Week 36

A-Level Chemistry

Homework bundle for this week

本周作业合集

exercises.lol

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A-Level Chemistry Name: _____ Score: _____

1. The conjugate base of CH_3COOH is:
   - ☐ CH_3COO^- (the acid minus one H^+)
   - ☐ $CH_3COOH_2^+$
   - ☐ H^+
   - ☐ OH^-
2. A buffer solution is made from:
   - ☐ a weak acid and its conjugate base
   - ☐ a strong acid only
   - ☐ a strong base only
   - ☐ pure water
3. The solubility product Ksp 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
4. 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
5. pH is defined as:
   - ☐ $-\log[H^+]$
   - $H^+ \times 14$
   - ☐ $\log[OH^-]$
   - $H^+ - [OH^-]$
6. 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 _____.

    _____

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, Ksp 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**

   Kpc = [solute in solvent 1] / [solute in solvent 2], constant at a fixed temperature.

5. **$-\log[H^+]$**

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

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 Ksp.

A-LEVEL CHEMISTRY • EXERCISE SHEET

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

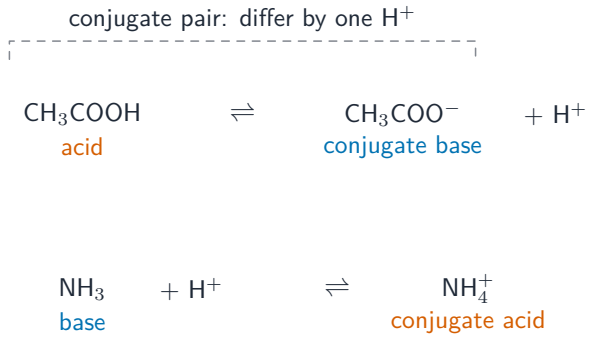
Build the skills to answer exam questions on **acids and bases** — **conjugate pairs** 共轭对, **pH**, K_a, K_w, **buffers** 缓冲液 and **solubility product** 溶度积 (K_{sp}).

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

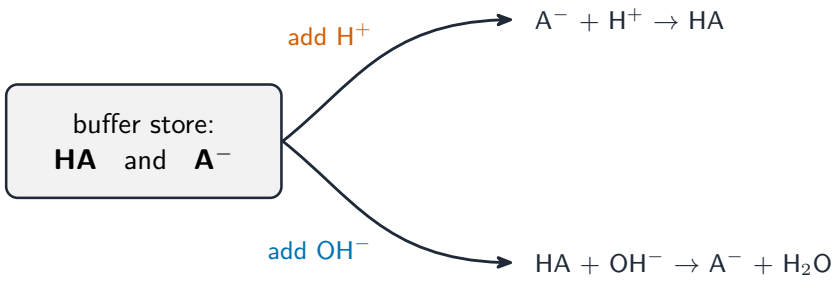


A conjugate pair differs by one H^+

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

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

■ Buffers



either way, the pH barely changes

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

Added H^+ reacts with A^-; added OH^- reacts with HA. In blood, HCO_3^- buffers the pH. $K_{\mathbf{sp}}$ = 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 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 $K_a = 1.8 \times 10^{-5}$ 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. $[H^+] = 10^{-14}/0.10 = 10^{-13}$, so pH = 13.

3.3 (a) $[H^+] = \sqrt{K_a[HA]} = \sqrt{1.8 \times 10^{-5} \times 0.10} = \sqrt{1.8 \times 10^{-6}} = 1.34 \times 10^{-3}$; $\text{pH} = -\log(1.34 \times 10^{-3}) = 2.87$.
(b) HA is only partly dissociated, so $[H^+]$ is lower than for fully-dissociated HCl, giving a higher pH.

3.4 (a) $[H^+] = K_a \dfrac{[HA]}{[A^-]} = 1.8 \times 10^{-5} \times \dfrac{0.20}{0.20} = 1.8 \times 10^{-5}$; pH = 4.74.
(b) added H^+ reacts with the ethanoate ion: $CH_3COO^- + H^+ \rightarrow CH_3COOH$, 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, CH_3CH_2COOH, is 1.35×10^{-5} mol dm^{-3} at 298 K.

Solution **C** is a solution of CH_3CH_2COOH with a pH of 3.60 at 298 K.

(i) Calculate the concentration of CH_3CH_2COOH in solution **C**.

$[CH_3CH_2COOH]$ = ... mol dm^{-3} [2]

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

$[OH^-]$ = ... mol dm^{-3} [1]

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

concentration = ... mol dm^{-3} [1]

(iv) Table 3.1 shows three possible values of the K_a of dimethylpropanoic acid, $(CH_3)_3CCOOH$.

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 mol dm^{-3} CH_3CH_2COOH and 100 cm^3 of 0.100 mol dm^{-3} NaC*l*.

The pH of solution **D** is measured as small amounts of H_2SO_4(aq) are added to it, and when small amounts of NaOH(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, $Mn(OH)_2$, is only slightly soluble in water.

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

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

$[Mn(OH)_2]$ = ... mol dm^{-3} [1]

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

K_{sp} =

units = ...
[2]

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

K_{sp} = ... [1]

[Total: 15]

1 The concentration of aqueous chloride ions can be found by titration with aqueous silver nitrate, $AgNO_3(aq)$.

$$Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$$

The indicator used is aqueous potassium chromate(VI), $K_2CrO_4(aq)$.

As $AgNO_3(aq)$ is added to aqueous chloride ions, a white precipitate of $AgCl(s)$ is formed.

When all the chloride ions have reacted, further addition of $AgNO_3(aq)$ leads to the formation of a red precipitate of silver chromate(VI), $Ag_2CrO_4(s)$. 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, $BaCl_2 \cdot xH_2O(s)$.

(a) The student makes 250.0 cm^3 of 0.0500 mol dm^{-3} $AgNO_3(aq)$ to use for the titration.

(i) Calculate the mass of solid silver nitrate, $AgNO_3(s)$, needed to make 250.0 cm^3 of 0.0500 mol dm^{-3} $AgNO_3(aq)$.

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

mass of $AgNO_3(s)$ = ... g [1]

(ii) Describe how the student should make 250.0 cm^3 of 0.0500 mol dm^{-3} $AgNO_3(aq)$ starting from the mass of $AgNO_3(s)$ 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 $BaCl_2 \cdot xH_2O(s)$ 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, $Na_2SO_4(aq)$, to the flask and swirl the mixture to remove barium ions from the solution.

step 4 Add 2–3 drops of $K_2CrO_4(aq)$ indicator to the flask.

step 5 Titrate the contents of the flask against 0.0500 mol dm^{-3} $AgNO_3(aq)$.

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.

$$2AgNO_3(aq) + BaCl_2(aq) \rightarrow Ba(NO_3)_2(aq) + 2AgCl(s)$$

(i) Calculate the amount, in mol, of $AgNO_3(aq)$ in the mean titre of 20.65 cm^3.

amount of $AgNO_3$ = ... mol [1]

(ii) Calculate the amount, in mol, of $BaCl_2(aq)$ in 250 cm^3 of solution **A**.

amount of $BaCl_2$ = ... mol [1]

(iii) Calculate the value of x in the formula $BaCl_2 \cdot xH_2O$.

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 $BaCl_2 \cdot xH_2O(s)$. 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]

[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

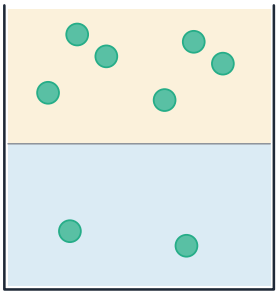
Build the skills to answer exam questions on **partition coefficients** 分配系数 — what K_{pc} is, calculating it, and the factors that affect it.

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

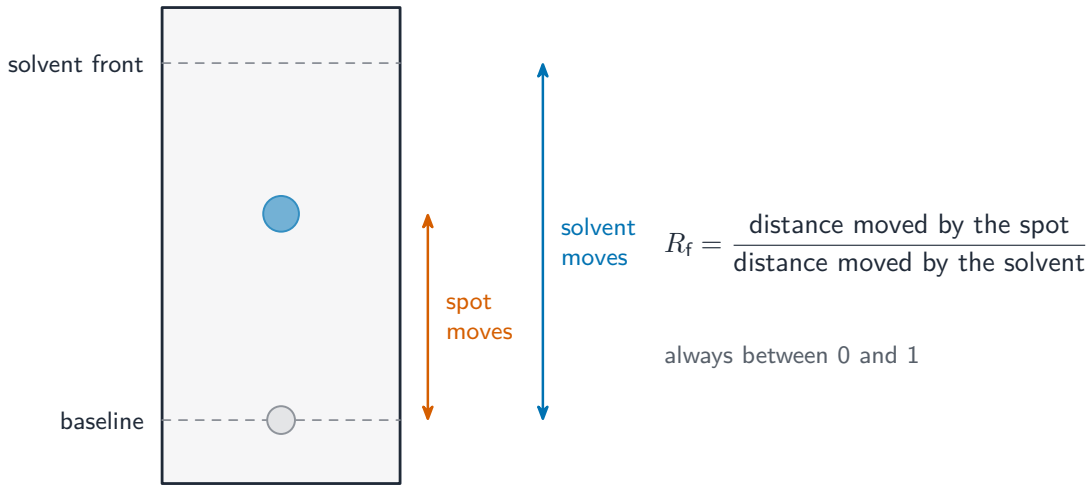


solvent 1 (non-polar)

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

solvent 2 (water)

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.