{10^{-3.37}} \approx 0.04$ $\Rightarrow [HC_6H_7O_2] > [C_6H_7O_2^-]$ **OR** The concentrations of $HC_6H_7O_2$ and $C_6H_7O_2^-$ are equal at the half-equivalence point. A pH of 3.37 is lower than that at the half-equivalence point, so the protonated form, $HC_6H_7O_2$, has a higher concentration in the soft drink.	1 point is earned for identifying the correct species and for making a comparison involving the pH (with or without calculation).