

Exercise walk-through

25.1

Acids and bases

A-Level Chemistry

Conjugate acids and bases

An acid loses H^+ to give its **conjugate base** ; a base gains H^+ to give its **conjugate acid** .

A **conjugate pair** differs by just one H^+ – e.g. CH_3COOH and CH_3COO^- .

conjugate pair: differ by one H^+



pH and the constants

$$\text{pH} = -\log[\text{H}^+]$$

$$K_a = \frac{[\text{H}^+][\text{A}^-]}{[\text{HA}]}$$

$$K_w = [\text{H}^+][\text{OH}^-]$$

A larger K_a

(smaller $\text{p}K_a$) is a stronger acid; $K_w = 1.0 \times 10^{-14}$ at 298 K.

Calculating pH

strong acid – $[\text{H}^+] = \text{conc.}$; $\text{HCl } 0.050 \Rightarrow \text{pH} = 1.30$

strong base – $[\text{H}^+] = K_w/[\text{OH}^-]$; $\text{NaOH } 0.10 \Rightarrow \text{pH} = 13.0$

weak acid – $[\text{H}^+] = \sqrt{K_a[\text{HA}]}$; ethanoic $0.10 \Rightarrow \text{pH} = 2.87$

The four pH calculations

strong acid

fully ionised, so $[\text{H}^+]$ is the acid's concentration; $\text{pH} = -\log[\text{H}^+]$

weak acid

only partly ionised, so use $[\text{H}^+] = \sqrt{K_a \times [\text{HA}]}$, where K_a is the **acid dissociation constant**

strong alkali

find $[\text{OH}^-]$, then use the **ionic product of water**
 $K_w = [\text{H}^+][\text{OH}^-] = 10^{-14}$

a buffer

$$[\text{H}^+] = K_a \frac{[\text{HA}]}{[\text{A}^-]}$$

a conjugate pair

an acid and the base left after it donates its proton – the two components of every buffer

A buffer works because the mixture holds **a store of both partners**: the acid mops up added alkali, and the conjugate base mops up added acid.

Exercises 2.1·2.2

2.1 Write the conjugate base of HNO_3 .

[1]

2.2 Calculate the pH of $0.010 \text{ mol dm}^{-3}$ hydrochloric acid (a strong acid).

[1]

Exercises 2.1·2.2

2.1 Write the conjugate base of HNO_3 .

[1]

2.1

- NO_3^-

2.2 Calculate the pH of $0.010 \text{ mol dm}^{-3}$ hydrochloric acid (a strong acid).

[1]

2.2

- $\text{pH} = -\log(0.010) = 2.0$

Exercises 3.1·3.2

3.1 A buffer solution can be made from:

[1]

☐

A a strong acid and a strong base

B a weak acid and its sodium salt

C water only

D two strong acids

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

[1]

☐

A 1

B 7

C 13

D 14

Exercises 3.1·3.2

3.1 A buffer solution can be made from:

[1]

☐

A a strong acid and a strong base

B a weak acid and its sodium salt

C water only

D two strong acids

3.1 B

- A weak acid and its salt make a buffer

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

[1]

☐

A 1

B 7

C 13

D 14

3.2 C

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

Exercise 3.3 (a)

3.3 A weak acid HA has $K_a = 1.8 \times 10^{-5} \text{ mol dm}^{-3}$.

(a) Calculate the pH of a 0.10 mol dm^{-3} solution of HA.

[3]

Exercise 3.3 (a)

3.3 A weak acid HA has $K_a = 1.8 \times 10^{-5} \text{ mol dm}^{-3}$.

(a) Calculate the pH of a 0.10 mol dm^{-3} solution of HA. [3]

(a)

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

Exercise 3.3 (b)

3.3 A weak acid HA has $K_a = 1.8 \times 10^{-5} \text{ mol dm}^{-3}$.

(b) Explain why this pH is higher than that of $0.10 \text{ mol dm}^{-3} \text{ HCl}$.

[2]

Exercise 3.3 (b)

3.3 A weak acid HA has $K_a = 1.8 \times 10^{-5} \text{ mol dm}^{-3}$.

(b) Explain why this pH is higher than that of $0.10 \text{ mol dm}^{-3} \text{ HCl}$. [2]

(b)

- HA is only partly dissociated, so $[\text{H}^+]$ is lower than for fully-dissociated HCl, giving a higher pH

Exercise 3.4 (a)

3.4 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.

[2]

Exercise 3.4 (a)

3.4 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.

[2]

(a)

- $$[\text{H}^+] = K_a \frac{[\text{HA}]}{[\text{A}^-]} = 1.8 \times 10^{-5} \times \frac{0.20}{0.20} = 1.8 \times 10^{-5}; \text{pH} = 4.74$$

Exercise 3.4 (b)

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

(b) Explain, with an equation, how the buffer resists a small addition of acid. [2]

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

(b) Explain, with an equation, how the buffer resists a small addition of acid. [2]

(b)

- added H^+ reacts with the ethanoate ion: $\text{CH}_3\text{COO}^- + \text{H}^+ \rightarrow \text{CH}_3\text{COOH}$, removing most of the added H^+ so the pH barely changes