

Week 36

A-Level Chemistry

Homework bundle for this week

本周作业合集

exercises.lol

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25. Equilibria

Starter Quiz · 课前小测

A-Level Chemistry

Name: _____ Score: _____

- The conjugate base of CH_3COOH is:
 - ☐ CH_3COO^- (the acid minus one H^+)
 - ☐ $\text{CH}_3\text{COOH}_2^+$
 - ☐ H^+
 - ☐ OH^-
- A buffer solution is made from:
 - ☐ a weak acid and its conjugate base
 - ☐ a strong acid only
 - ☐ a strong base only
 - ☐ pure water
- The solubility product K_{sp} is:
 - ☐ the product of the ion concentrations, each raised to its number in the formula
 - ☐ the sum of the ion concentrations
 - ☐ the solubility in grams
 - ☐ the pH of the solution
- The partition coefficient is:
 - ☐ the ratio of the solute's concentrations in the two immiscible solvents
 - ☐ the sum of the concentrations
 - ☐ the pH of the mixture
 - ☐ the solubility product
- pH is defined as:
 - ☐ $-\log[\text{H}^+]$
 - $\text{H}^+ \times 14$
 - ☐ $\log[\text{OH}^-]$
 - $\text{H}^+ - [\text{OH}^-]$
- A buffer keeps the pH almost constant when a small amount of acid or alkali is added.
 - ☐ True ☐ False

7. The value of the partition coefficient depends on the polarity of the solute and solvents.

☐ True ☐ False

8. An acid and the base formed when it loses a proton are a conjugate _____.

9. A buffer resists changes in pH when small amounts of acid or base are added.

☐ True ☐ False

10. The equilibrium constant for a sparingly soluble salt dissolving is the solubility _____.

25. Equilibria

Answers · 答案

A-Level Chemistry

1. CH_3COO^- (the acid minus one H^+)

Removing one H^+ from the acid leaves its conjugate base; the two differ by a single proton.

2. a weak acid and its conjugate base

A weak acid and its conjugate base (e.g. ethanoic acid + sodium ethanoate) make a buffer.

3. the product of the ion concentrations, each raised to its number in the formula

For a saturated solution, K_{sp} multiplies the ion concentrations (each to the power of its formula coefficient).

4. the ratio of the solute's concentrations in the two immiscible solvents

$K_{\text{pc}} = [\text{solute in solvent 1}] / [\text{solute in solvent 2}]$, constant at a fixed temperature.

5. $-\log[\text{H}^+]$

$\text{pH} = -\log[\text{H}^+]$; so $[\text{H}^+] = 10^{-(\text{pH})}$.

6. True

That is exactly what a buffer does — it resists changes in pH.

7. True

Polarity governs how the solute distributes, so it sets the partition coefficient.

8. pair

e.g. HA and A^- .

9. True

It contains a weak acid and its conjugate base.

10. product

Written K_{sp} .

25.1 Acids and bases

Name: _____ Class: _____ Date: _____

Total: 13 marks

KEY WORDS buffer solution 缓冲溶液 • conjugate acid 共轭酸 • solubility product 溶度积
• conjugate base 共轭碱 • conjugate acid–base pair 共轭酸碱对

Objective

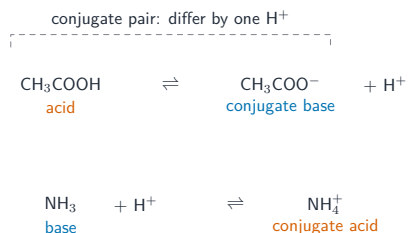
Build the skills to answer exam questions on **acids and bases** — **conjugate pairs** 共轭对, **pH**, K_a , K_w , **buffers** 缓冲液 and **solubility product** 溶度积 (K_{sp}).

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}

1 Worked examples

■ Conjugate pairs and key relationships

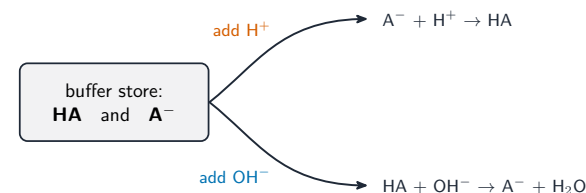


A conjugate pair differs by one H^+

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

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

■ Buffers



either way, the pH barely changes

$$A \text{ buffer (a weak acid + its salt) resists pH change: } [H^+] = K_a \frac{[HA]}{[A^-]}$$

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

2 Practice

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]

3 Exam-style questions

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

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]

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

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]

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

Solutions

2.1 NO_3^- .

2.2 $\text{pH} = -\log(0.010) = 2.0$.

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

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

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

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

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

(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.

3 (a) (i) Define conjugate acid–base pair.

.....
 [1]

(ii) Give the formulas of the conjugate acid and the conjugate base of the hydrogen phosphate ion, HPO_4^{2-} .

conjugate acid of HPO_4^{2-}

conjugate base of HPO_4^{2-} [1]

(b) The K_a of propanoic acid, $\text{CH}_3\text{CH}_2\text{COOH}$, is $1.35 \times 10^{-5} \text{ mol dm}^{-3}$ at 298 K.

Solution C is a solution of $\text{CH}_3\text{CH}_2\text{COOH}$ with a pH of 3.60 at 298 K.

(i) Calculate the concentration of $\text{CH}_3\text{CH}_2\text{COOH}$ in solution C.

$[\text{CH}_3\text{CH}_2\text{COOH}] = \dots\dots\dots \text{mol dm}^{-3}$ [2]

(ii) Calculate the concentration of hydroxide ions in solution C.

$[\text{OH}^-] = \dots\dots\dots \text{mol dm}^{-3}$ [1]

(iii) Calculate the concentration of a solution of hydrochloric acid with the same pH as solution C.

concentration = $\dots\dots\dots \text{mol dm}^{-3}$ [1]

(iv) Table 3.1 shows three possible values of the K_a of dimethylpropanoic acid, $(\text{CH}_3)_3\text{CCOOH}$.

Place a tick in Table 3.1 to show the correct value. Explain your answer.

Table 3.1

value of K_a / mol dm^{-3}	place one tick (✓) in this column
9.33×10^{-6}	
1.35×10^{-5}	
3.35×10^{-5}	

explanation

 [3]

(c) Solution D is made by mixing 100 cm^3 of $0.100 \text{ mol dm}^{-3}$ $\text{CH}_3\text{CH}_2\text{COOH}$ and 100 cm^3 of $0.100 \text{ mol dm}^{-3}$ NaCl .

The pH of solution D is measured as small amounts of $\text{H}_2\text{SO}_4(\text{aq})$ are added to it, and when small amounts of $\text{NaOH}(\text{aq})$ are added to it.

Solution D only acts as a buffer solution when **one** of these solutions is added to it.

(i) Complete the sentence and write an equation for the reaction that occurs.

Solution D acts as a buffer when is added to it.

equation [1]

(ii) Complete the sentence and explain why solution D does **not** act as a buffer when the other solution is added.

Solution D does **not** act as a buffer when is added to it.

explanation
 [1]

(d) Manganese(II) hydroxide, $\text{Mn}(\text{OH})_2$, is only slightly soluble in water.

The solubility of $\text{Mn}(\text{OH})_2$ in water is $3.28 \times 10^{-3} \text{ g dm}^{-3}$ at 298 K.

(i) Calculate the concentration of a saturated solution of $\text{Mn}(\text{OH})_2$ at 298 K.

$$[\text{Mn}(\text{OH})_2] = \dots\dots\dots \text{mol dm}^{-3} \quad [1]$$

(ii) Write an expression for the K_{sp} of $\text{Mn}(\text{OH})_2$. Give the units of K_{sp} .

$$K_{\text{sp}} =$$

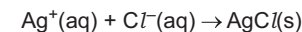
$$\text{units} = \dots\dots\dots [2]$$

(iii) Use your answers to **(d)(i)** and **(d)(ii)** to calculate the value of K_{sp} of $\text{Mn}(\text{OH})_2$ at 298 K.

$$K_{\text{sp}} = \dots\dots\dots [1]$$

[Total: 15]

1 The concentration of aqueous chloride ions can be found by titration with aqueous silver nitrate, $\text{AgNO}_3(\text{aq})$.



The indicator used is aqueous potassium chromate(VI), $\text{K}_2\text{CrO}_4(\text{aq})$.

As $\text{AgNO}_3(\text{aq})$ is added to aqueous chloride ions, a white precipitate of $\text{AgCl}(\text{s})$ is formed.

When all the chloride ions have reacted, further addition of $\text{AgNO}_3(\text{aq})$ leads to the formation of a red precipitate of silver chromate(VI), $\text{Ag}_2\text{CrO}_4(\text{s})$. The first appearance of the red precipitate shows the end-point of the titration.

A student carries out an experiment to determine the number of molecules of water of crystallisation, x , in hydrated barium chloride, $\text{BaCl}_2 \cdot x\text{H}_2\text{O}(\text{s})$.

(a) The student makes 250.0 cm^3 of $0.0500 \text{ mol dm}^{-3}$ $\text{AgNO}_3(\text{aq})$ to use for the titration.

(i) Calculate the mass of solid silver nitrate, $\text{AgNO}_3(\text{s})$, needed to make 250.0 cm^3 of $0.0500 \text{ mol dm}^{-3}$ $\text{AgNO}_3(\text{aq})$.

Give your answer to **two** decimal places.

$$\text{mass of AgNO}_3(\text{s}) = \dots\dots\dots \text{g} \quad [1]$$

(ii) Describe how the student should make 250.0 cm^3 of $0.0500 \text{ mol dm}^{-3}$ $\text{AgNO}_3(\text{aq})$ starting from the mass of $\text{AgNO}_3(\text{s})$ calculated in **(a)(i)** in a 50 cm^3 beaker.

Give the name and size of any key apparatus used.

Write your answer using a series of numbered steps.

.....

.....

.....

.....

.....

.....

.....

..... [3]

(b) The student uses the following method.

step 1 Dissolve 1.58 g of $\text{BaCl}_2 \cdot x\text{H}_2\text{O}(\text{s})$ to form 250 cm^3 of aqueous solution. Label this solution **A**.

step 2 Transfer 20.0 cm^3 of solution **A** into a conical flask.

step 3 Add aqueous sodium sulfate, $\text{Na}_2\text{SO}_4(\text{aq})$, to the flask and swirl the mixture to remove barium ions from the solution.

step 4 Add 2–3 drops of $\text{K}_2\text{CrO}_4(\text{aq})$ indicator to the flask.

step 5 Titrate the contents of the flask against $0.0500\text{ mol dm}^{-3}$ $\text{AgNO}_3(\text{aq})$.

step 6 Repeat steps 2 to 5 to collect sufficient data for analysis.

(i) Suggest a suitable piece of apparatus for transferring 20.0 cm^3 of solution **A** in step 2.

..... [1]

(ii) Suggest why barium ions are removed in step 3 before performing the titration.

.....

..... [1]

(iii) Suggest why chemically resistant gloves should be worn to carry out step 4.

..... [1]

(c) The student's results are shown in Table 1.1.

Table 1.1

	rough titration	titration 1	titration 2	titration 3
burette reading (final)/ cm^3	20.10	40.55	20.75	20.90
burette reading (initial)/ cm^3	0.00	20.25	0.05	0.30
titre/ cm^3	20.10	20.30	20.70	20.60

The student uses the titres from titrations 2 and 3 shown in Table 1.1 to calculate a mean titre value of 20.65 cm^3 .

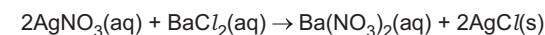
(i) Explain why only these two values are used.

..... [1]

(ii) Calculate the percentage error in the titre volume for titration 3.
Show your working.

percentage error = [1]

(d) The equation for the reaction of silver nitrate with barium chloride is shown.



(i) Calculate the amount, in mol, of $\text{AgNO}_3(\text{aq})$ in the mean titre of 20.65 cm^3 .

amount of AgNO_3 = mol [1]

(ii) Calculate the amount, in mol, of $\text{BaCl}_2(\text{aq})$ in 250 cm^3 of solution **A**.

amount of BaCl_2 = mol [1]

(iii) Calculate the value of x in the formula $\text{BaCl}_2 \cdot x\text{H}_2\text{O}$.

x = [2]

- (e) Another student uses a different experimental method to check the value of x obtained by the method described in (b).

Give a **brief** description of another method, not involving titration, that could be used to determine the value of x in the formula $\text{BaCl}_2 \cdot x\text{H}_2\text{O}(\text{s})$. Write your answer using a series of numbered steps.

Your plan should include details of the following:

- the apparatus and method you would use
- the measurements you would make.

You are provided with standard laboratory apparatus.

..... [3]

[3]

[Total: 16]

25.2 Partition coefficients

Name: _____ Class: _____ Date: _____

Total: 9 marks

KEY WORDS partition coefficient 分配系数 • solvent 溶剂 • solute 溶质 • polarity 极性

Objective

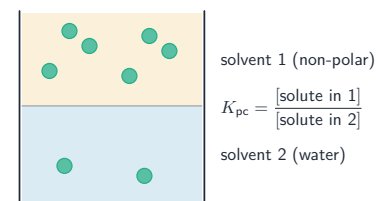
Build the skills to answer exam questions on **partition coefficients** 分配系数 — what K_{pc} is, calculating it, and the factors that affect it.

You must be able to:

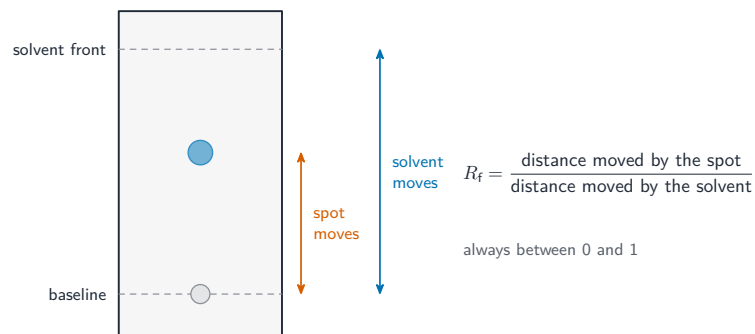
- state what a partition coefficient is
- calculate and use a partition coefficient
- explain how solute and solvent polarity affect its value

1 Worked examples

- Partition coefficient



A solute shaken with two immiscible solvents distributes between them in a fixed ratio



Chromatography separates by partition

The **partition coefficient** K_{pc} is the ratio of the concentrations of a solute in two immiscible solvents at equilibrium (the solute in the same physical state in both):

$$K_{pc} = \frac{[\text{solute in solvent 1}]}{[\text{solute in solvent 2}]}$$

A solute dissolves better in the solvent of **similar polarity** (“like dissolves like”), so the value depends on the polarities of the solute and the two solvents.

2 Practice

2.1 State what a partition coefficient measures. [1]

2.2 State the rule that decides which solvent a solute prefers. [1]

3 Exam-style questions

3.1 A non-polar solute is shaken with water and hexane (a non-polar solvent). It will mostly be found in: [1]

- A the water
- B the hexane
- C equally in both
- D neither

3.2 The partition coefficient depends on: [1]

- A the temperature only
- B the polarities of the solute and the two solvents
- C the volume of the container
- D the colour of the solute

3.3 A solute is shaken with equal volumes of two immiscible solvents. At equilibrium its concentration is 0.80 mol dm^{-3} in solvent A and 0.20 mol dm^{-3} in solvent B.

(a) Calculate the partition coefficient $K_{pc} = \frac{[A]}{[B]}$. [1]

(b) State, with a reason, which solvent the solute dissolves in better. [2]

3.4 Explain why a polar solute has a higher concentration in water than in hexane. [2]

Solutions

2.1 the ratio of the concentrations of a solute distributed between two immiscible solvents at equilibrium.

2.2 “like dissolves like” — a solute prefers the solvent of similar polarity.

3.1 B. A non-polar solute dissolves better in the non-polar hexane.

3.2 B. It depends on the polarities of the solute and the solvents.

3.3 (a) $K_{\text{pc}} = 0.80/0.20 = 4.0$.

(b) solvent A; the higher concentration shows the solute is more soluble in A (it is of more similar polarity).

3.4 a polar solute and water can form strong interactions (e.g. hydrogen bonds / dipole-dipole); hexane is non-polar and cannot, so the solute prefers the water.