RSC | Advancing the Chemical Sciences

Reckitt Benckiser

Determining the pK_a's of glycine

Student worksheet

Health and safety note

Wear eye protection. 0.10 mol dm^{-3} sodium hydroxide solution and 0.1 mol dm^{-3} nitric acid are irritant.

Principle

Glycine (figure 1) is an amino acid. It contains both a carboxylic acid group and an amine group.

In aqueous solution glycine can exist in three forms (figure 2). The relative amounts of each depend on the pH of the solution.

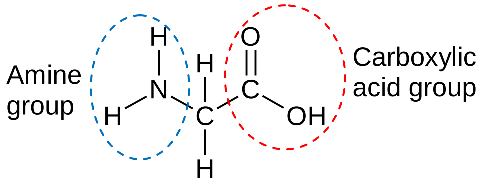

Figure 1 Glycine.

In acidic solution the species present is a cation, while in alkaline solution it is an anion.

At pH 6 the species present is a zwitterion. One group in it has a positive charge and another group has a negative charge. These balance out and overall the species has no charge.

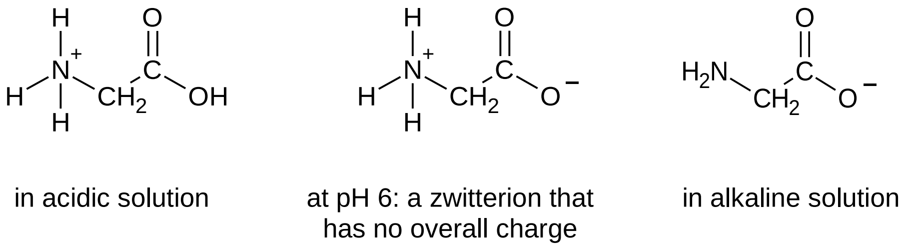

Figure 2 Glycine may exist in the three different forms in aqueous solution.

In solution, two equilibrium reactions are happening. Each has an acid dissociation constant:

$$\mathrm{H_3N^+CH_2COOH(aq)} \rightleftarrows \mathrm{H_3N^+CH_2COO^-(aq)} + \mathrm{H^+(aq)}$$

$$K_{a1} = \frac{[\mathrm{H_3N^+CH_2COO^-}][\mathrm{H^+}]}{[\mathrm{H_3N^+CH_2COOH}]}$$

$$\mathrm{H_3N^+CH_2COO^-(aq)} \rightleftarrows \mathrm{H_2NCH_2COO^-(aq)} + \mathrm{H^+(aq)}$$

$$K_{a2} = \frac{[\mathrm{H_2NCH_2COO^-}][\mathrm{H^+}]}{[\mathrm{H_3N^+CH_2COO^-}]}$$

pH titrations may be used to estimate the values of K_{a1} and K_{a2}.

Equipment and materials

- Balance
- 50 cm^3 burette
- 250 cm^3 beaker
- Glass stirring rod
- 100 cm^3 measuring cylinder
- 10 cm^3 pipette and pipette filler
- Spatula
- pH probe and pH meter
- Glycine
- 0.10 mol dm^{-3} sodium hydroxide solution − Irritant
- 0.05 mol dm^{-3} potassium nitrate(V) solution
- 0.1 mol dm^{-3} nitric acid − Irritant

Method

1. Fill a burette with 0.10 mol dm^{-3} sodium hydroxide solution.
2. Weigh 0.10 g of glycine into a 250 cm^3 beaker. Add 100 cm^3 of 0.05 mol dm^{-3} potassium nitrate solution. Stir with a glass rod to dissolve the solid.
3. Place a pH probe in the solution and connect it to a pH meter. Note: The pH probe should have been calibrated using suitable buffer solutions. Measure the pH of the solution.
4. Pipette 10 cm^3 of 0.10 mol dm^{-3} nitric acid into the beaker and measure the pH of the solution.
5. Add 1 cm^3 quantities of sodium hydroxide solution from the burette to the beaker, stirring well between additions and recording the pH. Continue until a total of 40 cm^3 has been added.

   Note: Plot a graph of pH against volume of sodium hydroxide added as you go along.

Processing data

The graph of pH against volume of 0.10 mol dm^3 sodium hydroxide solution added should look similar to the one in figure 3.

- End point 1 corresponds to the complete reaction:

$$\mathrm{H_3N^+CH_2COOH(aq)\ +\ OH^- \rightarrow H_3N^+CH_2COO^-(aq)\ +\ H_2O(l)}$$

- End point 2 corresponds to the complete reaction:

$$\mathrm{H_3N^+CH_2COO^-(aq)\ +\ OH^- \rightarrow H_2NCH_2COO^-(aq)\ +\ H_2O(l)}$$

1. Calculate the end points 1 and 2 from the number of moles of glycine used (relative molecular mass = 75) and, therefore, the volume of 0.10 mol dm^{-3} sodium hydroxide solution needed to react with it in a 1:1 mole ratio (end point 1) and a 2:1 mole ratio (end point 2).
2. Draw these lines on the pH titration graph (see figure 3).
   - Point **A** on the graph corresponds to the pH at which glycine is present as a zwitterions. Estimate this value.
   - Point **B** is when $[H_3N^+CH_2COO^-] = [H^+]$. Determine a value for pK_{a1}.
   - Point **C** is when $[H_2NCH_2COO^-] = [H^+]$. Determine a value for pK_{a2}.
3. Finally, calculate K_{a1} and K_{a2}.