

IBDP HL Chemistry: Acids and Bases

Worksheet

Total Marks: 70

Time: 120 minutes

SECTION A: Multiple Choice Questions (20 × 1 mark = 20 marks)

Instructions: Select the best answer for each question.

1. What is the pH of a 0.1 M solution of a strong acid (HCl)?

- (A) 0
- (B) 1
- (C) 2
- (D) 3

2. For a weak acid with $K_a = 1.8 \times 10^{-5}$, which expression correctly represents the pH?

- (A) $pH = -\log(1.8 \times 10^{-5})$
- (B) $pH = -\log \sqrt{K_a \times c}$
- (C) $pH = 14 - pK_a$
- (D) All of the above

3. At the equivalence point of a weak acid-strong base titration, the pH is:

- (A) Exactly 7
- (B) Greater than 7 (basic)
- (C) Less than 7 (acidic)
- (D) Cannot be determined without more information

4. The half-equivalence point in a titration is the point where:

- (A) The volume of titrant added equals half the equivalence point volume
- (B) The pH equals the pK_a of the weak acid
- (C) The concentration of weak acid equals the concentration of its conjugate base
- (D) All of the above

5. Which indicator would be most suitable for a titration of a weak acid (CH_3COOH) against a strong base (NaOH)?

- (A) Methyl orange (pH range 3.1–4.4)
- (B) Methyl red (pH range 4.4–6.2)
- (C) Phenolphthalein (pH range 8.2–10.0)
- (D) Methylene blue (pH range 3.0–3.6)

6. A buffer solution consists of:

- (A) A strong acid and its salt
- (B) A weak acid and its conjugate base salt
- (C) A strong base and its salt
- (D) Any acid and any base

7. For an acid buffer containing acetic acid (CH_3COOH) and sodium acetate (CH_3COONa), according to the Henderson-Hasselbalch equation:

- (A) $pH = pK_a + \log \frac{[\text{acid}]}{[\text{salt}]}$
- (B) $pH = pK_a + \log \frac{[\text{salt}]}{[\text{acid}]}$
- (C) $pH = pK_a - \log \frac{[\text{acid}]}{[\text{salt}]}$
- (D) $pH = K_a + \log \frac{[\text{salt}]}{[\text{acid}]}$

8. When a small amount of strong acid is added to an acid buffer, the buffer works by:

- (A) The conjugate base reacting with the added H^+ ions
- (B) The weak acid reacting with the added H^+ ions
- (C) The weak acid dissociating further
- (D) Increasing the pH significantly

9. In the titration of a weak base against a strong acid, the equivalence point occurs:

- (A) At pH = 7
- (B) At pH < 7 (acidic)
- (C) At pH > 7 (basic)
- (D) At a variable pH depending on the concentrations

10. The initial pH of a 0.1 M weak acid solution with $K_a = 1 \times 10^{-5}$ is approximately:

- (A) 1
- (B) 2
- (C) 3
- (D) 5

11. What happens to the pH of a buffer when you add a small amount of strong base?

- (A) pH increases significantly
- (B) pH increases slightly
- (C) pH remains the same
- (D) pH decreases

12. For a titration curve of a weak acid against a strong base, which statement is true?

- (A) The initial pH is 0
- (B) The pH rises slowly at first, then rapidly near the equivalence point
- (C) The equivalence point occurs at pH = 7
- (D) The curve is symmetric around the equivalence point

13. In a weak base-strong acid titration, the pH at the equivalence point can be calculated using:

- (A) The K_b of the weak base only
- (B) The K_a of the conjugate acid formed at equivalence point
- (C) Assuming the pH is 7
- (D) The concentration of the strong acid only

14. A buffer of pH 4.5 is prepared using acetic acid ($pK_a = 4.74$) and its salt. The ratio of [salt]/[acid] should be approximately:

- (A) 0.56
- (B) 1.74
- (C) 0.42
- (D) 1.0

15. When methyl orange is used as an indicator in a strong acid-strong base titration, its color changes from:

- (A) Red to yellow
- (B) Yellow to red
- (C) Colorless to pink
- (D) Pink to colorless

16. The buffer capacity of a buffer solution:

- (A) Depends only on the K_a of the weak acid
- (B) Is independent of the concentrations of the acid and conjugate base
- (C) Increases with higher concentrations of the acid and conjugate base
- (D) Is always the same regardless of pH

17. For the titration of ammonia (NH_3) with HCl, the equivalence point pH will be:

- (A) 7
- (B) Less than 7
- (C) Greater than 7
- (D) Dependent on the initial concentration of ammonia

18. In a titration curve, the steepest part (vertical section) represents:

- (A) The initial pH region
- (B) The buffer region
- (C) The region near the equivalence point
- (D) The region after the equivalence point

19. How does the Henderson-Hasselbalch equation help predict buffer behavior?

- (A) It shows pH depends only on K_a
- (B) It shows pH depends on the ratio of conjugate base to acid
- (C) It proves buffers work for any acid-base combination
- (D) It eliminates the need for experimental pH measurement

20. For an acid buffer, when the concentration of the weak acid is much greater than the concentration of its conjugate base, the pH will be:

- (A) Greater than pK_a
 - (B) Approximately equal to pK_a
 - (C) Less than pK_a
 - (D) Equal to 7
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SECTION B: Structured Questions (5 × 10 marks = 50 marks)**Question 1: Titration Curve Analysis – Weak Acid Against Strong Base (10 marks)**

A student performs a titration by adding **0.1 M NaOH** to **25.0 cm³** of **0.1 M ethanoic acid (CH₃COOH)**.

$$K_a(\text{CH}_3\text{COOH}) = 1.8 \times 10^{-5}$$

(a) Calculate the **initial pH** of the ethanoic acid solution before any NaOH is added. (2 marks)

$$\text{For a weak acid: } \text{pH} = \frac{1}{2}(\text{p}K_a - \log c)$$

(b) Calculate the **volume of NaOH required to reach the equivalence point**. (1 mark)

(c) Determine the **pH at the half-equivalence point**. Explain the relationship between pH and $\text{p}K_a$ at this point. (2 marks)

(d) Calculate the **pH at the equivalence point**. (You may assume the concentration of the conjugate base formed is 0.05 M and use $K_b = \frac{K_w}{K_a}$) (3 marks)

(e) Sketch the titration curve showing:

- Initial pH
- Half-equivalence point
- Equivalence point
- Buffer region
- Steep section near equivalence point

Label all key points with their pH values. (2 marks)

Question 2: Weak Base Against Strong Acid Titration (10 marks)

25.0 cm³ of **0.1 M ammonia (NH₃)** is titrated with **0.1 M HCl**.

$$K_b(\text{NH}_3) = 1.8 \times 10^{-5}$$

(a) Calculate the **initial pH** of the ammonia solution. (2 marks)

$$\text{For a weak base: } \text{pH} = 14 - \frac{1}{2}(\text{p}K_b - \log c)$$

(b) Write the **balanced equation** for the reaction between ammonia and hydrochloric acid. (1 mark)

(c) Calculate the **volume of HCl at the equivalence point**. (1 mark)

(d) Explain why the **pH at the equivalence point is less than 7** (acidic). Include the relevant equilibrium equation showing the hydrolysis of the conjugate acid. (3 marks)

(e) Which indicator would be most suitable for this titration? Justify your choice by considering the pH range at the equivalence point. (2 marks)

Suitable indicators:

- Methyl orange (pH 3.1–4.4)
- Methyl red (pH 4.4–6.2)
- Phenolphthalein (pH 8.2–10.0)

(f) Sketch the titration curve for the weak base-strong acid titration, clearly showing the equivalence point and the steepest section. (1 mark)

Question 3: Acid Buffer and Its Operation (10 marks)

An acid buffer is prepared by mixing **100 cm³ of 0.2 M ethanoic acid (CH₃COOH)** with **100 cm³ of 0.2 M sodium ethanoate (CH₃COONa)**.

$$K_a(\text{CH}_3\text{COOH}) = 1.8 \times 10^{-5}$$

(a) Calculate the **initial pH** of the buffer using the Henderson-Hasselbalch equation:

$$\text{pH} = \text{p}K_a + \log \frac{[\text{salt}]}{[\text{acid}]}$$

(2 marks)

(b) Explain, using a **reversible equation**, how the buffer **resists a decrease in pH** when a small amount of strong acid (HCl) is added. (2 marks)

(c) Explain, using a **reversible equation**, how the buffer **resists an increase in pH** when a small amount of strong base (NaOH) is added. (2 marks)

(d) Calculate the **new pH** when **10 cm³ of 1.0 M HCl** is added to **100 cm³ of the original buffer**. (Assume the volume change is negligible for the first approximation.)

Hint: Calculate the moles of acid and salt before and after the addition of HCl. (3 marks)

(e) Describe a **real-world application** where an acid buffer is essential. Explain how the buffer maintains a relatively constant pH in this scenario. (1 mark)

Question 4: Determination of Equivalence Point and Indicator Selection (10 marks)

A student is tasked with selecting an appropriate indicator for different titrations. Three indicators are available:

Indicator	pH Range	Color Change
Methyl orange	3.1–4.4	Red → Yellow
Methyl red	4.4–6.2	Red → Yellow
Phenolphthalein	8.2–10.0	Colorless → Pink

(a) For a titration of **0.1 M HCl** (strong acid) against **0.1 M NaOH** (strong base):

- State the **pH at the equivalence point**. (1 mark)
- Select the **most suitable indicator** and justify your choice. (2 marks)

(b) For a titration of **0.1 M ethanoic acid (CH₃COOH)** against **0.1 M NaOH**:

- Explain why the equivalence point pH is **greater than 7**. (2 marks)
- Which indicator would be most suitable? Justify your choice. (2 marks)

(c) For a titration of **0.1 M ammonia (NH₃)** against **0.1 M HCl**:

- Explain why the equivalence point pH is **less than 7**. (2 marks)

(d) Why is it important that the **indicator's color change range overlaps with the equivalence point pH**? (1 mark)

Question 5: Buffer Capacity and pH Changes (10 marks)

Two buffer solutions are prepared:

- **Buffer A:** 50 cm³ of 0.5 M ethanoic acid + 50 cm³ of 0.5 M sodium ethanoate
- **Buffer B:** 50 cm³ of 0.1 M ethanoic acid + 50 cm³ of 0.1 M sodium ethanoate

$$K_a(\text{CH}_3\text{COOH}) = 1.8 \times 10^{-5}$$

(a) Calculate the **initial pH of Buffer A**. (2 marks)

$$\text{pH} = \text{p}K_a + \log \frac{[\text{salt}]}{[\text{acid}]}$$

(b) Calculate the **initial pH of Buffer B**. What do you observe about the pH values of the two buffers? (2 marks)

(c) **10 cm³ of 1.0 M HCl** is added to both buffers. Calculate the **new pH of Buffer A** after the addition. (3 marks)

Hint: Calculate moles of acid and conjugate base before and after HCl addition.

(d) Calculate the **new pH of Buffer B** after the same volume of HCl is added. (2 marks)

(e) Compare the **change in pH (ΔpH)** for both buffers. Which buffer has greater **buffer capacity**? Explain why in terms of the **concentrations of the weak acid and its conjugate base**. (1 mark)
