Acid-base indicators

This resource accompanies the article Ocean acidification in Education in Chemistry which can be viewed at: https://rsc.li/368k27r

Learning objectives

1. To understand that indicators are weak acids in which the colour of the aqueous solution of the acid is distinctly different from that of its conjugate base.

2. To know that the pH range over which a colour change occurs can be estimated by $\text{pH} = -\text{pK}_a \pm 1$.

3. To be able to sketch the pH curves for different acid-base titrations and suggest suitable indicators based on data given.

Introduction

Test learners’ understanding of acid-base equilibria with this series of questions on indicators.

Answers

1. phenolphthalein:

   \[
   \begin{align*}
   \text{weak acid} & \quad \text{conjugate base} \\
   \text{methyl orange:} & \\
   \text{weak acid} & \quad \text{conjugate base}
   \end{align*}
   \]
2.

(a) The alkaline solution reacts with the H⁺ ions and removes them from the equilibrium. As a result, according to le Chatelier’s principle the equilibrium shifts to the right to replace the lost H⁺ ions. The concentration of yellow weak acid is reduced and the concentration of the red conjugate base is increased.

(b) According to le Chatelier’s principle, on the addition of H⁺ ions the equilibrium shifts to the left in favour of the yellow weak acid to remove the extra H⁺ ions added.

(c) We can express this equilibrium as:

\[ \text{HIn(aq)} + \text{H}_2\text{O(l)} ⇌ \text{In}^-(\text{aq}) + \text{H}_3\text{O}^+(\text{aq}) \]

At the theoretical point of a colour change [HIn(aq)] = [In⁻(aq)] meaning that at this point \( K_{\text{In}} = [\text{H}_3\text{O}^+] \) and therefore \( pK_{\text{In}} = \text{pH} \).

If \( K_{\text{In}} \) for this equilibrium is \( 1.26 \times 10^{-8} \text{ mol dm}^{-3} \) then the theoretical pH at the point of colour change can be determined as:

\[ \text{pH} = -\log (1.26 \times 10^{-8}) = 7.9 \]

The colour change is assumed to be distinguishable when [HIn] and [In⁻] differ by a factor of 10 meaning that the pH range over which the colour change occurs can be estimated as:

7.9 ± 1 = 6.9–8.9
3. 

(a) Addition of ammonia solution to hydrochloric acid:

Suitable indicator = methyl orange or 4-nitrophenol

(b) Addition of ethanoic acid to sodium hydroxide.

Suitable indicator = phenolphthalein