Exercise walk-through

Acids and bases ▪ 25.1

eXercise

You must be able to

- identify conjugate acid–base pairs and use pH, K_a, pK_a, K_w
- calculate pH for strong acids, strong alkalis, weak acids and buffers
- define a buffer, explain its action, and use K_{sp}

Method — Conjugate pairs and key relationships

$$\mathrm{pH} = -\log[\mathrm{H}^+];\ K_a = \frac{[\mathrm{H}^+][\mathrm{A}^-]}{[\mathrm{HA}]};\ K_w = [\mathrm{H}^+][\mathrm{OH}^-] = 1.0 \times 10^{-14}.$$

- **strong acid:** $[\mathrm{H}^+]$ = the acid concentration.
- **strong alkali:** $[\mathrm{H}^+] = K_w/[\mathrm{OH}^-]$.
- **weak acid:** $[\mathrm{H}^+] = \sqrt{K_a \times [\mathrm{HA}]}$.

Method — Conjugate pairs and key relationships

conjugate pair: differ by one H^+

$$\underset{\text{acid}}{CH_3COOH} \rightleftharpoons \underset{\text{conjugate base}}{CH_3COO^-} + H^+$$

$$\underset{\text{base}}{NH_3} + H^+ \rightleftharpoons \underset{\text{conjugate acid}}{NH_4^+}$$

Ethanoic acid losing H to its conjugate base; ammonia gaining H to its conjugate acid

Method — Buffers

Added H reacts with A ; added OH reacts with HA. In blood, HCO_3^- buffers the pH. $K_{\mathbf{sp}}$ = the product of the ion concentrations of a saturated solution of a sparingly soluble salt.

Method — Buffers

buffer store:
HA and $\mathbf{A}^-$

add H^+ : $A^- + H^+ \rightarrow HA$

add OH^- : $HA + OH^- \rightarrow A^- + H_2O$

either way, the pH barely changes

A buffer resisting pH change: added acid removed by A , added alkali removed by HA

Practice 2.1 ▪ 1 mark

Write the conjugate base of HNO .

Solution 2.1

Method: Conjugate pairs and key relationships

Worked steps

NO_3^- **B1**.

Practice 2.2 ▪ 1 mark

Calculate the pH of 0.010 mol dm^{3} hydrochloric acid (a strong acid).

Solution 2.2

Method: Conjugate pairs and key relationships

Worked steps

pH $= -\log(0.010) = 2.0$ **B1**.

Exam-style 3.1 ▪ 1 mark

A buffer solution can be made from:

A a strong acid and a strong base

B a weak acid and its sodium salt

C water only

D two strong acids

Solution 3.1

Method: Buffers

A a strong acid and a strong base

B a weak acid and its sodium salt ✓

C water only

D two strong acids

Worked steps

B. A weak acid and its salt make a buffer.

Exam-style 3.2 ▪ 1 mark

The pH of 0.10 mol dm ^{3} NaOH (a strong base) is ($K_w = 1.0 \times 10^{-14}$):

A 1

B 7

C 13

D 14

Solution 3.2

Method: Conjugate pairs and key relationships

A 1

B 7

C 13 ✓

D 14

Worked steps

C. $[\mathrm{H}^+] = 10^{-14}/0.10 = 10^{-13}$, so pH $= 13$.

Exam-style 3.3 ▪ 3 marks

A weak acid HA has $K_a = 1.8 \times 10^{-5}$ mol dm^{-3}.
(a) Calculate the pH of a 0.10 mol dm ^{3} solution of HA.
(b) Explain why this pH is higher than that of 0.10 mol dm ^{3} HCl.

Solution 3.3

Worked steps

(a) $[\mathrm{H}^+] = \sqrt{K_a[\mathrm{HA}]} = \sqrt{1.8 \times 10^{-5} \times 0.10}$ **M1** $= \sqrt{1.8 \times 10^{-6}} = 1.34 \times 10^{-3}$ **M1**; $\mathrm{pH} = -\log(1.34 \times 10^{-3}) = 2.87$ **A1**.

(b) HA is only partly dissociated, so $[\mathrm{H}^+]$ is lower than for fully-dissociated HCl **M1**, giving a higher pH **A1**.

Exam-style 3.4 ▪ 2 marks

A buffer contains 0.20 mol dm ^{3} ethanoic acid and 0.20 mol dm ^{3} sodium ethanoate ($K_a = 1.8 \times 10^{-5}$).

(a) Calculate its pH.

(b) Explain, with an equation, how the buffer resists a small addition of acid.

Solution 3.4

Worked steps

(a) $[\mathrm{H}^+] = K_a \dfrac{[\mathrm{HA}]}{[\mathrm{A}^-]} = 1.8 \times 10^{-5} \times \dfrac{0.20}{0.20} = 1.8 \times 10^{-5}$ **M1**; pH $= 4.74$ **A1**.

(b) added H reacts with the ethanoate ion: $\mathrm{CH_3COO^-} + \mathrm{H^+} \rightarrow \mathrm{CH_3COOH}$ **M1**, removing most of the added H so the pH barely changes **A1**.