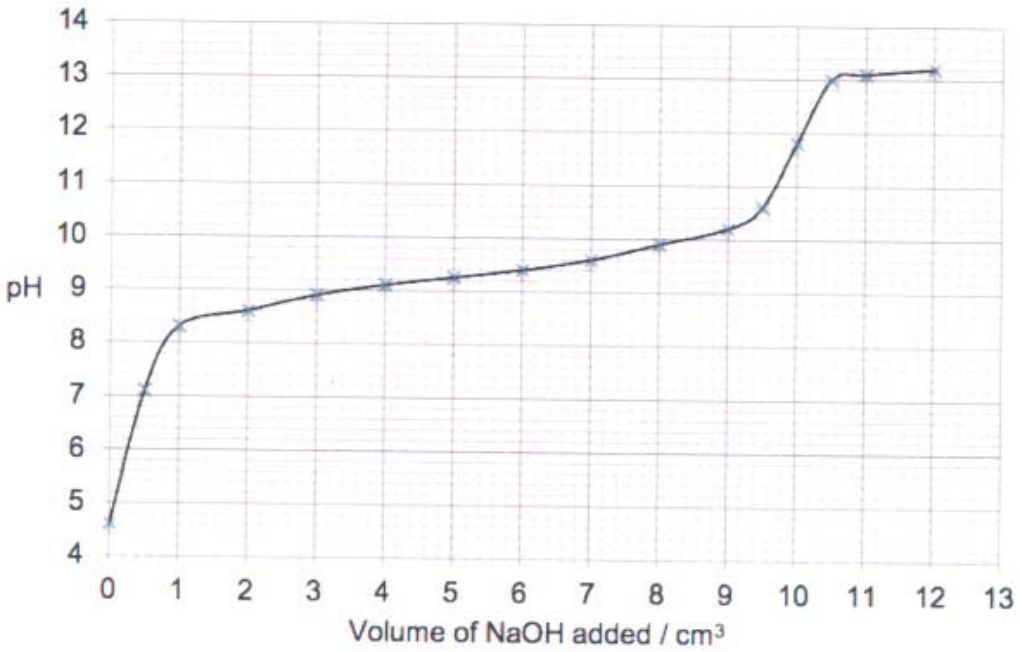
[AQA A2 Specimen Paper 1 2015]

Figure 1 shows a graph of data obtained by a student when a solution of sodium hydroxide was added to a solution of ammonium chloride. The pH of the reaction mixture was measured initially and after each addition of the sodium hydroxide solution.

Figure 1



The pH at the end point of this reaction is 11.8

a) Use this pH value and Kw, 10^{-14} mol^2dm^{-6}, to calculate the concentration of hydroxide ions at the end point of the reaction.

① Calculate $[H^+]$ ions:

$\Rightarrow 10^{-11.8} = 1.58 \times 10^{-12}$

$[H^+] = 10^{-pH}$

② Use Kw to find $[OH^-]$ ions:

$$[OH^-] = \frac{Kw}{[H^+]}$$

$$= \frac{10^{-14}}{1.58 \times 10^{-12}}$$

$$= 6.33 \times 10^{-3} \text{ moldm}^{-3}$$

$Kw = [H^+][OH^-]$

The expression for the acid dissociation constant for aqueous ammonium ions is:

$$Ka = \frac{[NH_3][H^+]}{[NH_4^+]}$$

The initial concentration of the ammonium chloride solution was 2.00 moldm^{-3}.

b) Use the pH of this solution, before any sodium hydroxide had been added, to calculate a value for Ka.

① Rewrite the Ka expression:

$$Ka = \frac{[H^+]^2}{[NH_4^+]}$$

← At this point, $[NH_3]$ is equal to $[H^+]$.

② Use the graph to find the initial pH:

y intercept = pH 4·6

③ Use pH to find $[H^+]$ ions:

$[H^+] = 10^{-pH}$

$[H^+] = 10^{-4.6}$

$= 2.51 \times 10^{-5}$

④ Sub these values into the Ka expression:

$$Ka = \frac{(2.51 \times 10^{-5})^2}{2.00}$$

$$= 3.15 \times 10^{-10}$$

⑤ Find the units of Ka:

$$\frac{(moldm^{-3})^2}{moldm^{-3}} \Rightarrow moldm^{-3}$$

A solution contains equal concentrations of ammonia and ammonium ions.

c) Use your value of Ka from part (b) to calculate the pH of this solution.

① Rewrite the Ka expression:

$$K_a = \frac{[H^+][NH_3]}{[NH_4^+]}$$

In this reaction, $[NH_3] = [NH_4^+]$ so they cancel.

$\Rightarrow K_a = [H^+]$

② Find the value of $[H^+]$ ions:

$\Rightarrow K_a = [H^+] = 3.15 \times 10^{-10}$ moldm^{-3}

③ Use $[H^+]$ ions to find pH:

$pH = -\log_{10}[H^+]$

$pH = -\log_{10}(3.15 \times 10^{-10})$

$\Rightarrow pH = 9.50$

pH values are always given to 2d.p.