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CHEMISTRY

Topic Questions

OCR
AS & A LEVEL

Module 5: Physical chemistry and transiton elements

1 Chemists and biochemists use pK_a values to compare the strengths of different acids. pK_a is a more convenient way of comparing acid strengths than K_a values.
pK_a values of several naturally occurring Brønsted–Lowry acids are shown in **Table 4.1** below.

common name and source	systematic name	structural formula	pK_a (at 25 °C)
benzoic acid (from bark resin)	benzenecarboxylic acid	C_6H_5COOH	4.19
acetic acid (from vinegar)	ethanoic acid	CH_3COOH	4.76
pyruvic acid (formed during metabolism)	2-oxopropanoic acid	$CH_3COCOOH$	2.39
lactic acid (from milk)	2-hydroxypropanoic acid	$CH_3CHOHCOOH$	3.86

Table 4.1

(a) (i) What is meant by the term *Brønsted–Lowry acid*?

..... **[1]**

(ii) What is meant by the *strength* of an acid?

In your answer, include an equation for one of the acids in **Table 4.1**.

.....

.....

..... **[2]**

(iii) Place the four acids in **Table 4.1** in order of increasing strength.

weakest acid .....

.....

.....

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strongest acid ..... **[1]**

(iv) Aqueous benzoic acid was mixed with aqueous lactic acid. An equilibrium mixture was formed containing conjugate acid–base pairs.

Complete the equilibrium below to show the components in the equilibrium mixture.

$C_6H_5COOH + CH_3CHOHCOOH \rightleftharpoons$ ..... + ... **[1]**

(b) Aqueous pyruvic acid was reacted with an aqueous solution of calcium hydroxide.

(i) Write an equation for this reaction.

..... **[1]**

(ii) Write an ionic equation for this reaction.

..... **[1]**

(c) The pH of an acid solution can be calculated from its pK_a value.

Calculate the pH of a 0.0150 mol dm^{-3} solution of pyruvic acid at 25 °C.

Show **all** your working.
Give the pH to **two** decimal places.

pH = ... **[4]**

(d) Oxalic acid (ethanedioic acid), $C_2H_2O_4$, is present in the leaves of rhubarb plants. Oxalic acid has two dissociations with $pK_a = 1.23$ and $pK_a = 4.19$.

(i) Draw the structure of oxalic acid.

[1]

(ii) Predict the equations that give rise to each dissociation.

$pK_a = 1.23$

$pK_a = 4.19$

[2]

(e) The 'magic tang' in many sweets is obtained by use of acid buffers. A sweet manufacturer carried out tasting tests with consumers and identified the acid taste that gives the 'magic tang' to a sweet.

The manufacturer was convinced that the 'magic tang' would give the company a competitive edge and he asked the company's chemists to identify the chemicals needed to generate the required taste. The chemists' findings would be a key factor in the success of the sweets.

The team of chemists identified that a pH of 3.55 was required and they worked to develop a buffer at this pH.

The chemists decided to use one of the acids in **Table 4.1** (page 8) and a salt of the acid to prepare this buffer.

- Deduce the chemicals required by the chemists to prepare this buffer.
- Calculate the relative concentrations of the acid and its salt needed by the chemist to make this buffer.
- Comment on the validity of the prediction that the pH of the sweet would give the sweets the 'magic tang'.

[6]

[Total: 20]

2 The chemicals that we call 'acids' have been known for thousands of years. However, modern theories of acids have been developed comparatively recently. It wasn't until the early 1900s that the concept of dissociation became accepted by the scientific community and the concept of pH was introduced.

A student carried out a series of experiments with acids and alkalis.

(a) Propanoic acid, CH_3CH_2COOH, is a naturally occurring weak acid. The equation for the dissociation of propanoic acid is shown below.

$$CH_3CH_2COOH(aq) \rightleftharpoons H^+(aq) + CH_3CH_2COO^-(aq)$$

The student wanted to prove that propanoic acid is a weak acid. The student had access to a pH meter and 0.100 mol dm^{-3} propanoic acid.

- Explain how the student could prove that propanoic acid is a weak acid by taking a single pH measurement.
- Show how the student could then calculate the acid dissociation constant, K_a, for propanoic acid.

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..... **[4]**

(b) The student measured the pH of a solution of sodium hydroxide at 25 °C.
The measured pH was 13.46.

Calculate the concentration of the aqueous sodium hydroxide.

concentration = ... mol dm^{-3} **[2]**

(c) A student made a buffer solution by mixing an excess of propanoic acid to an aqueous solution of sodium hydroxide at 25 °C. This buffer solution contains an equilibrium system that minimises changes in pH when small amounts of acids and alkalis are added.

- Explain why a buffer solution formed when an excess of propanoic acid was mixed with aqueous sodium hydroxide.
- Explain how this buffer solution controls pH when an acid or an alkali is added.

In your answer you should explain how the equilibrium system allows the buffer solution to control the pH.

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.... **[7]**

(d) A student added nitric acid to propanoic acid. A reaction took place to form an equilibrium mixture containing two acid–base pairs.

Complete the equilibrium below and label the two conjugate acid–base pairs.

HNO_3 + CH_3CH_2COOH $\rightleftharpoons$ ..... + ...

[2]

(e) Finally, the student reacted an aqueous solution of propanoic acid with a reactive metal and with a carbonate.

(i) Write an equation for the reaction of aqueous propanoic acid with magnesium.

..... **[1]**

(ii) Write an ionic equation for the reaction of aqueous propanoic acid with aqueous sodium carbonate.

..... **[1]**

[Total: 17]

3 This question looks at acids, bases and buffer solutions.

(a) Nitric acid, HNO_3, is a strong Brønsted–Lowry acid.
Nitrous acid, HNO_2, is a weak Brønsted–Lowry acid with a K_a value of 4.43×10^{-4} mol dm^{-3}.

(i) What is the difference between a strong acid and a weak acid?

.....

.....

..... **[1]**

(ii) What is the expression for the acid dissociation constant, K_a, of nitrous acid, HNO_2?

[1]

(iii) Calculate the pH of 0.375 mol dm^{-3} nitrous acid, HNO_2.

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

pH = ... **[2]**

(iv) A student suggests that an acid–base equilibrium is set up when nitric acid is mixed with nitrous acid.

Complete the equation for the equilibrium that would be set up and label the conjugate acid–base pairs.

HNO_3 + HNO_2 $\rightleftharpoons$ ..... + ...

....

[2]

(b) Calcium hydroxide, $Ca(OH)_2$, is a strong Brønsted–Lowry base.

(i) Explain what is meant by the term *Brønsted–Lowry base*.

.....

..... **[1]**

(ii) Calculate the pH of 0.0400 mol dm^{-3} $Ca(OH)_2$.

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

pH = ... **[3]**

(c) Aqueous calcium hydroxide is added to nitrous acid, HNO_2.

Write the overall equation and the ionic equation for the reaction that takes place.

overall: .....

ionic: ..... **[2]**

(d) Carbonic acid, H_2CO_3, is a weak Brønsted–Lowry acid formed when carbon dioxide dissolves in water. Healthy blood is buffered to a pH of 7.40. The most important buffer solution in blood is a mixture of carbonic acid and hydrogencarbonate ions, HCO_3^-.

(i) Explain how the carbonic acid–hydrogencarbonate mixture acts as a buffer in the control of blood pH.

In your answer you should explain how equilibrium allows the buffer solution to control the pH.

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.... **[5]**

(ii) Healthy blood at a pH of 7.40 has a hydrogencarbonate : carbonic acid ratio of 10.5 : 1. A patient is admitted to hospital. The patient's blood pH is measured as 7.20.

Calculate the hydrogencarbonate : carbonic acid ratio in the patient's blood.

[5]

[Total: 22]