# Chemguide – answers

BUFFER SOLUTIONS

1. a) A buffer solution is one which resists changes in pH when small quantities of an acid or an alkali are added to it.

    b) You could choose any weak acid and one of its sodium (or potassium) salts. For safety, always choose one you are certain about - in this case, ethanoic acid and sodium ethanoate.

    c) You could choose any weak base and one of its salts. Again, for safety, choose one you are certain about - in this case, ammonia and ammonium chloride.
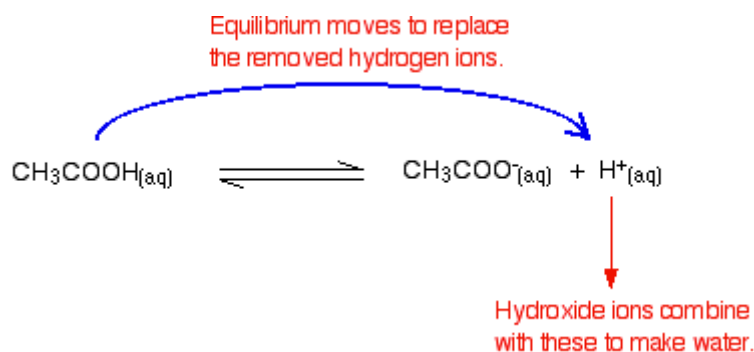
2. a) Most of the hydrogen ions are removed by reacting with ethanoate ions to make ethanoic acid.

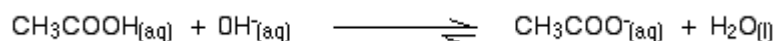 $$CH_3COO^-_{(aq)} + H^+_{(aq)} \rightleftharpoons CH_3COOH_{(aq)}$$
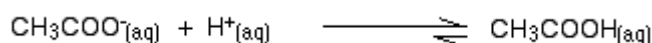
    b) The hydroxide ions can be removed by reacting with either hydrogen ions or ethanoic acid molecules.

    With hydrogen ions:

    The hydroxide ions combine with the hydrogen ions from the equilibrium. The hydrogen ions are replaced by the equilibrium moving to the right. This continues until most of the hydroxide ions are removed.
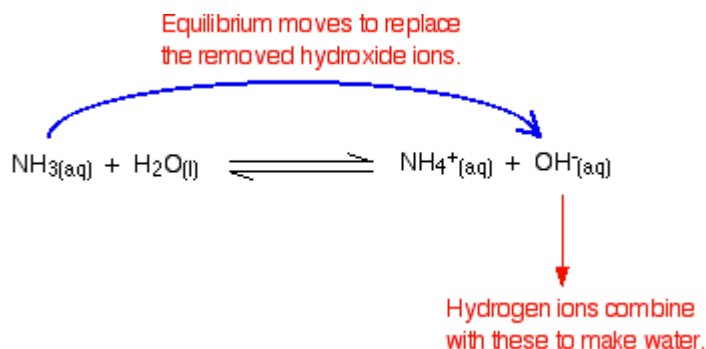
    Equilibrium moves to replace the removed hydrogen ions.

    $$CH_3COOH_{(aq)} \rightleftharpoons CH_3COO^-_{(aq)} + H^+_{(aq)}$$

    Hydroxide ions combine with these to make water.

    With ethanoic acid molecules:

    $$CH_3COOH_{(aq)} + OH^-_{(aq)} \rightleftharpoons CH_3COO^-_{(aq)} + H_2O_{(l)}$$

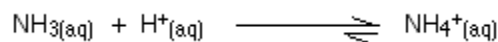3. a) The hydrogen ions can react with hydroxide ions or ammonia molecules

    With hydroxide ions:

    The explanation here is similar to the one above.
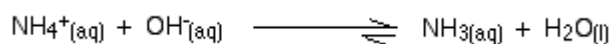
    Equilibrium moves to replace the removed hydroxide ions.

    $$NH_{3(aq)} + H_2O_{(l)} \rightleftharpoons NH_4^+_{(aq)} + OH^-_{(aq)}$$

    Hydrogen ions combine with these to make water.

    With ammonia molecules:

    $$NH_{3(aq)} + H^+_{(aq)} \rightleftharpoons NH_4^+_{(aq)}$$

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b) The hydroxide ions react with ammonium ions:

$$NH_4^+{}_{(aq)} + OH^-{}_{(aq)} \rightleftharpoons NH_3{}_{(aq)} + H_2O_{(l)}$$

4. a)

$$K_a = \frac{[CH_3COO^-][H^+]}{[CH_3COOH]}$$

In buffer solution calculations we assume that all the ethanoate ions come from the sodium ethanoate, and the acid is almost un-ionised.

Therefore:

$$1.74 \times 10^{-5} = \frac{0.100 \times [H^+]}{0.100}$$

$$[H^+] = 1.74 \times 10^{-5}$$

$$pH = 4.76$$

b)

$$K_a = \frac{[CH_3COO^-][H^+]}{[CH_3COOH]}$$

$$1.74 \times 10^{-5} = \frac{0.250 \times [H^+]}{0.500}$$

$$[H^+] = 3.48 \times 10^{-5}$$

$$pH = 4.46$$

c) First you need to find the hydrogen ion concentration in a solution of pH 5.00. You should find that comes out to 1.00×10^{-5} mol dm^{-3}.

$$K_a = \frac{[CH_3COO^-][H^+]}{[CH_3COOH]}$$

$$1.74 \times 10^{-5} = \frac{[CH_3COO^-] \times 1.00 \times 10^{-5}}{[CH_3COOH]}$$

$$\frac{[CH_3COO^-]}{[CH_3COOH]} = \frac{1.74 \times 10^{-5}}{1.00 \times 10^{-5}}$$

$$= \frac{1.74}{1}$$

(Note that the concentrations here are the concentrations in the final buffer solution, and not the concentrations in the individual solutions you are mixing.)

So the sodium ethanoate to ethanoic acid in the buffer solution should be in the molar ratio of 1.74:1. If you had equimolar solutions (the same molar concentration of both), then you could mix, say, 174 cm^3 of sodium ethanoate solution with 100 cm^3 of ethanoic acid solution.

5. a) $NH_4^+{}_{(aq)} \rightleftharpoons NH_3{}_{(aq)} + H^+{}_{(aq)}$
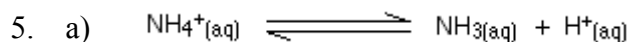
$$K_a = \frac{[NH_3][H^+]}{[NH_4^+]}$$

$$5.62 \times 10^{-10} = \frac{0.100 \times [H^+]}{0.100}$$

$$[H^+] = 5.62 \times 10^{-10}$$

$$pH = 9.25$$

b)

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

$$5.62 \times 10^{-10} = \frac{0.100 \times [H^+]}{0.200}$$

$$[H^+] = 1.124 \times 10^{-9}$$

$$pH = 8.95$$

c) A pH of 10.00 corresponds to a hydrogen ion concentration of 1.00×10^{-10} mol dm^{-3}.

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

$$5.62 \times 10^{-10} = \frac{[NH_3] \times 1.00 \times 10^{-10}}{[NH_4^+]}$$

$$\frac{[NH_3]}{[NH_4^+]} = \frac{5.62 \times 10^{-10}}{1.00 \times 10^{-10}}$$

$$= \frac{5.62}{1}$$

If you had equimolar solutions of ammonia and ammonium chloride, you would mix them in the molar ratio of 5.62:1 - for example, 56.2 cm^3 of ammonia solution to 10 cm^3 of ammonium chloride solution.