

## Chapter test with answers

# Chapter 2 Acid–base equilibrium system

**Time permitted: 50 minutes**

	Section	Number of questions	Marks available
<b>A</b>	Multiple choice	15	15
<b>B</b>	Short answer	5	15
	<b>Total</b>	<b>20</b>	<b>30</b>

**Scale:**

<b>A+</b>	29–30	<b>A</b>	26–28	<b>B</b>	23–25	<b>C</b>	19–22	<b>D</b>	15–18	<b>E</b>	9–14	<b>UG</b>	0–8
-----------	-------	----------	-------	----------	-------	----------	-------	----------	-------	----------	------	-----------	-----

### Section A Multiple choice (15 marks)

Section A consists of 15 questions, each worth one mark. Each question has only one correct answer. Circle the correct answer. Attempt all questions. Marks will not be deducted for incorrect answers. You are advised to spend no more than 15 minutes on this section.

- A safe and accurate way of distinguishing between a strong and weak base is by:

  - A** taste.
  - B** *electrical conductivity.*
  - C** litmus paper.
  - D** addition of acid.
- An Arrhenius acid:

  - A** accepts protons.
  - B** donates protons.
  - C** *releases hydrogen ions in solution.*
  - D** releases hydroxide ions in solution.

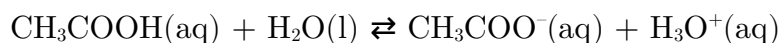
- 3 Which is the correct conjugate pairing, in order, of the following?  
 $\text{H}_2\text{O}$ ,  $\text{OH}^-$ ,  $\text{NH}_3$ ,  $\text{CO}_3^{2-}$
- A  $\text{OH}^-$ ,  $\text{H}_2\text{O}$ ,  $\text{NH}_4^+$ ,  $\text{CO}_2$   
 B  $\text{H}_3\text{O}^+$ ,  $\text{H}^+$ ,  $\text{NH}_2$ ,  $\text{HCO}_3^-$   
 C  $\text{H}_3\text{O}^+$ ,  $\text{H}_2\text{O}$ ,  $\text{NH}_4^+$ ,  $\text{HCO}_3^-$   
 D  $\text{H}_3\text{O}^+$ ,  $\text{H}_2\text{O}$ ,  $\text{NH}_4^+$ ,  $\text{H}_2\text{CO}_3$
- 4 In which of the following equilibriums does water act as a base?
- i  $\text{NH}_4^+ + \text{H}_2\text{O} \rightleftharpoons \text{NH}_3 + \text{H}_3\text{O}^+$ ,  
 ii  $\text{HCO}_3^- + \text{H}_2\text{O} \rightleftharpoons \text{H}_2\text{CO}_3 + \text{OH}^-$   
 iii  $\text{HSO}_4^- + \text{H}_3\text{O}^+ \rightleftharpoons \text{H}_2\text{SO}_4 + \text{H}_2\text{O}$   
 iv  $\text{H}_2\text{O} + \text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{O}^+ + \text{OH}^-$
- A i, ii and iii  
 B iii and iv  
 C i, iii and iv  
 D i and iv
- 5 What is the pH of a  $6 \text{ mol L}^{-1}$  solution of HCl?
- A 12.2  
 B 0.3  
 C 0.8  
 D 1.3
- 6 What is the pH of a  $2 \text{ mol L}^{-1}$  solution of  $\text{Ba}(\text{OH})_2$ ?
- A 0.3  
 B 0.6  
 C 14.6  
 D 13.7
- 7 What is the concentration (in M) of  $\text{H}^+$  ions in a solution with pH = 5.3?
- A  $5.0 \times 10^{-6}$   
 B 5.3  
 C  $1.0 \times 10^{-7}$   
 D  $3.3 \times 10^3$
- 8 What volume of  $0.1 \text{ mol L}^{-1}$  HCl will neutralise 100 mL,  $0.5 \text{ mol L}^{-1}$  NaOH?
- A 50 mL  
 B 100 mL  
 C 200 mL  
 D 500 mL
- 9 Which one of the following pairs represents a conjugate acid-base pair?
- A  $\text{CH}_3\text{COOH}$  and  $\text{OH}^-$

**B** NaOH and  $\text{H}_3\text{O}^+$

**C** HCl and  $\text{OH}^-$

**D**  $\text{H}_2\text{O}$  and  $\text{OH}^-$

**10** What is the  $K_a$  expression for the following weak acid?



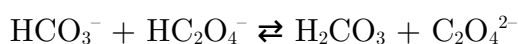
**A** 
$$\frac{[\text{CH}_3\text{COOH}][\text{H}_2\text{O}]}{[\text{CH}_3\text{COO}^-][\text{H}_3\text{O}^+]}$$

**B** 
$$\frac{[\text{CH}_3\text{COO}^-][\text{H}_3\text{O}^+]}{[\text{CH}_3\text{COOH}]}$$

**C** 
$$\frac{[\text{CH}_3\text{COO}^-][\text{H}_3\text{O}^+]}{[\text{CH}_3\text{COOH}][\text{H}_2\text{O}]}$$

**D** 
$$\frac{[\text{CH}_3\text{COOH}]}{[\text{CH}_3\text{COO}^-][\text{H}_3\text{O}^+]}$$

**11** Identify the correct order of Brønsted–Lowry acids and bases for the following reaction.



**A** Base, acid, acid, base

**B** Acid, base, base, acid

**C** Acid, base, acid, base

**D** Base, acid, base, acid

**12** The  $K_w$  of water at  $40^\circ\text{C}$  is  $2.92 \times 10^{-14}$ . What is the pH of water at this temperature?

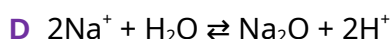
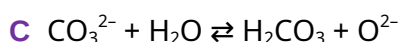
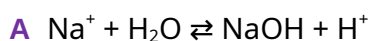
**A** 6.5

**B** 7.0

**C** 7.2

**D** 2.9

**13** what is the ionic equation for the hydrolysis of the salt  $\text{Na}_2\text{CO}_3$ ?



**14** When writing the  $K_a$  expression for a weak acid,  $\text{H}_2\text{O}(\text{l})$  is not included in the expression. Why is this so?

**A**  $[\text{H}_2\text{O}]$  is considered to be constant.

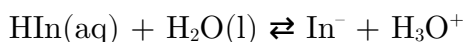
**B**  $[\text{H}_2\text{O}]$  does not exist for weak acid equilibria.

**C**  $[\text{H}_2\text{O}]$  is too large.

**D**  $[\text{H}_2\text{O}]$  is too small.



- 15** For the following equilibrium involving an indicator, what will the addition of acid on a blue solution cause?



(Reactants are colourless; products are blue.)

- A** Equilibrium shifts to the right; solution becomes more blue.
- B** Equilibrium shifts to the right; solution becomes less blue.
- C** Equilibrium shifts to the left; solution becomes more blue.
- D** *Equilibrium shifts to the left; solution becomes less blue.*

### Section B Short answer (15 marks)

Section B consists of five questions. Write your answers in the spaces provided. You are advised to spend 20 minutes on this section.

- 1 a** Calculate the pH of a 0.2 mol L<sup>-1</sup> HCl solution.

*Answer:*

$$\begin{aligned}\text{pH} &= -\log [\text{H}^+] \\ &= -\log 0.2 \\ &= 0.70\end{aligned}$$

(1 mark)

- b** Calculate the pH of a 0.2 mol L<sup>-1</sup> NaOH solution.

*Answer:*  $\text{pH} = -\log[\text{H}^+]$  and  $\text{pH} + \text{pOH} = 14$

$$\text{pOH} = -\log[\text{OH}^-]$$

$$= 14 - \text{pOH}$$

$$\text{pOH} = -\log 0.2$$

$$\text{pH} = 14 - 0.7$$

$$\text{pH} = 13.3$$

(1 mark)

- c** Calculate the pH of a 0.2 mol L<sup>-1</sup> Ba(OH)<sub>2</sub> solution.

*Answer:* Ba(OH)<sub>2</sub> releases 2 mol of OH<sup>-</sup> ions per mol.

$$\text{pH} = 14 - \text{pOH}$$

$$\text{pOH} = -\log 0.4$$

$$\text{pH} = 14 - 0.4$$

$$\text{pH} = 13.6$$

(1 mark)

(= 3 marks total)

- 2 a** Ethanoic acid and the ethanoate ion are an acid base conjugate pair. Using an equation explain the meaning of conjugate pair.

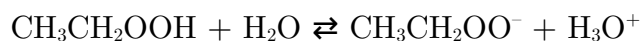
*Answer:*



If two species differ by just one proton they are classed as a conjugate acid–base pair. (1 mark)

- b** Write an ionic equation showing ethanoic acid reacting with water; explain how water acts as a base.

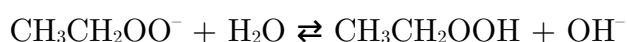
*Answer:*



Water acts as a base as it is accepting a proton from the ethanoic acid; the hydronium ion is water's conjugate acid in the acid base pair. (1 mark)

- c** Write an ionic equation showing the ethanoate ion with water and explain how water acts as an acid.

*Answer:*



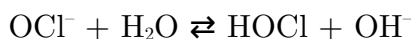
Water donates a proton to the ethanoate ion, thereby acting as a Brønsted–Lowry acid. (1 mark)

(= 3 marks total)

- 3** Swimming pools commonly are cleansed of bacteria by solution containing HOCl,  $\text{p}K_a(\text{HOCl}) = 7.54$

- a** Is the conjugate base of HOCl weak or strong? Show this with a reaction of the base with water.

*Answer:*  $\text{OCl}^-$  is a weak base, the conjugate of the weak acid HOCl



(1 mark)

- b** At what pH are the concentrations of the acid base conjugate pair equal?

*Answer:*  $\text{pH} = 7.54$  when the concentration of the acid and its conjugate base are the same  $\text{pH} = \text{p}K_a$

It turns out that the  $\text{p}K_a$  of an acid is the pH at which it is exactly half-dissociated. This can be seen by re-arranging the expression for  $K_a$ :

$$[\text{H}_3\text{O}^+] = K_a \times \frac{[\text{AH}]}{[\text{A}^-]}$$

$$\text{pH} = \text{p}K_a - \log \left( \frac{[\text{AH}]}{[\text{A}^-]} \right)$$

Clearly when  $[\text{AH}] = [\text{A}^-]$ ,  $\text{pH} = \text{p}K_a$  (1 mark)

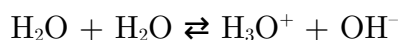
- c** What happens as pH is decreased? Answer using equations.

*Answer:*  $\text{OH}^-$  ions also decrease, so equilibrium moves to increase them again, to the right. So  $[\text{HOCl}]$  will increase. (1 mark)

(= 3 marks total)

- 4 a The pH of water at STP is 7.0; explain with the use of an equation the autoionisation of water.

Answer:



$$[\text{H}_3\text{O}^+] = 1 \times 10^{-7} \text{ mol L}^{-1}$$

$$\text{pH} = -\log[\text{H}_3\text{O}^+], \text{ which is } 7.0. \quad (1 \text{ mark})$$

- b At 60°, the pH of pure water is 6.5. Is the water slightly acidic? Explain.

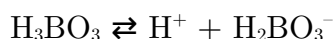
Answer: No the water is not acidic although the pH has dropped. As the temperature increases the amount of dissociation of water also increases. So there are more hydronium ions *and* the same amount of hydroxide ions, so it is still neutral. (1 mark)

(= 2 marks total)

- 5 A solution of 0.2 mol L<sup>-1</sup> boric acid, H<sub>3</sub>BO<sub>3</sub>, has a pH of 5.45.

- a Write an equation for the dissociation of boric acid and write the K<sub>a</sub> expression.

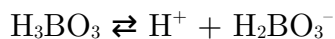
Answer:



(1 mark)

- b Calculate the pK<sub>a</sub> of boric acid.

Answer:



$$K_a = \frac{[\text{H}^+][\text{H}_2\text{BO}_3^-]}{[\text{H}_3\text{BO}_3]} = \frac{[\text{H}^+]^2}{[\text{H}_3\text{BO}_3]}$$

$$\text{and if } [\text{H}^+] = x \text{ then } [\text{H}_3\text{BO}_3] = 0.2 - x$$

$$[\text{H}^+] = 10^{-\text{pH}} = 10^{-5.45} = 3.55 \times 10^{-6}$$

$$K_a = \frac{(3.55 \times 10^{-6})^2}{(0.2 - 3.55 \times 10^{-6})}$$

$$\text{So } = 6.29 \times 10^{-11}$$

$$\text{and } \text{pK}_a = -\log K_a = 10.20$$

(3 marks)

(= 4 marks total)