Equivalence point and endpoint

Before we visit equivalence point it pays to refresh ourselves with the strength of acid base conjugate. Click here for more information

Strong acids have weak conjugate bases whilst weak acids have strong conjugate bases. Strong bases have weak conjugate acids and weak bases have strong conjugate acid. Diagrams 1 and 2 below summarise these points in an acid base reaction between ethanoic acid and water nitric acid and hydroxide ions.

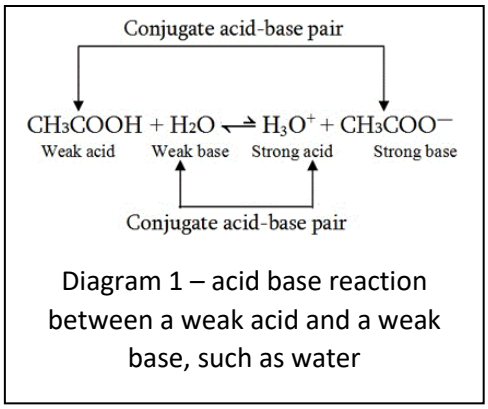

Diagram 1 – acid base reaction between a weak acid and a weak base, such as water

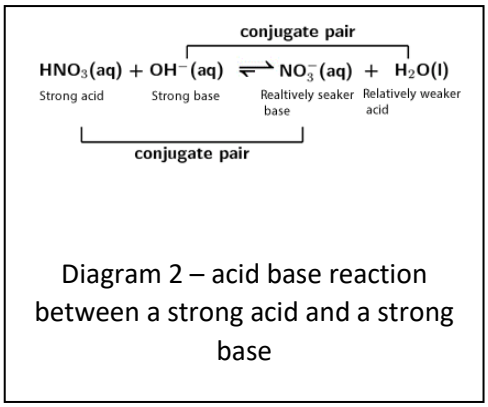

Diagram 2 – acid base reaction between a strong acid and a strong base

The equivalence point in a titration is not always at pH 7 because it depends on the nature of the acid and base involved. The equivalence point is the point at which the amount of titrant added is stoichiometrically equivalent to the amount of substance being titrated. The pH at this point varies depending on the strength of the acid and base:

1. **Strong Acid vs. Strong Base**: In a titration between a strong acid (e.g. HCl) and a strong base (e.g., NaOH), the equivalence point typically occurs at pH 7. This is because the reaction produces water and a neutral salt (e.g. NaCl), and the resulting solution is neutral.
2. **Weak Acid vs. Strong Base**: In a titration between a weak acid (e.g. acetic acid) and a strong base (e.g. NaOH), the equivalence point occurs at a pH greater than 7. This is because the conjugate base of the weak acid (e.g. acetate ion) is formed, which hydrolyzes in water to produce hydroxide ions, making the solution slightly basic.

$$CH_3COO^-(aq) + H_2O(l) \rightarrow OH^-(aq) + CH_3COOH(aq)$$

3. **Strong Acid vs. Weak Base**: In a titration between a strong acid (e.g. HCl) and a weak base (e.g. ammonia), the equivalence point occurs at a pH less than 7. This is because the conjugate acid of the weak base (e.g. ammonium ion) is formed, which hydrolyzes in water to produce hydronium ions, making the solution slightly acidic.

$$HCl(aq) + NH_3(aq) \rightarrow Cl^-(aq) + NH_4^+(aq)$$

4. **Weak Acid vs. Weak Base**: The pH at the equivalence point can vary significantly and is usually not at pH 7. The exact pH depends on the relative strengths of the weak acid and weak base.

Thus, the pH at the equivalence point is determined by the relative strengths of the acid and base involved in the titration.

Using the information in table 1 answer the following questions.

Neutral salts	Strong acid	Weak acid	Strong base	Weak base
$NaNO_3$	HNO_3	H_2CO_3	NaOH	NH_3
NaCl	H_2SO_4	CH_3COOH	$Ca(OH)_2$	Na_2CO_3
KNO_3	HCl	H_3PO_4	LiOH	HCO_3^-

Table 1

1. **Explain why the pH at the equivalence point is not always 7. Provide examples using the following titrations. HNO_3 titrated with NaOH and H_2CO_3 and NaOH.**

2. **In a titration of a weak acid with a strong base, what is the expected pH range at the equivalence point? Explain your reasoning.**

3. **Describe how an indicator is selected for a titration provide an example**

4. **During a titration, the endpoint is observed at pH 8.3. What does this indicate about the strength of the acid and base involved?**

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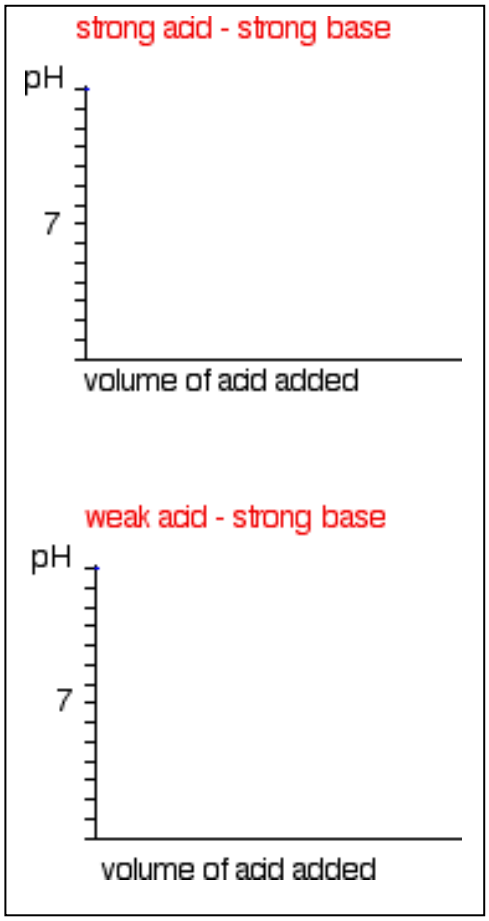
5. **How does the titration curve of a strong acid with a strong base differ from that of a weak acid with a strong base? Discuss the differences in their equivalence points and draw their pH curves in the space provided.**

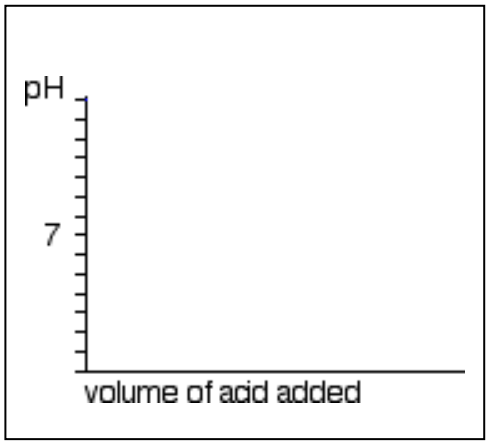


6. **If the pH at the equivalence point of a titration is 5.5, what can you infer about the nature of the acid and base being titrated?**

7. **A titration takes place between carbonic acid (H_2CO_3) and calcium hydroxide (Ca(NaOH).**

   a. **Write a balanced chemical equation for the reaction**

   b. **What indicator should be used? Explain your reasoning by drawing an appropriate pH curve for the titration in the space below.**



Solutions