Basic buffer solutions

We are talking here about a mixture of a weak base and one of its salts - for example, a solution containing the weak base, ammonia, NH_3 and the salt, ammonium chloride, NH_4Cl.

Example: Calculate the pH of a solution containing 0.100 mol L^{-1} NH_3 and 0.0500 mol L^{-1} NH_4Cl? $K_a(NH_4^+)$ = 5.62 x 10^{-10}

You may have learnt the (Henderson-Hasselbalch) buffer equation in class:

$$\mathrm{pH} = \mathrm{pK_a} + \log\frac{[\mathrm{base}]}{[\mathrm{acid}]}$$

But this equation is **NOT** on the supplied resource sheet so you either must rely on remembering it OR use the equation that is supplied….

That looks a bit unlikely as it is a K_a expression….. and weak acid and all…. 😊 Don't panic!

$$\mathrm{K_a} = \frac{[\mathrm{H_3O^+}][\mathrm{A^-}]}{[\mathrm{HA}]}$$

The way of doing this basic buffer calculation is to *re-think it* from the point of view of the ammonium ion rather than of the ammonia solution.

Once you have taken this different view-point, you can easily use the equation supplied by NZQA.

$$\mathrm{K_a} = \frac{[\mathrm{H_3O^+}][\mathrm{A^-}]}{[\mathrm{HA}]}$$

The buffer will contain lots of unreacted ammonia molecules and lots of ammonium ions from the salt, NH_4Cl. These ammonium ions are weakly acidic.

$$\mathrm{NH_4^+ + H_2O \rightleftharpoons NH_3 + H_3O^+}$$

Write the K_a expression for the ammonium ion.

$$\mathrm{K_a} = \frac{[\mathrm{NH_3}][\mathrm{H_3O^+}]}{[\mathrm{NH_4^+}]}$$

We assume $[NH_3]$ is the same concentration as the original ammonia solution and that $[NH_4^+]$ is the same as the concentration of the ammonium chloride.

Put the values into the K_a expression and calculate $[H_3O^+]$ and then the pH.

$$5 \cdot 62 \times 10^{-10} = \frac{0 \cdot 100 \times [\mathrm{H_3O^+}]}{0.0500}$$

$[H_3O^+]$ = (5.62 x 10^{-10} x 0.0500) ÷ 0.100 = 2.81 x 10^{-10}

pH = - log $[H_3O^+]$ = - log 2.81 x 10^{-10} = **9.55**

If you are looking for a way to calculate buffer composition, you can reverse the equation. Using known pH to calculate H_3O^+ and the known K_a, you can calculate the ratio of concentrations of the acid and conjugate base, necessary to prepare the buffer.

Alternatively….. using the buffer equation that you have carefully memorised….

$$\mathrm{pH} = \mathrm{pK_a} + \log\frac{[\mathrm{base}]}{[\mathrm{acid}]}$$

pH = -log 5.62 x 10^{-10} + log (0.100 / 0.0500)

pH = 9.25 + log (0.100 / 0.0500)

pH = 9.25 + log (2)

pH = 9.55

Again, if you are looking for a way to calculate buffer composition, you can reverse the equation. Using known ***pH*** *and known* ***pK_a*** *you can calculate the ratio of concentrations of the acid and conjugate base, necessary to prepare the buffer.*