# Titration or pH Curves

- The concentration of $H_3O^+$ ions or $OH^-$ ions in a solution can be determined experimental using *titration curves* or *pH curves*

- During an acid-base titration, as a weak base sample is titrated with a strong acid titrant (or vice versa) the pH of the sample solution is constantly being measured and recorded.
  - With acid-base titrations, the titrant continues to be added even well past the **end point** (the point in which a color change in the sample can be observed)
  - A graph showing how the pH of the solution changed in relation to the amount of titrant added is then used to calculate the concentration of the of $H_3O^+$ ions or $OH^-$ ions in the original sample. This graph is called a **pH curve** or **titration curve.**

- With acid-base titrations, an indicator is needed to observe the end point
  - Acid/base **indicators** are weak acids. Therefore, they will have a small acid ionization constant ($K_a$) and will establish equilibrium ∴ can do calculations with indicators!
  - The indicator/weak acid is one color and the conjugate base is another color

- EXAMPLE: Consider the indicator phenol red.
  a. Write out the Bronsted-Lowry equation for the phenol red indicator.

yellow

$$\underset{\text{weak acid indicator}}{HPr_{(aq)}} + \underset{\text{base}}{H_2O_{(\ell)}} \rightleftharpoons \underset{\text{red}}{Pr^-_{(aq)}} + H_3O^+_{(aq)}$$

  b. Predict which way the equilibrium will shift when a strong base is added to phenol red indicator. Le Chatelier's → lowers $[H_3O^+]$

#1 - $[H_3O^+]$ ↓

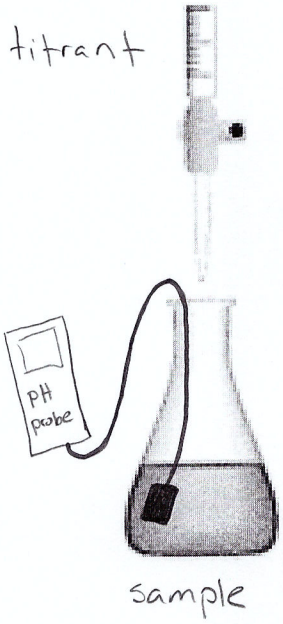
#2 - system will try ∴ $[H_3O^+]$ ↑

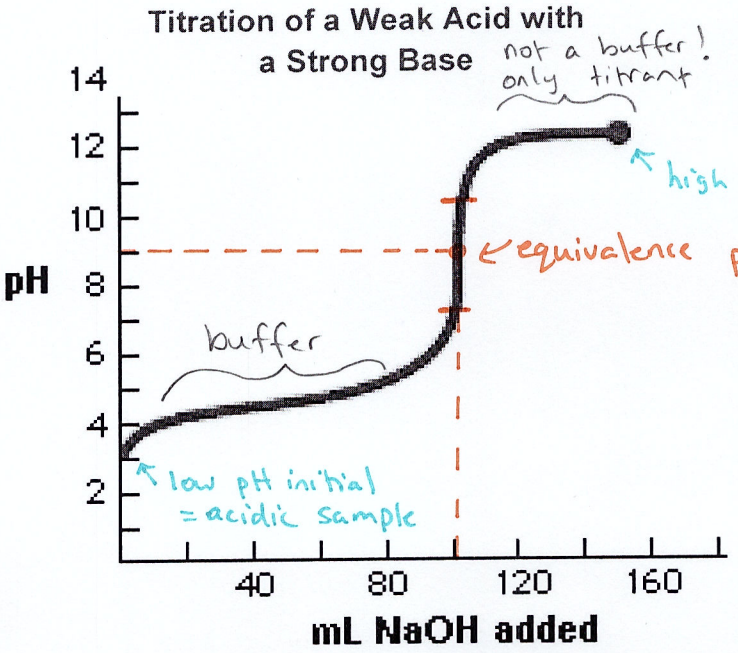
#3 - forward rxn is favoured

  c. What observations would you see?

solution will become a more red colour

- Let's analyze the following pH/titration curve




*The *equivalence point* is when the moles in the sample are equal to the moles of the titrant added.

✳

| Graph Information | Location on Graph | Analysis of Example |
|---|---|---|
| Sample Type (weak) | Indicated by the initial pH reading because no titrant has been added yet | weak acid |
| Titrant Type (strong) | Indicated by final pH reading because the solution is just excess titrant | strong base |
| *Equivalence Point** | The midway point on the vertical section of the graph | occurs at pH of 9 |
| Indicator Selection | The pH range of the indicator needs to include the pH of the equivalence point | phenolphthalein |
| Buffer Region | After a small amount of strong base is added, a buffer will form and the pH of the solution will remain somewhat constant even when more strong base is added | See graph |

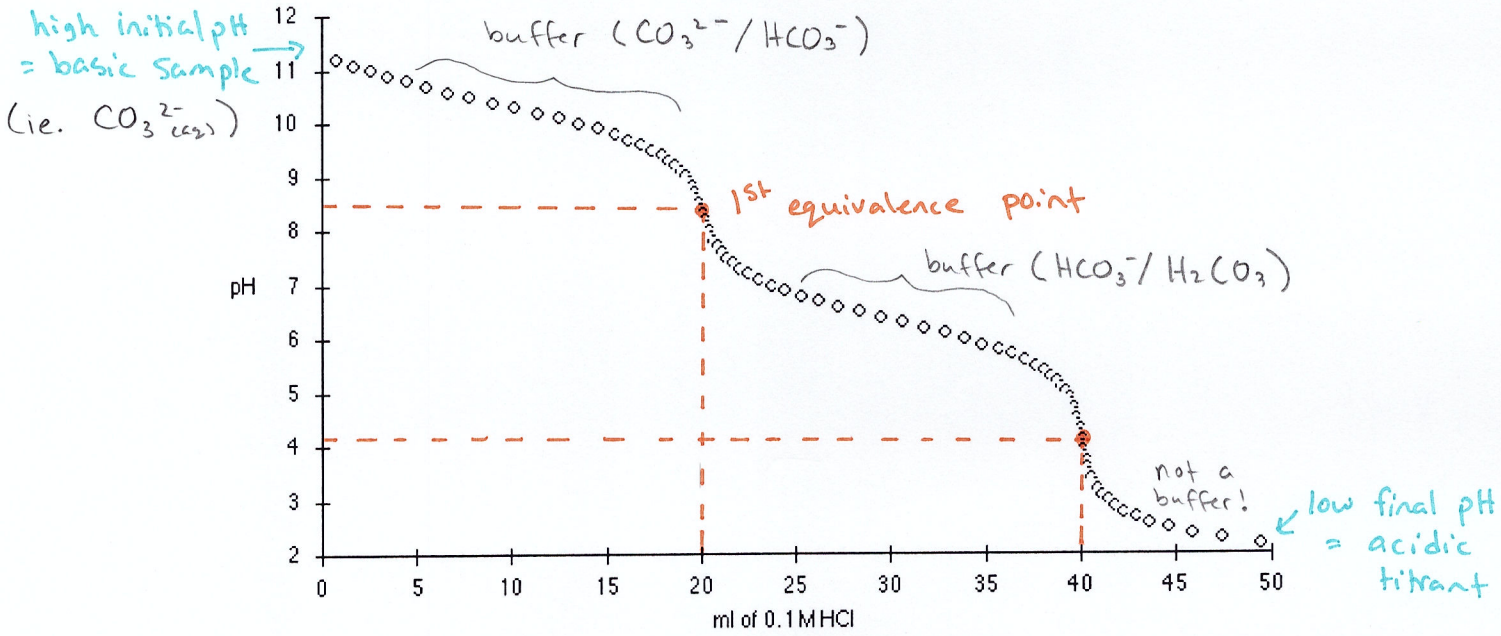
- Polyprotic substances can also be titrated with a strong acid/base and can produce titration/pH curves that can be analyzed in the same fashion as the previous two curve.
    - The only difference is that since a polyprotic substance can lose or gain more than one hydrogen ion ($H^+$), the titration/pH curve will have more than one equivalence points

- EXAMPLE:

from strong acid titrant

1st equivalence point : $CO_{3\,(aq)}^{2-} + H^+_{(aq)} \rightarrow HCO_{3\,(aq)}^-$

2nd equivalence point : $HCO_{3\,(aq)}^- + H^+_{(aq)} \rightarrow H_2CO_{3\,(aq)}$




| Graph Information | Location on Graph | Analysis of Example |
|---|---|---|
| Sample Type | Indicated by the initial pH reading because no titrant has been added yet | weak polyprotic base |
| Titrant Type | Indicated by final pH reading because the solution is just excess titrant | strong acid |
| *Equivalence Point** | The midway point on the vertical section of the graph | 1st at pH of 8.5<br>2nd at pH of 4.1 |
| Indicator Selection | The pH range of the indicator needs to include the pH of the equivalence point | 1st – thymol blue OR phenolphthalein<br>2nd – bromocresol green OR methyl orange |
| Buffer Region | After a small amount of strong base is added, a buffer will form and the pH of the solution will remain somewhat constant even when more strong base is added | see graph |

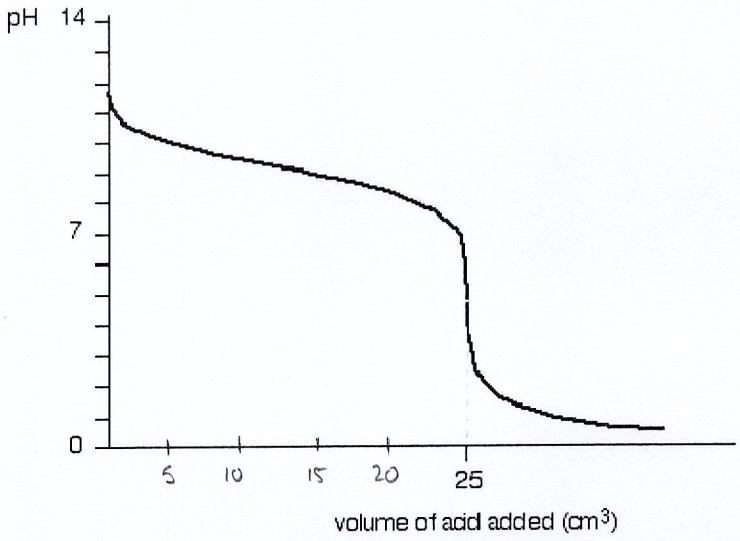
*****Now try Practice Problems*****

# Practice Problems

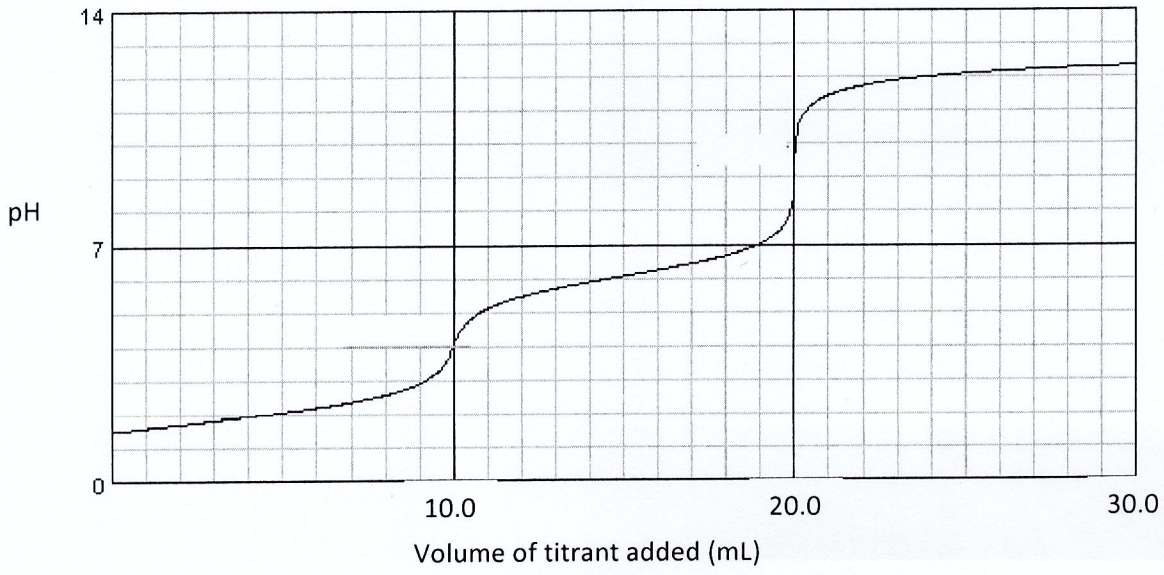
Answer the next questions for all 3 titration curves.

a) What is the type of sample that is being titrated (weak acid or weak base)?
b) What is the type titrant (strong acid or strong base)?
c) What is the pH at the equivalence point/s?
d) What is an appropriate indicator to use for this titration for each equivalent point?
e) Identify the regions on the graph where a buffer exists.

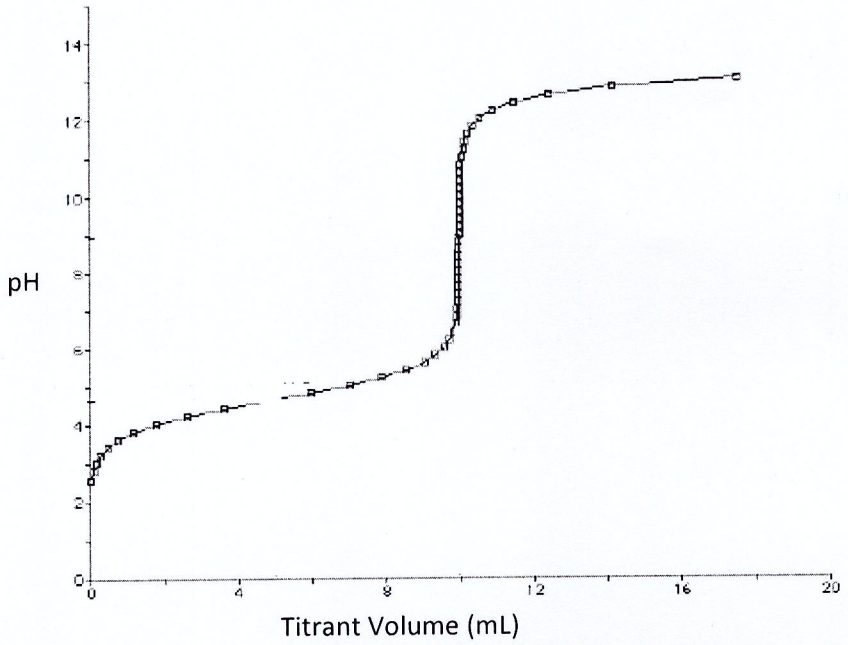
1.




2.



3.




# Answers

1.

a. Weak base
b. Strong acid
c. pH = 5
d. bromocresol green or methyl red
e. Buffer exists when a volume of titrant added is approximately 5-20 $cm^3$

2.

a. Weak polyprotic acid
b. Strong base
c. pH = 4 and pH = 9
d. 1st Equivalence point use methyl red or bromocresol green. 2nd equivalence point use phenolphthalein
e. Buffer exists when a volume of titrant added is 1-8 mL and 12-18 mL

3.

a. Weak acid
b. Strong base
c. pH = 9
d. Phenolphthalein
e. Buffer exists when a volume of titrant added is 2-8 mL