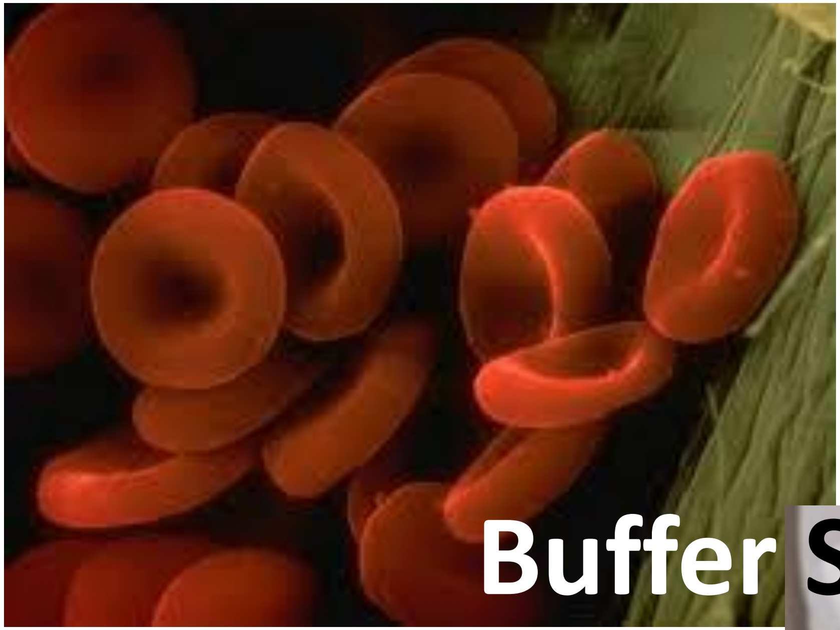


Buffer Solutions

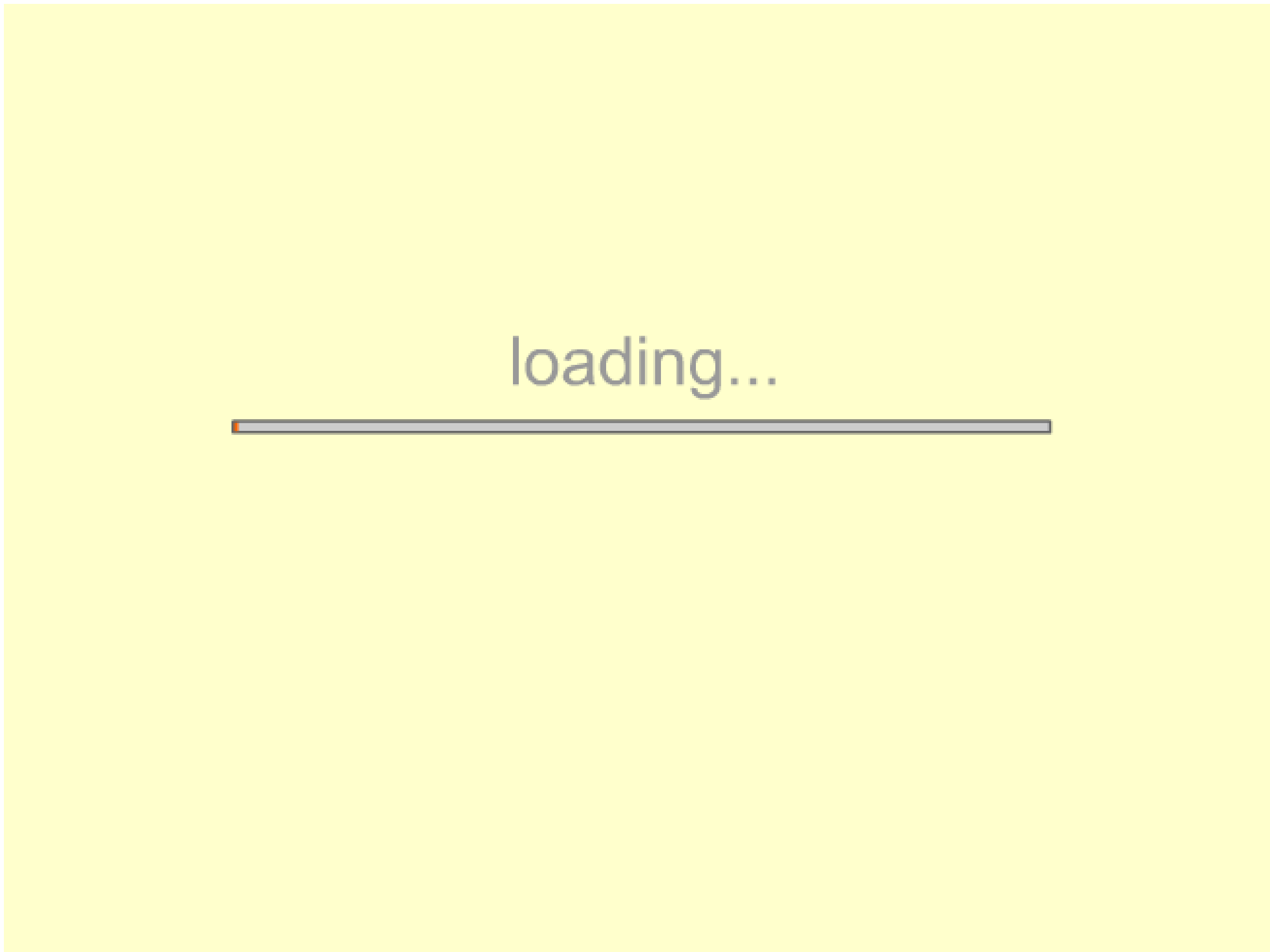
What is a buffer solution?

A buffer solution is a solution that minimises the change in pH when either a strong acid or a strong base is added.

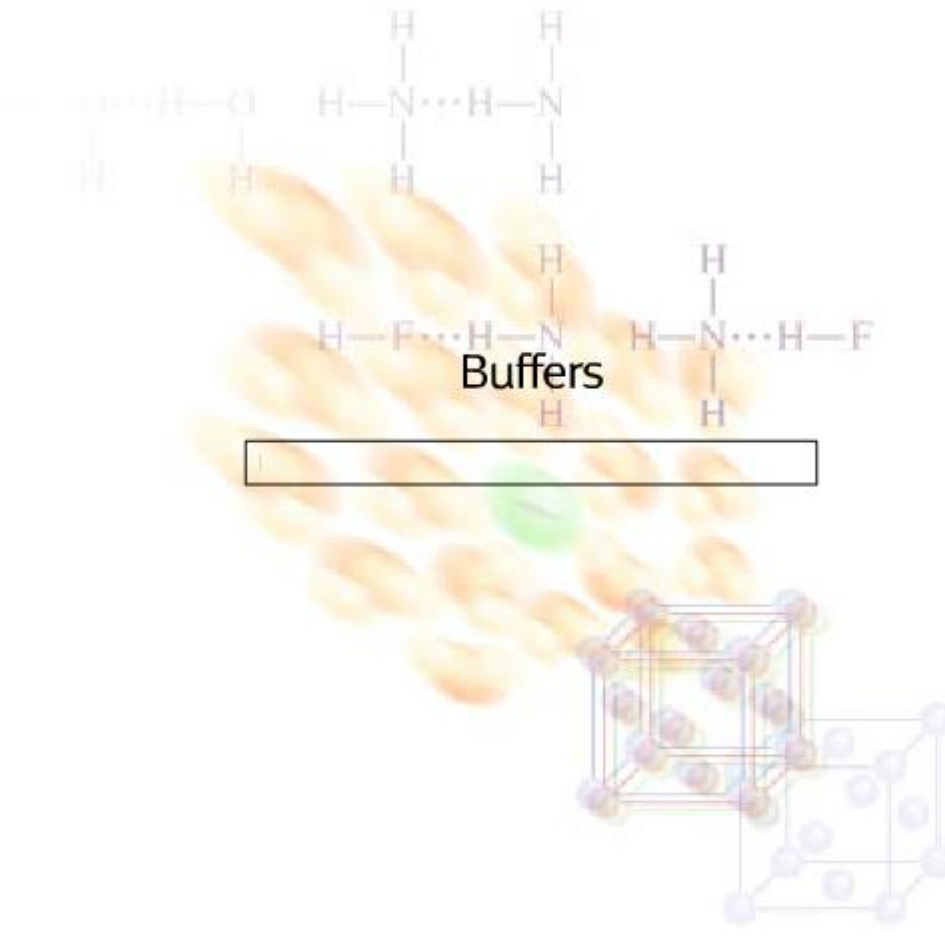
Buffer solutions are made from either:

- A weak acid and its conjugate base OR
- A weak base and its conjugate acid

What is a buffer solution?

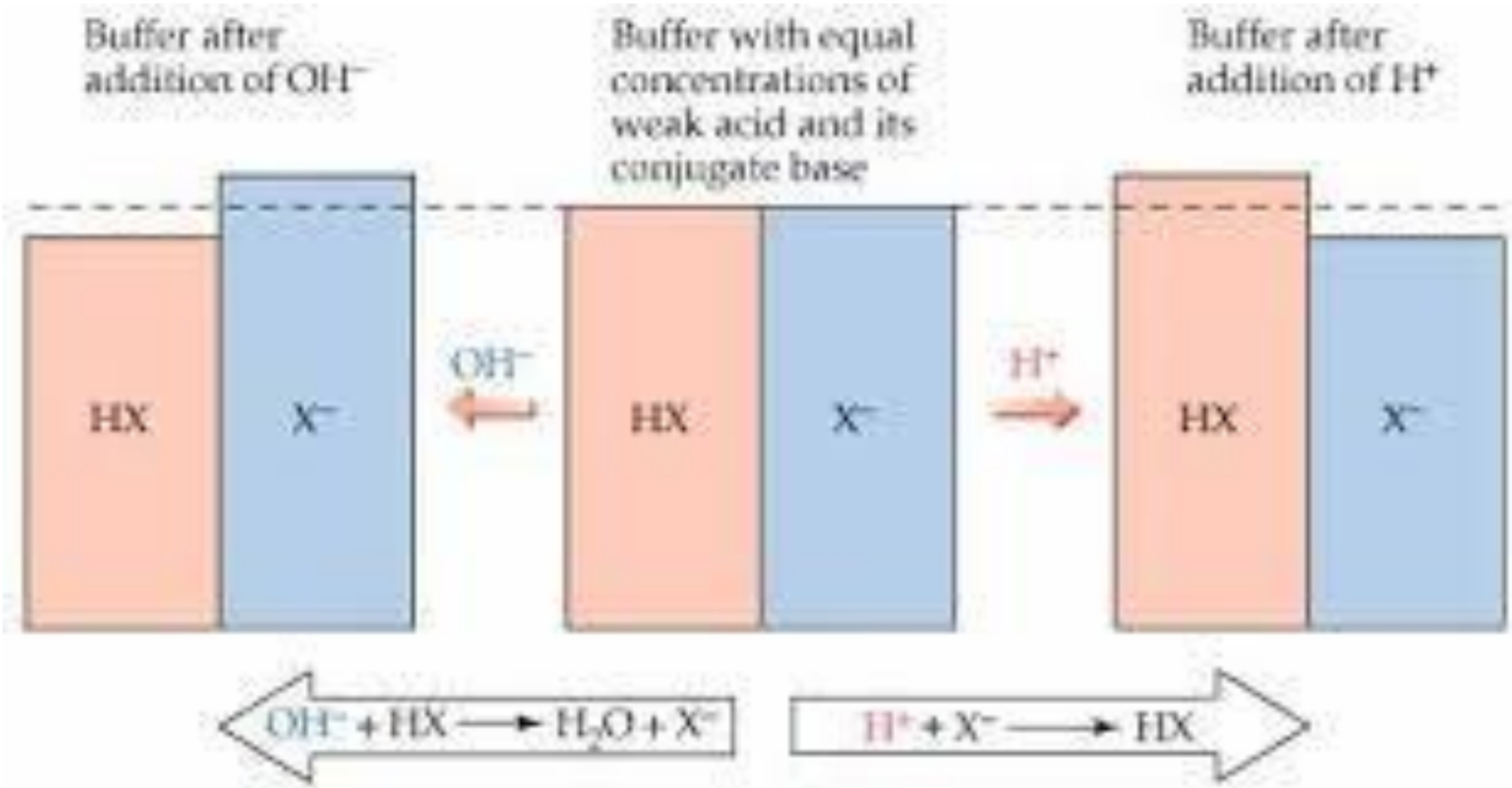


How does a buffer solution work?



How does a buffer solution work?

A buffer is made from a weak acid and its conjugate base (or vice versa)



Some HX from buffer reacts with added OH^- to make X^- and H_2O, OH^- is used up

Some X^- from buffer reacts with added H^+ to make HX, H^+ is used up

2013 Exam

(c) (i) The following two solutions from part (a) are mixed to form a buffer solution:

20.0 mL of 1 mol L^{-1} CH_3NH_3Cl and 30.0 mL of 1 mol L^{-1} CH_3NH_2

(ii) Explain the effect on the solution formed in (i) when a small amount of acid is added.

Need to explain reaction that is occurring (ie using specific acid or base from question)

AND/OR

Correct equation for reaction occurring

(ii)	• Correct equation. OR Shows understanding that $CH_3NH_2(aq)$ reacts with added acid.	• Correct equation. AND Shows understanding that $CH_3NH_2(aq)$ reacts with added acid.	Correct equation and correct discussion of reaction.

pH of buffer solutions

If we are given the concentrations of the acid and base in the buffer and the K_a we can rearrange the expression for K_a to find H_3O^+.

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

Once H_3O^+ is found then use $pH = -\log_{10}[H_3O^+]$ as usual

Remember that if you are given information when the acid and base are added together to form a solution the concentration needs to be recalculated.
[new] = [given] x volume/total volume

pH of buffer solutions

Example: A buffer solution is made by dissolving 5.0×10^{-3} mol of methanoic acid (HCOOH), K_a (HCOOH) = 1.8×10^{-4}, and 7.0×10^{-3} mol of sodium methanoate (NaHCOO) to form 1.00 L of aqueous solution.

a) Calculate the concentration of acid and base present

b) Calculate the pH of this buffer solution

a) c(HCCOH) = 5.0×10^{-3} mol.L^{-1}, c(NaHCCO) = 7.0×10^{-3} mol.L^{-1}

b) $$[H_3O^+] = \frac{K_a\,[HCOOH]}{[HCOO^-]} = \frac{1.8 \times 10^{-4} \times 5.0 \times 10^{-3}}{7.0 \times 10^{-3}} = 1.286 \times 10^{-4}$$

$$pH = -\log_{10} 1.286 \times 10^{-4} = 3.89$$

2013 Exam

(c) (i) The following two solutions from part (a) are mixed to form a buffer solution:

20.0 mL of 1 mol L^{-1} CH_3NH_3Cl and 30.0 mL of 1 mol L^{-1} CH_3NH_2

Calculate the pH of the resultant buffer solution.

$pK_a\ (CH_3NH_3^+) = 10.64$

(c)(i)

$$K_a = \frac{[CH_3NH_2][H_3O^+]}{[CH_3NH_3^+]}$$

$$[H_3O^+] = \frac{K_a[CH_3NH_3^+]}{[CH_3NH_2]}$$

$$[CH_3NH_2] = \frac{30\times10^{-3}\times1}{50\times10^{-3}} = 0.600 \text{ mol L}^{-1}$$

$$[CH_3NH_3^+] = \frac{20\times10^{-3}\times1}{50\times10^{-3}} = 0.400 \text{ mol L}^{-1}$$

$$[H_3O^+] = 1.52705\times10^{-11} \text{ mol L}^{-1}$$

$$pH = 10.8$$

Candidates should not be penalised for using ratio of volume and getting correct answer.

For A:

- Correct K_a expression.

OR

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

OR

Correct concentrations or number of moles.

For M:

- Correct process with minor error.

For E:

- Correct answer.

Workbook pg 239 – 240 Q1,2,3,4

Do now:

Complete the 2010 exam question

A buffer solution is made by adding solid sodium methanoate, HCOONa, to an aqueous solution of methanoic acid, HCOOH.

$pK_a(\text{HCOOH}) = 3.74$

(a) Describe the function of a buffer solution.

FOUR (a)	A solution which will maintain its pH / resist change of pH.

(b) Explain why the solution made with methanoic acid, HCOOH, and sodium methanoate, HCOONa, has the ability to act as a buffer.

Your answer should include relevant equations.

(b)

- $HCOO^-$ / HCOOH is a conjugate weak base / acid pair.
- Any acid that is added to the buffer system will react with $HCOO^-$ thus maintaining the pH / removing H_3O^+.
- Any base that is added to the buffer system will react with the HCOOH, thus maintaining the pH / removing OH^-.

$HCOOH + OH^- \rightarrow HCOO^- + H_2O$

$HCOO^- + H_3O^+ \rightarrow HCOOH + H_2O$

Ratio of acid and base in buffer solutions

If we are asked for the ratio of acid:base in a buffer solution of a given pH with a given K_a we can rearrange the expression for K_a to find $\frac{\text{acid}}{\text{base}}$.

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

Once the ratio is found you can apply whatever is asked for in the question

If you are given pK_a and pH you can rearrange the K_a expression differently

$$K_a = \frac{[H_3O^+]\,[A^-]}{[HA]} \qquad pK_a = pH - \log_{10}\frac{[A^-]}{[HA]} \qquad pH - pK_a = \log_{10}\frac{[A^-]}{[HA]}$$

Ratio of acid and base in buffer solutions

Example: HCN is a weak acid, $K_a = 6.0 \times 10^{-10.}$ In a mixture of NaCN and HCN with a pH of 9.0 which species is present in greater concentration?

$$K_a = \frac{[H_3O^+]\,[CN^-]}{[HCN]} \qquad \frac{K_a}{[H_3O^+]} = \frac{[CN^-]}{[HCN]} \qquad \frac{6.0 \times 10^{-4}}{1 \times 10^{-9}} = \frac{[CN^-]}{[HCN]}$$

$$0.6 = \frac{[CN^-]}{[HCN]}$$

HCN is present in greater concentration as CN^-/HCN is less than 1

Tips for solving buffer problems

Write the K_a expression for the system you are give (ie NOT A^- and HA)

Work out what information the question gives you and write it down

Work out if you need to recalculate concentrations because two solutions have been added together

Work out what you are trying to find and rearrange K_a expression to do this

2012 Exam

A mixture of aqueous solutions of NH_3 and ammonium chloride, NH_4Cl, can act as a buffer solution.

(b) Calculate the mass of NH_4Cl required, when added to 250 mL of a 0.150 mol L^{-1} NH_3 solution, to give a buffer solution with a pH of 8.60.

Assume there is no change in volume.

M (NH_4Cl) = 53.5 g mol^{-1} pK_a (NH_4^+) = 9.24

(b)

$NH_4^+ + H_2O \rightleftharpoons NH_3 + H_3O^+$

$[NH_4^+] = [NH_3]\,[H_3O^+] / K_a$

$[NH_4^+] = 0.150 \times 10^{-8.60} / 10^{-9.24}$

$[NH_4^+] = 0.655$ mol L^{-1}

n (NH_4^+) = 0.655 mol L^{-1} × 0.250 L = 0.164 mol

m (NH_4Cl) = 0.164 mol × 53.5 g mol^{-1} = 8.76 g

Note: allow use of pH = pK_a + log $[NH_3]$ / $[NH_4^+]$

For A:

- K_a expression or pH = pK_a + log$[NH_3]$ / $[NH_4^+]$ rearranged for $[NH_4^+]$.

For M:

- Either:
  Correct method but error in calculation / units missing / unit incorrect
  OR
  $[NH_4^+]$ calculated.

For E:

Correct answer with units (3 s.f.).

Workbook pg 240 – 243
Q5,6,7,8,9

2014 Exam

(c) An aqueous solution containing a mixture of HF and sodium fluoride, NaF, can act as a buffer solution.

Calculate the mass of NaF that must be added to 150 mL of 0.0500 mol L^{-1} HF to give a buffer solution with a pH of 4.02.

Assume there is no change in volume.

$M(\text{NaF}) = 42.0 \text{ g mol}^{-1}$ $\quad$ $\text{p}K_a(\text{HF}) = 3.17$

(c)

$$K_a = \frac{[F^-][H_3O^+]}{[HF]}$$

$$10^{-3.17} = \frac{[F^-] \times 10^{-4.02}}{0.0500}$$

$[F^-] = 0.354 \text{ mol L}^{-1}$

$n(\text{NaF}) = 0.354 \text{ mol L}^{-1} \times 0.150 \text{ L} = 0.0531 \text{ mol}$

$m(\text{NaF}) = 0.0531 \text{ mol} \times 42.0 \text{ g mol}^{-1} = 2.23 \text{ g}$

For A:

- Writes correct K_a or pH expression.
  OR
  Calculates K_a or $[H_3O^+]$.
- Correct 'n' and 'm' step with incorrect $[F^-]$.

For M:

- Correct method but error in calculation / units missing / unit incorrect.

For E:

- Correct answer with units.

2010 Exam

A buffer solution is made by adding solid sodium methanoate, HCOONa, to an aqueous solution of methanoic acid, HCOOH.

$pK_a(HCOOH) = 3.74$

(c) Calculate the mass of sodium methanoate that must be added to 100 mL of 0.861 mol L^{-1} methanoic acid to give a solution with a pH of 3.24.

Assume there is no volume change on adding the salt.

$pK_a(HCOOH) = 3.74 \quad K_a = 1.82 \times 10^{-4} \quad M(HCOONa) = 68.0\ g\ mol^{-1}$

(c)

$pK_a(HCOOH) = 3.74\ K_a = 1.82 \times 10^{-4}$

$$K_a = \frac{[HCOO^-][H_3O^+]}{[HCOOH]}$$

$$[HCOO^-] = \frac{K_a \times [HCOOH]}{[H_3O^+]}$$

$$[H_3O^+] = 10^{-3.24} = 5.75 \times 10^{-4}\ mol\ L^{-1}$$

$$= \frac{1.82 \times 10^{-4} \times 0.861}{5.75 \times 10^{-4}} = 0.2725\ mol\ L^{-1}$$

$m = nM = 0.2725 \times 68.0 = 18.53\ g\ L^{-1}$

Which is 1.85 g in 100 mL