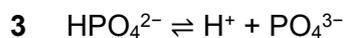
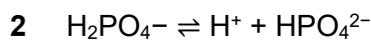
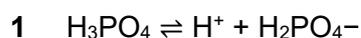


1. This question is about the chemistry of compounds containing phosphorus.

Phosphorus forms several acids including H_3PO_4 and H_3PO_3 .

H_3PO_4 is a tribasic acid. The equilibria for the dissociations are shown below.



i. During the equilibria, H_2PO_4^- behaves both as an acid and as a base.

Explain this statement, using the equilibria **1**, **2** and **3**, as required.

[2]

ii. In a H_3PO_3 molecule, the O atoms are covalently bonded to the P atom. The H atoms are bonded to the O atoms.

Draw the structure of a H_3PO_3 molecule, showing all the bonds.

On your diagram, add the values for the O–P–O and P–O–H bond angles.

[3]

iii. The systematic name of H_3PO_4 is phosphoric(V) acid.

What is the systematic name of H_3PO_3 ?

[1]

2(a). What is the pH of 1.00 dm^3 of $0.400 \text{ mol dm}^{-3}$ of $\text{NaOH}(\text{aq})$ at 298 K?

pH = [2]

..... [5]

4(a). Chloroethanoic acid, C/CH₂COOH, is a weak monobasic acid.

i. Write the expression for the acid dissociation constant, K_a , of C/CH₂COOH.

[1]

ii. The expression for the acid dissociation constant, K_a , of C/CH₂COOH can be simplified to:

$$K_a = \frac{[\text{H}^+]^2}{[\text{C/CH}_2\text{COOH}]}$$

Expression 19.1

State one approximation that allows the expression from **(a)(i)** to be simplified to **Expression 19.1**.

..... [1]

iii. A student carries out an experiment to determine the pK_a value of a solution of C/CH₂COOH.

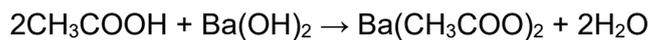
- The concentration of C/CH₂COOH is 0.090 mol dm⁻³.
- The pH of C/CH₂COOH is 1.95.

Use **Expression 19.1** to calculate the pK_a value of C/CH₂COOH.

Give your answer to **2** decimal places.

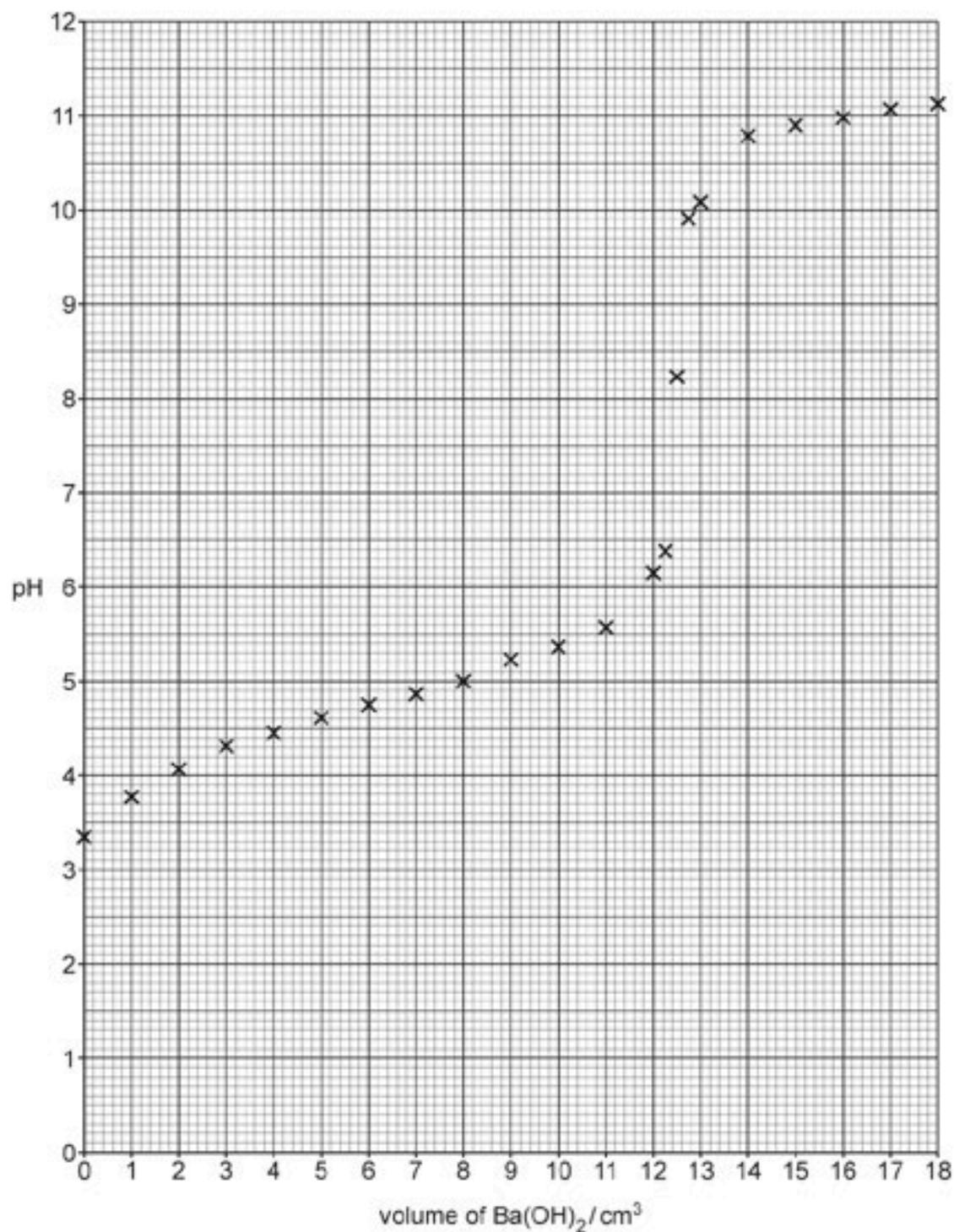
$pK_a = \dots\dots\dots$ [3]

(b). A student titrates a 10.0 cm^3 sample of ethanoic acid, CH_3COOH , against an aqueous solution of $0.0560 \text{ mol dm}^{-3} \text{ Ba}(\text{OH})_2$.



The student used a pH meter to measure the pH of the mixture after every addition of $\text{Ba}(\text{OH})_2$ throughout the titration.

The student's results are shown below.



- i. Draw a best-fit curve on the graph and calculate the concentration of the CH_3COOH solution.

CH_3COOH concentration = mol dm^{-3} [5]

- ii. The end point of the titration can also be found by observing the colour change of an indicator.

The pH ranges of some indicators are shown in the table.

Indicator	pH range
Malachite green	0.2 – 1.8
Bromophenol blue	2.8 – 4.6
Phenol red	6.8 – 8.4
Phenolphthalein	8.2 – 10.0

Identify the indicator in the table that would be suitable to observe the end point of the titration between CH_3COOH and $\text{Ba}(\text{OH})_2$.

..... [1]

5. Which solution can be added to $\text{CH}_3\text{COOH}(\text{aq})$ to make a buffer solution?

- A $\text{CH}_3\text{COONa}(\text{aq})$
- B $\text{HCOOH}(\text{aq})$
- C $\text{HCl}(\text{aq})$
- D $\text{NaCl}(\text{aq})$

Your answer

[1]

6. A student investigates the rate of a reaction that is 1st order with respect to hydrochloric acid, $\text{HCl}(\text{aq})$.

- The student carries out a reaction using $0.680 \text{ mol dm}^{-3} \text{ HCl}(\text{aq})$. The initial rate is $9.52 \times 10^{-4} \text{ mol dm}^{-3} \text{ s}^{-1}$.
- The student dilutes a different sample of $0.680 \text{ mol dm}^{-3} \text{ HCl}(\text{aq})$ with water. The pH of this diluted acid is 1.50.
- The student repeats the reaction using the same volume of this diluted acid.

Determine the initial rate using this diluted acid.

initial rate = $\text{mol dm}^{-3} \text{ s}^{-1}$ [3]

7(a). This question is about acids and bases.

Table 20.1 shows the ionic product, K_w , of water at $25 \text{ }^\circ\text{C}$ and $40 \text{ }^\circ\text{C}$.

Table 20.1

Temperature / $^\circ\text{C}$	$K_w / \text{mol}^2 \text{ dm}^{-6}$
25	1.00×10^{-14}
40	2.92×10^{-14}

- i. Calculate the pH of water at $40 \text{ }^\circ\text{C}$.

Give your answer to **2** decimal places.

pH = [2]

- ii. Table 20.1 shows different K_w values at $25 \text{ }^\circ\text{C}$ and at $40 \text{ }^\circ\text{C}$. A student suggests that water is neutral at these temperatures.

Explain why this student is correct.

..... [1]

(b). A student reacts strontium metal with water to make a 250.0 cm³ solution of aqueous strontium hydroxide, Sr(OH)₂. The solution contains 0.145 g of strontium hydroxide.

- Write an equation for the reaction of strontium with water.
Calculate the pH of this 250.0 cm³ solution of strontium hydroxide at 40 °C.
- You should refer back to **Table 20.1** at the start of **(a)**.

Give your answer to **2** decimal places.

Equation _____

Calculation

pH = **[5]**

(c). A student reacts an excess of magnesium with 25.0 cm³ of 0.500 mol dm⁻³ hydrochloric acid, HCl.

The student also reacts an excess of magnesium with 25.0 cm³ of 0.500 mol dm⁻³ ethanoic acid, CH₃COOH.

- i. Construct an ionic equation for the reaction of magnesium with an acid.

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

- ii. Explain why these two reactions of magnesium produce the same volume of gas but at different rates.

..... **[3]**

(d). Butanoic acid, $\text{CH}_3\text{CH}_2\text{CH}_2\text{COOH}$, is a weak monobasic acid.

- i. Explain what is meant by the term **monobasic acid**.

[1]

- ii. A buffer solution is prepared by dissolving 3.39g of potassium hydroxide in 250 cm^3 of $0.376 \text{ mol dm}^{-3}$ butanoic acid.

This buffer solution has a pH of 5.07 at $25 \text{ }^\circ\text{C}$.

Calculate the acid dissociation constant, K_a , of butanoic acid at 25°C .

Assume that the volume of the solution remains constant at 250 cm^3 when the potassium hydroxide is dissolved.

$K_a = \dots\dots\dots \text{ mol dm}^{-3}$ [4]

(e). A buffer solution has a pH of 4.50.

When a small volume of water is added to this buffer solution, the pH does **not** change.

Explain why the pH does **not** change.

[1]

8. What is the percentage dissociation of a $0.015 \text{ mol dm}^{-3}$ solution of methanoic acid, HCOOH ($K_a = 1.60 \times 10^{-4} \text{ mol dm}^{-3}$)?

- A 0.016%
- B 1.1%
- C 1.82%
- D 10.3%

Your answer

[1]

9. This question is about acids and buffer solutions.

Glycolic acid, HOCH_2COOH , ($\text{p}K_a = 3.83$) is a weak monobasic acid used in some skincare products.

A buffer solution is prepared by adding 60.0 cm^3 of $0.750 \text{ mol dm}^{-3}$ glycolic acid to 40.0 cm^3 of $0.625 \text{ mol dm}^{-3}$ potassium hydroxide, KOH .

- i. Explain why a buffer solution is formed.

[1]

- ii. Calculate the pH of the buffer solution that has been prepared.

Give your answer to **2** decimal places.

pH = [4]

- iii. A small amount of aqueous ammonia, $\text{NH}_3(\text{aq})$, is added to the buffer solution.

Explain, in terms of equilibrium, how the buffer solution would respond to the added $\text{NH}_3(\text{aq})$.

[2]

10. This question is about the reactions of Group 2 metals and their compounds.

A sample of barium oxide is added to distilled water at 25 °C.

A colourless solution forms containing barium hydroxide, Ba(OH)₂.

The solution is made up to 250.0 cm³ with distilled water.

The pH of this solution is 13.12.

- i. Determine the mass of barium oxide that was used.

Give your answer to **3** significant figures.

mass of barium oxide = g **[5]**

- ii. 10 cm³ of dilute sulfuric acid is added to 10 cm³ of the colourless solution of Ba(OH)₂. Write an ionic equation, including state symbols, for the reaction.

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

11. The equilibrium equation for an indicator, HA, is shown below.



The indicator is added to a solution. The indicator turns a yellow colour.

An excess of aqueous sodium hydroxide is then added.

Which statement describes how the colour of this solution would be expected to change?

- A** Colour changes from yellow to blue.
B Colour changes from yellow to green.
C Colour changes from yellow to green and then to blue.
D Colour stays yellow.

Your answer

[1]

12. Ammonia and water react to set up an acid-base equilibrium. What are the Brønsted-Lowry acids in the equilibrium mixture?

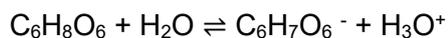
- A H_2O and OH^-
 B OH^- and NH_3
 C NH_4^+ and H_2O
 D NH_4^+ and NH_3

Your answer

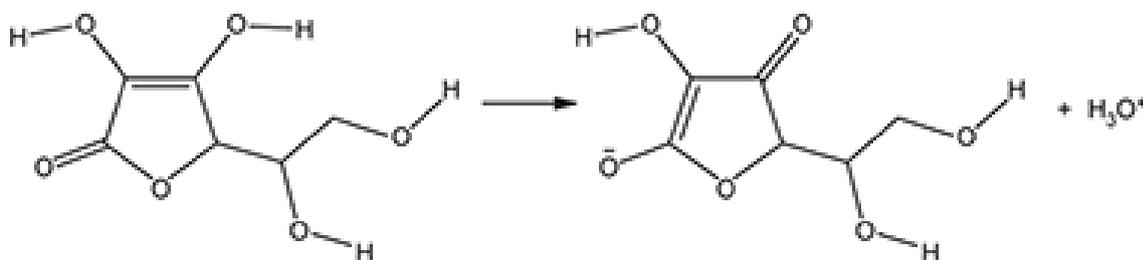
[1]

13. Vitamin C, $\text{C}_6\text{H}_8\text{O}_6$, is a weak acid ($K_a = 7.94 \times 10^{-5}$ (mol dm^{-3})), which is often referred to as ascorbic acid.

i. In aqueous solution, vitamin C donates a proton to water:



Add curly arrows to the diagram to suggest the mechanism for this process.



[2]

ii. The student dissolves 0.150 mol of vitamin C in water and makes the solution up to 250 cm^3 in a volumetric flask.

Calculate the pH of this solution of vitamin C.

Give your answer to **2** decimal places.

pH = [3]

END OF QUESTION PAPER