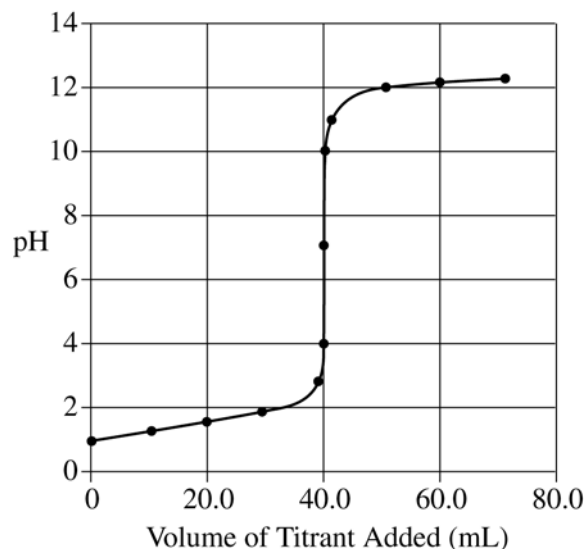


**AP<sup>®</sup> CHEMISTRY**  
**2010 SCORING GUIDELINES (Form B)**

**Question 5**  
**(9 points)**



A solution of 0.100 *M* HCl and a solution of 0.100 *M* NaOH are prepared. A 40.0 mL sample of one of the solutions is added to a beaker and then titrated with the other solution. A pH electrode is used to obtain the data that are plotted in the titration curve shown above.

(a) Identify the solution that was initially added to the beaker. Explain your reasoning.

The solution in the beaker was the 0.100 <i>M</i> HCl because the initial pH was 1 (the pH of 0.100 <i>M</i> HCl).	One point is earned for the correct identification with rationale.
--------------------------------------------------------------------------------------------------------------------	--------------------------------------------------------------------

(b) On the titration curve above, circle the point that corresponds to the equivalence point.

The point with coordinates (40.0, 7) is circled.	One point is earned for the correct choice of point.
--------------------------------------------------	------------------------------------------------------

(c) At the equivalence point, how many moles of titrant have been added?

$0.0400 \text{ L} \times \frac{0.100 \text{ mol NaOH}}{1.00 \text{ L}} = 0.00400 \text{ mol NaOH}$	One point is earned for the correct numerical answer.
----------------------------------------------------------------------------------------------------	-------------------------------------------------------

(d) The same titration is to be performed again, this time using an indicator. Use the information in the table below to select the best indicator for the titration. Explain your choice.

Methyl red would be best because its color change will occur closest to the equivalence point (when the pH changes from about 4 to 10).	One point is earned for the correct selection of indicator.  One point is earned for the explanation.
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**AP<sup>®</sup> CHEMISTRY**  
**2010 SCORING GUIDELINES (Form B)**

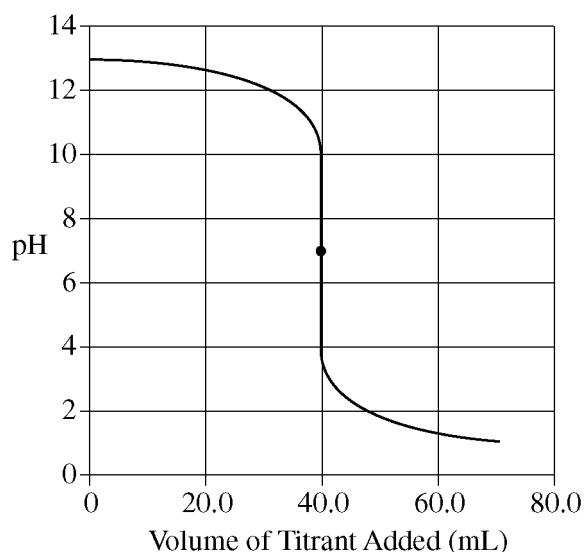
**Question 5 (continued)**

Indicator	pH Range of Color Change
Methyl violet	0 – 1.6
Methyl red	4 – 6
Alizarin yellow	10 – 12

- (e) What is the difference between the equivalence point of a titration and the end point of a titration?

<p>The equivalence point in a titration occurs when the number of moles of titrant added is exactly sufficient to react completely with the number of moles of the titrated species present in the sample being titrated.</p> <p>The end point of a titration is the point in a titration at which the indicator undergoes its color change.</p>	<p>One point is earned for each correct definition.</p>
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- (f) On the grid provided below, sketch the titration curve that would result if the solutions in the beaker and buret were reversed (i.e., if 40.0 mL of the solution used in the buret in the previous titration were titrated with the solution that was in the beaker).



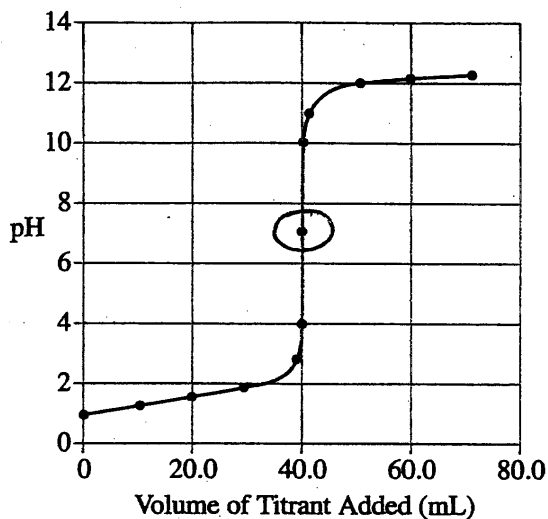
One point is earned for starting between pH 12 and 14 and for finishing below pH 2.

One point is earned for locating the equivalence point at pH 7 and volume 40.0 mL.

One point is earned for the overall shape of the curve.

Answer Question 5 and Question 6. The Section II score weighting for these questions is 15 percent each.

Your responses to these questions will be scored on the basis of the accuracy and relevance of the information cited. Explanations should be clear and well organized. Examples and equations may be included in your responses where appropriate. Specific answers are preferable to broad, diffuse responses.

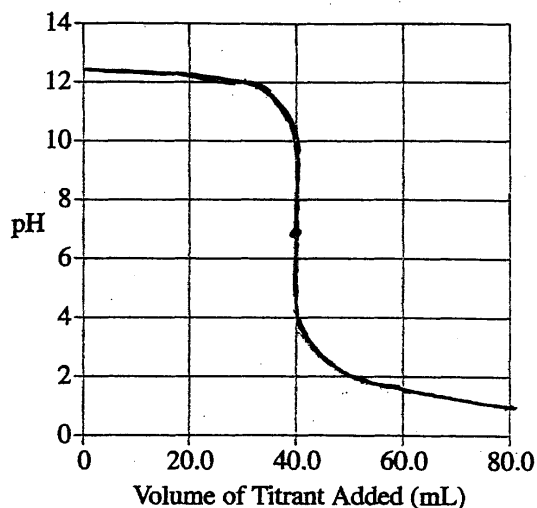


5. A solution of 0.100 M HCl and a solution of 0.100 M NaOH are prepared. A 40.0 mL sample of one of the solutions is added to a beaker and then titrated with the other solution. A pH electrode is used to obtain the data that are plotted in the titration curve shown above.
- Identify the solution that was initially added to the beaker. Explain your reasoning.
  - On the titration curve above; circle the point that corresponds to the equivalence point.
  - At the equivalence point, how many moles of titrant have been added?
  - The same titration is to be performed again, this time using an indicator. Use the information in the table below to select the best indicator for the titration. Explain your choice.

Indicator	pH Range of Color Change
Methyl violet	0 – 1.6
Methyl red	4 – 6
Alizarin yellow	10 – 12

- What is the difference between the equivalence point of a titration and the end point of a titration?
- On the grid provided on the next page, sketch the titration curve that would result if the solutions in the beaker and buret were reversed (i.e., if 40.0 mL of the solution used in the buret in the previous titration were titrated with the solution that was in the beaker).

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b) a) since the initial pH is less than 7 then the acid must have been in the beaker therefore HCl was initially added to the beaker

b) c)  $C = \frac{n}{V} \Rightarrow n = CV = (40)(0.1) = 4 \text{ millimoles}$   
 $= 4 \times 10^{-3} \text{ moles}$

d) methyl red since its range of color change is at the pH of equivalence

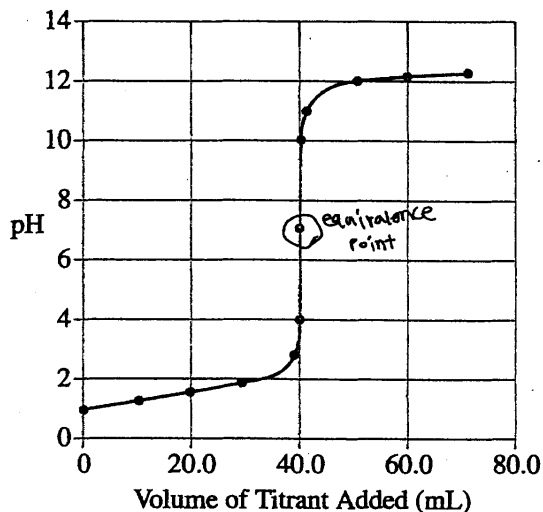
e) equivalence pt is the pt at which number of moles of acid = number of moles of base

the end pt of the titration is the <sup>eq pt</sup> when the indicator changes color.

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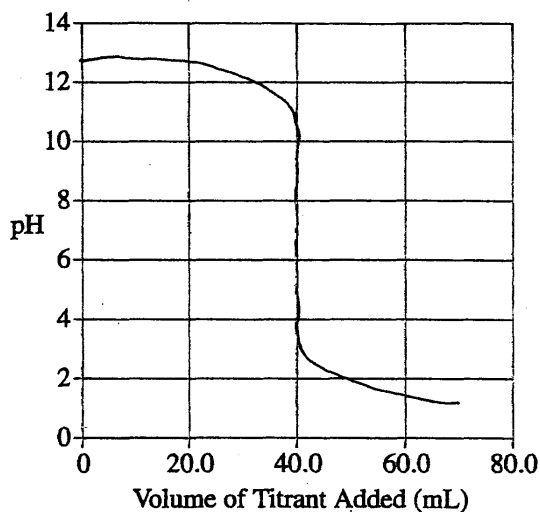
5. A solution of 0.100 M HCl and a solution of 0.100 M NaOH are prepared. A 40.0 mL sample of one of the solutions is added to a beaker and then titrated with the other solution. A pH electrode is used to obtain the data that are plotted in the titration curve shown above.

- (a) Identify the solution that was initially added to the beaker. Explain your reasoning.
- (b) On the titration curve above, circle the point that corresponds to the equivalence point.
- (c) At the equivalence point, how many moles of titrant have been added?
- (d) The same titration is to be performed again, this time using an indicator. Use the information in the table below to select the best indicator for the titration. Explain your choice.

Indicator	pH Range of Color Change
Methyl violet	0 – 1.6
Methyl red	4 – 6
Alizarin yellow	10 – 12

- (e) What is the difference between the equivalence point of a titration and the end point of a titration?
- (f) On the grid provided on the next page, sketch the titration curve that would result if the solutions in the beaker and buret were reversed (i.e., if 40.0 mL of the solution used in the buret in the previous titration were titrated with the solution that was in the beaker).

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5 - (a). HCl. At initial point where no titrant is added, the pH of solution is very low.

(b). in picture.

(c) 1 mole.

(d) methyl red is most appropriate, since range of color change of methyl red and range of equivalence of the solution ~~overlaps~~ overlap.

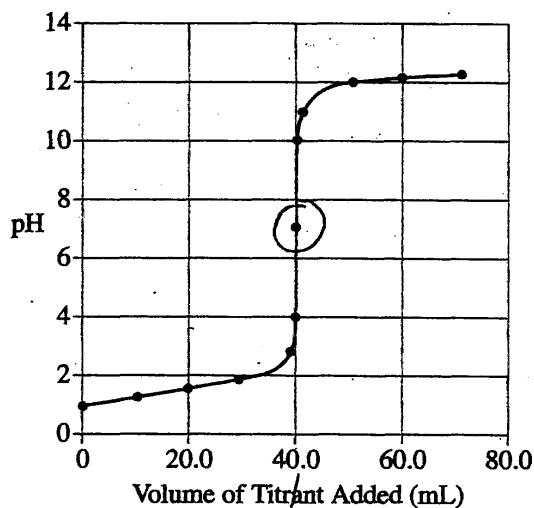
(e) At equivalence point, titration is still in progress, while at end point, titration ends.

(f). in figure above.

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Answer Question 5 and Question 6. The Section II score weighting for these questions is 15 percent each.

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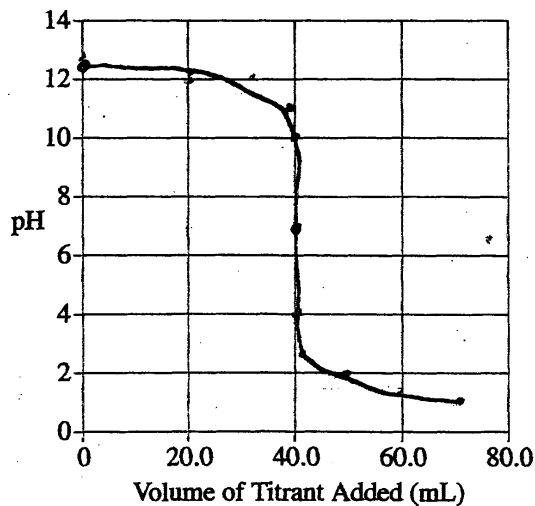
5. A solution of 0.100 M HCl and a solution of 0.100 M NaOH are prepared. A 40.0 mL sample of one of the solutions is added to a beaker and then titrated with the other solution. A pH electrode is used to obtain the data that are plotted in the titration curve shown above.

- (a) Identify the solution that was initially added to the beaker. Explain your reasoning.
- (b) On the titration curve above, circle the point that corresponds to the equivalence point.
- (c) At the equivalence point, how many moles of titrant have been added?
- (d) The same titration is to be performed again, this time using an indicator. Use the information in the table below to select the best indicator for the titration. Explain your choice.

Indicator	pH Range of Color Change
Methyl violet	0 – 1.6
Methyl red	4 – 6
Alizarin yellow	10 – 12

- (e) What is the difference between the equivalence point of a titration and the end point of a titration?
- (f) On the grid provided on the next page, sketch the titration curve that would result if the solutions in the beaker and buret were reversed (i.e., if 40.0 mL of the solution used in the buret in the previous titration were titrated with the solution that was in the beaker).

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a. HCl was added first because the titration curve begins acidic and HCl is an acid

b.

c.  $40 \text{ mL} \times .100 \text{ M} \rightarrow .04 \text{ moles of titrant}$

d. Alizarin yellow - Methyl violet's range is too low, methyl red would ~~disrupt~~ not be effective as there is a large cluster line on 4-6, Alizarin yellow is perfect because it captures the curve from 10 to 12.

e. Equivalence point is when the ~~best~~ solution is at equilibrium, in this case a pH of 7. The end point is after all the titrant has been added.

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**AP<sup>®</sup> CHEMISTRY**  
**2010 SCORING COMMENTARY (Form B)**

**Question 5**

**Sample: 5A**

**Score: 10**

This response earned all 10 points: 1 point for part (a), 1 point for part (b), 1 point for part (c), 2 points for part (d), 2 points for part (e), and 3 points for part (f).

**Sample: 5B**

**Score: 7**

This response earned 7 of the possible 10 points. The point was not earned in part (c) because the student gives an incorrect number of moles of titrant. The points were not earned in part (e) because neither definition is acceptable.

**Sample: 5C**

**Score: 4**

This response earned 4 of the possible 10 points. In part (a) the point was not earned for indicating that HCl was in the beaker because the explanation is not sufficiently clear (e.g., it does not make an explicit reference to low pH). In part (b) 1 point was earned because the student correctly circles the equivalence point. In part (c) the point was not earned because the student calculates an incorrect number of moles of titrant. In part (d) the points were not earned because the student does not select the correct indicator for the titration. In part (e) the points were not earned because neither definition is acceptable. In part (f) 3 points were earned for sketching a titration curve that contains all three required characteristics.