Acids, Bases and Buffers

1(a). This question is about reactions and uses of the weak acids methanoic acid, HCOOH, and ethanoic acid, CH_3COOH.

The K_a values of HCOOH and CH_3COOH are shown in **Table 18.1**.

Weak acid	K_a / mol dm^{-3}
HCOOH	1.82×10^{-4}
CH_3COOH	1.78×10^{-5}

Table 18.1

A student adds methanoic acid to ethanoic acid.

An equilibrium is set up containing two acid-base pairs.

Complete the equilibrium and label the conjugate acid-base pairs as **A1**, **B1** and **A2**, **B2**.

HCOOH + CH_3COOH ⇌ .... + ...

....

[2]

(b). Use **Table 18.1** to answer the following questions.

i. The student measures the pH of $CH_3COOH(aq)$ as 2.72.

Show that the concentration of the $CH_3COOH(aq)$ is 0.204 mol dm^{-3}.

[2]

ii. The student plans to make a buffer solution of pH 4.00 from a mixture of $CH_3COOH(aq)$ and sodium ethanoate, $CH_3COONa(aq)$.

The student mixes 400 cm^3 of 0.204 mol dm^{-3} $CH_3COOH(aq)$ with 600 cm^3 of $CH_3COONa(aq)$.

Calculate the concentration of $CH_3COONa(aq)$ needed to prepare this buffer solution of pH 4.00.

concentration = ... mol dm^{-3} **[4]**

2. This question is about two different types of acid found in organic compounds, carboxylic acids and sulfonic acids, as shown in **Fig. 6.1**.

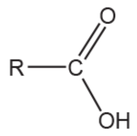
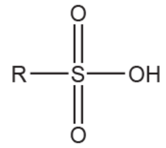
	
Carboxylic acid	Sulfonic acid

Fig. 6.1

Ethanoic acid, CH_3COOH, and methanesulfonic acid, CH_3SO_2OH, are both monobasic acids. The pK_a values are shown in the table.

Acid		**pK_a**
Ethanoic acid	CH_3COOH	4.76
Methanesulfonic acid	CH_3SO_2OH	–1.90

A student suggests that 1.0 mol dm^{-3} CH_3SO_2OH should have a lower pH value than 1.0 mol dm^{-3} CH_3COOH.

Write an equation, showing conjugate acid–base pairs, for the equilibrium of CH_3SO_2OH with water and explain, with reasons, whether the student is correct.

Label the conjugate acid–base pairs: **A1**, **B1** and **A2**, **B2**.

____

____

____

____

____

____ **[4]**

3(a). This question is about weak acids.

The K_a values of three weak acids are shown in **Table 20.1**.

Weak acid	**K_a / mol dm^{-3}**
iodic(V) acid, $HIO_3(aq)$	1.78×10^{-1}
propanoic acid, $C_2H_5COOH(aq)$	1.35×10^{-5}
hydrocyanic acid, $HCN(aq)$	6.17×10^{-10}

Table 20.1

Calculate the pH of 0.0800 mol dm^{-3} $C_2H_5COOH(aq)$.

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

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

(b). A student adds a total of 45.0 cm^3 of 0.100 mol dm^{-3} $NaOH(aq)$ to 25.0 cm^3 of 0.0800 mol dm^{-3} $C_2H_5COOH(aq)$ and monitors the pH throughout.

i. Show by calculation that 20.0 cm^3 of $NaOH(aq)$ is required to reach the end point.

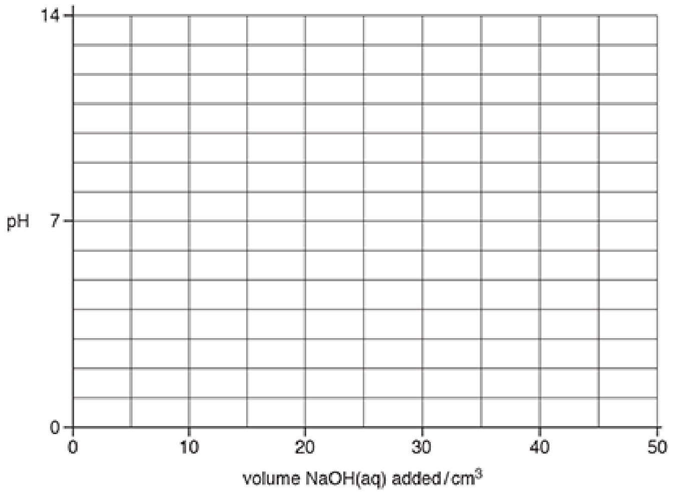
[1]

ii. Calculate the pH of the final solution.

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

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

iii. On the axes below, sketch a pH curve for the pH changes during the addition of 45.0 cm^3 of 0.100 mol dm^{-3} NaOH(aq) to 25.0 cm^3 of 0.0800 mol dm^{-3} C_2H_5COOH(aq).



[3]

iv. The student considers using the four indicators in **Table 20.2** for the titration.

Indicator	**pH range**
Cresol red	0.2 – 1.8
Bromophenol blue	3.0 – 4.6
Cresol purple	7.6 – 9.2
Indigo carmine	11.6 – 14.0

Table 20.2

Explain which indicator would be most suitable for the titration.

____

____

____

____

____ **[1]**

v. The student repeats the experiment starting with 25.0 cm^3 of 0.0800 mol dm^{-3} **HCN**(aq) and adding a total of 45.0 cm^3 of 0.100 mol dm^{-3} NaOH(aq).

Predict **one** similarity and **one** difference between the pH curve with C_2H_5COOH(aq) and the pH curve with HCN(aq). Use the information in **Table 20.1**, and your answer to **(b)(iii)**.

Similarity ---

Difference ---

--- **[2]**

(c). The student calculates the pH of 0.0800 mol dm^{-3} HIO_3(aq). The student assumes that the equilibrium concentration of HIO_3(aq) is the same as the initial concentration of HIO_3(aq).

The student measures the pH, and finds that the measured pH value is different from the calculated pH value.

Explain why the measured pH is different from the calculated pH.

--- **[1]**

4. Healthy human blood needs to be maintained at a pH of 7.40 for the body to function normally.

*Carbonic acid, H_2CO_3, is a weak acid which, together with hydrogencarbonate ions, HCO_3^-, acts as a buffer to maintain the pH of blood.

The pK_a value for the dissociation of carbonic acid is 6.38.

Explain, in terms of equilibrium, how the carbonic acid–hydrogencarbonate mixture acts as a buffer in the control of blood pH, and calculate the $[HCO_3^-]$: $[H_2CO_3]$ ratio in healthy blood.

[6]

5. A reaction is first order with respect to H^+. At a pH of 1, the initial rate is 2.4×10^{-3} mol dm^{-3} s^{-1}.

What is the initial rate at a pH of 3?

initial rate =... mol dm^{-3} s^{-1} **[1]**

6(a). Benzoic acid, C_6H_5COOH, is added to some foods as a preservative.

A student prepares benzoic acid as outlined below.

Step 1	The student mixes 4.00 cm^3 of phenylmethanol, $C_6H_5CH_2OH$, (density = 1.04 g cm^{-3}) with sodium carbonate and aqueous potassium manganate(VII), as an oxidising agent. The mixture is heated under reflux.
Step 2	The resulting mixture is cooled and then acidified with concentrated HC*l* . Impure crystals of benzoic acid appear.
Step 3	The student recrystallises the impure crystals to obtain 1.59 g of pure benzoic acid.

In **Step 1**, sodium carbonate, Na_2CO_3, makes the reaction mixture alkaline.

Write an ionic equation to show how carbonate ions form an alkaline solution in water.

-- **[1]**

(b). In **Step 2**, explain why the mixture must be acidified so that crystals of benzoic acid appear.

-- **[1]**

(c). Write the overall equation for the preparation of benzoic acid from phenylmethanol.

Use [O] for the oxidising agent.

-- **[1]**

(d). Calculate the percentage yield of benzoic acid.

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

percentage yield = ... % **[3]**

(e). In **Step 3**, describe how the student can recrystallise the impure crystals to obtain pure benzoic acid.

____

____

____

____

____

____

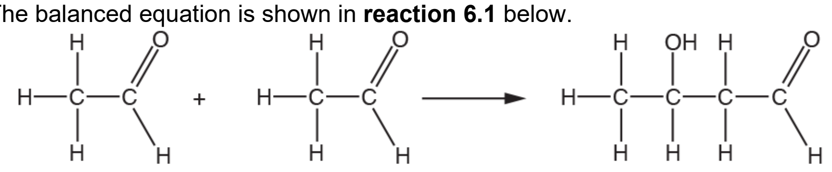
____

____ **[2]**

7. This question is about organic reactions.

Compound **A** is formed when ethanal is mixed with $OH^{-}(aq)$ ions, which act as a catalyst.

The balanced equation is shown in **reaction 6.1** below.



Reaction 6.1

Compound **A**

i. Give the systematic name for compound **A**.

-- **[1]**

ii. What type of reaction has taken place?

-- **[1]**

iii. **Reaction 6.1** takes place in two steps. OH^{-} ions act as a catalyst.

In **step 1**, ethanal reacts with OH^{-} ions to set up an acid–base equilibrium.
In **step 2**, compound **A** is formed.

- Complete the equilibrium for **step 1** and label the conjugate acid–base pairs as: **A1**, **B1** and **A2**, **B2**.

CH^3CHO + OH^{-} ⇌ --------------- + ---------------

---------- ---------- --------------- ---------------

- Suggest the equation for **step 2**.

[3]

iv. A similar reaction takes place when propanone, $(CH_3)_2CO$, is mixed with $OH^{-}(aq)$ ions.

Draw the structure of the organic product of this reaction.

[1]

8(a). This question is about acids and bases found in the home.

Ethanoic acid, CH_3COOH, is the acid present in vinegar.

A student carries out an experiment to determine the pK_a value of CH_3COOH.

- The concentration of CH_3COOH in the vinegar is 0.870 mol dm^{-3}.
- The pH of the vinegar is 2.41.

i. Write the expression for the acid dissociation constant, K_a, of CH_3COOH.

[1]

ii. Calculate the pK_a value of CH_3COOH.

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

pK_a = ... **[3]**

iii. Determine the percentage dissociation of ethanoic acid in the vinegar.

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

percentage dissociation = ... % **[1]**

(b). Many solid drain cleaners are based on sodium hydroxide, NaOH.

- A student dissolves 1.26 g of a drain cleaner in water and makes up the solution to 100.0 cm^3.
- The student measures the pH of this solution as 13.48.

Determine the percentage, by mass, of NaOH in the drain cleaner.

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

percentage = ... % **[4]**

9(a). This question is about the properties and reactions of ethanoic acid, CH_3COOH.
Ethanoic acid is a weak acid with an acid dissociation constant, K_a, of 1.75×10^{-5} mol dm^{-3} at 25 °C.

A student uses a pH meter to measure the pH of a solution of CH_3COOH at 25 °C.
The measured pH is 2.440.

Calculate the concentration of ethanoic acid in the solution.

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

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

(b). Ethanoic acid is a weak acid with an acid dissociation constant, K_a, of 1.75×10^{-5} mol dm^{-3} at 25 °C.

Ethanoic acid is added to another weak acid, fluoroethanoic acid, FCH_2COOH ($K_a = 2.19 \times 10^{-3}$ mol dm^{-3}).
An equilibrium is set up containing two acid-base pairs.

Complete the equilibrium and label the conjugate acid-base pairs as **A1**, **B1** and **A2**, **B2**.

$CH_3COOH + FCH_2COOH \leftrightharpoons$ ---------------------- + ----------------------

---------------------- ---------------------- ---------------------- ----------------------

[2]

(c). The student plans to prepare a buffer solution that has a pH of 4.50. The buffer solution will contain ethanoic acid, CH_3COOH, and sodium ethanoate, CH_3COONa.

The student plans to add 9.08 g CH_3COONa to 250 cm^3 of 0.800 mol dm^{-3} CH_3COOH. The student assumes that the volume of the solution does not change.

i. Show by calculation whether, or not, the student's experimental method would produce the required pH.

Show **all** your working.

[5]

ii. When the student prepares the buffer solution, the volume of solution increases slightly.

Suggest whether the pH of the buffer solution would be the same, greater than, or less than your calculated value in **(c)(i)**.

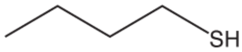
Explain your reasoning.

---**[2]**

10. This question is about organic molecules that have a strong smell.

Thiols are foul-smelling, organic sulfur compounds with the functional group –SH.

Butane-1-thiol, shown below, contributes to the strong smell of skunks.



butane-1-thiol

i. Thiols are weak acids.

Write the expression for the acid dissociation constant, K_a, for butane-1- thiol.

ii. Thiols react with carboxylic acids to form thioesters.

Write an equation for the reaction of butane-1-thiol with ethanoic acid.

Use structures for all organic compounds with the functional groups clearly displayed.

iii. When beer is exposed to light, 3-methylbut-2-ene-1-thiol is formed, which gives an unpleasant smell and flavour to the beer.

Draw the **skeletal** formula for 3-methylbut-2-ene-1-thiol.

iv. Propane-1,3- dithiol reacts with carbonyl compounds in a condensation reaction to form a cyclic organic sulfur product.

Write an equation for the reaction of propane-1,3-dithiol with propanone.

Use structures for organic compounds.

11. When concentrated sulfuric acid is added to water, dissociation takes place in two stages.

Stage 1: $H_2SO_4 \rightarrow H^+ + HSO_4^-$

Stage 2: $HSO_4^- \rightleftharpoons H^+ + SO_4^{2-}$

i. 0.100 mol dm^{-3} sulfuric acid has a pH of 0.96.

Explain this observation. Your answer should include a calculation.

[3]

ii. A student adds an excess of aqueous sodium carbonate to dilute sulfuric acid.

- Predict what the student would observe.
- Explain what happens to the equilibrium in **Stage 2** as the aqueous sodium carbonate is added.

Observation

Explanation

[2]

12(a). This question is about vitamin C, $C_6H_8O_6$.

Vitamin C is a weak monobasic acid with a K_a value of 6.76×10^{-5} mol dm^{-3}.

i. Write the expression for K_a for vitamin C.

[1]

ii. Calculate pK_a for vitamin C, to **two** decimal places.

[1]

iii. A bottle of vitamin C supplements contains tablets, each containing 500 mg of vitamin C.

A student dissolves three vitamin C tablets in water and makes up the solution to a volume of 250.0 cm^3.

Calculate the pH of the solution.

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

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

(b). Low acidity vitamin C tablets are less acidic than tablets containing just vitamin C.

A student dissolves a low acidity vitamin C tablet in water.

- The tablet contains a mixture of 300 mg of vitamin C, $C_6H_8O_6$, and the sodium salt of vitamin C, $C_6H_7O_6Na$.
- The pH of the solution is 4.02.

i. Calculate the ratio $C_6H_7O_6^-$: $C_6H_8O_6$ in the solution.

Show your working.

$$\frac{[C_6H_7O_6^-]}{[C_6H_8O_6]} = \frac{\text{...............}}{1}$$ **[3]**

ii. Calculate the mass of $C_6H_7O_6Na$, in mg, in the low acidity vitamin C tablet.

mass = ... mg **[1]**

(c). The sodium salt of vitamin C can be made by reacting vitamin C with aqueous sodium hydroxide.

An aqueous solution of sodium hydroxide had a pH of 12.72 at 298 K.

Calculate the concentration, in mol dm^{-3}, of the NaOH solution.

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

13(a). A chemist carries out some experiments using nitrous acid, HNO_2(aq).

HNO_2 is a weak acid with a K_a value of 4.69×10^{-4} mol dm^{-3} at the temperature of the chemist's experiments.

Write the expression for K_a for HNO_2(aq).

[1]

(b). Calculate the pH of 0.120 mol dm^{-3} HNO_2(aq).

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

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

(c). The chemist prepares 1dm^3 of a buffer solution by mixing 200 cm^3 of 0.200 mol dm^{-3} HNO_2 with 800 cm^3 of 0.0625 mol dm^{-3} sodium nitrite, $NaNO_2$.

i. Calculate the pH of the buffer solution.

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

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

ii. Explain how this buffer solution controls pH when:

- a small amount of HC*l*(aq) is added
- a small amount of NaOH(aq) is added.

*In your answer, include the equation for the equilibrium in the buffer solution and explain how **this** equilibrium system controls the pH.*

[4]

(d). The dissociation of water is shown below.

$H_2O(l) \rightleftharpoons H^+(aq) + OH^-(aq)$

At 60 °C, the ionic product of water, K_w, is 9.311×10^{-14} $mol^2\ dm^{-6}$.

At 25 °C, the ionic product of water, K_w, is 1.000×10^{-14} $mol^2\ dm^{-6}$.

i. Explain whether the dissociation of water is an exothermic or endothermic process.

--- **[1]**

ii. Predict, using a calculation, whether a pH of 7 at 60 °C is neutral, acidic or alkaline.

--- **[2]**

iii. pK_w, pK_a and pH are logarithmic scales.

Calculate pK_w at 60 °C.

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

pK_w = ... **[1]**

iv. 20.0 cm^3 of 0.0270 mol dm^{-3} NaOH is diluted with water and the solution made up to 100 cm^3 at 60 °C.

Calculate the pH of the diluted solution of NaOH at 60 °C.

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

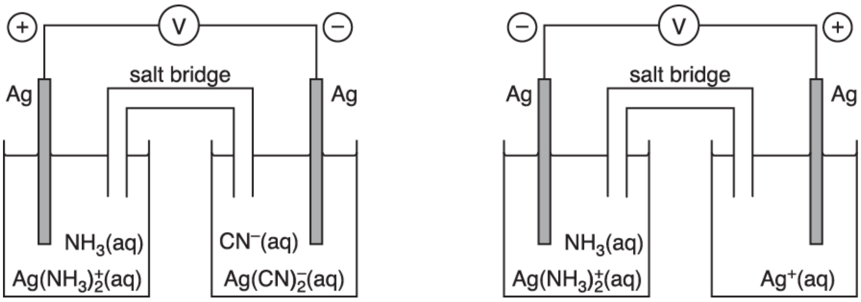
pH = ... **[3]**

14. Three redox systems, **C**, **D** and **E** are shown in Table 6.1.

C	$Ag(NH_3)_2{}^+(aq) + e^- \rightleftharpoons Ag(s) + 2NH_3(aq)$
D	$Ag^+(aq) + e^- \rightleftharpoons Ag(s)$
E	$Ag(CN)_2{}^-(aq) + e^- \rightleftharpoons Ag(s) + 2CN^-(aq)$

Table 6.1

The two cells below were set up in an experiment to compare the standard electrode potentials of redox systems **C**, **D** and **E**. The signs on each electrode are shown.



The CN^- ion is the conjugate base of a very toxic weak acid.

In aqueous solutions of CN^- ions, an acid–base equilibrium is set up.

i. Complete the equation for this equilibrium and label the conjugate acid–base pairs.

CN^- + H_2O $\rightleftharpoons$ .... + ...

....

[1]

ii. Explain, in terms of equilibrium, why acidic conditions should **not** be used with cells containing $CN^-(aq)$ ions.

--- **[1]**

15(a). A student is supplied with 0.500 mol dm^{-3} potassium hydroxide, KOH, and 0.480 mol dm^{-3} propanoic acid, C_2H_5COOH.

The acid dissociation constant, K_a, for C_2H_5COOH is 1.35×10^{-5} mol dm^{-3}.

C_2H_5COOH is a weak Brønsted−Lowry acid.

What is meant by a *weak acid* and *Brønsted−Lowry acid*?

--- **[1]**

(b). Calculate the pH of 0.500 mol dm^{-3} potassium hydroxide.

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

(c). The student dilutes 25.0 cm^3 0.480 mol dm^{-3} C_2H_5COOH by adding water until the total volume is 100.0 cm^3.

i. Write the expression for K_a for C_2H_5COOH.

[1]

ii. Calculate the pH of the diluted solution.

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

(d). A student prepares a buffer solution containing propanoic acid C_2H_5COOH and propanoate ions, $C_2H_5COO^-$. The concentrations of C_2H_5COOH and $C_2H_5COO^-$ are both 1.00 mol dm^{-3}.

The following equilibrium is set up.

$$C_2H_5COOH(aq) \rightleftharpoons C_2H_5COO^-(aq) + H^+(aq)$$

The acid dissociation constant, K_a, for C_2H_5COOH is 1.35×10^{-5} mol dm^{-3}.

i. Calculate the pH of this buffer solution.

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

pH = ... **[1]**

ii. A small amount of aqueous ammonia, $NH_3(aq)$, is added to the buffer solution.

Explain, in terms of equilibrium, how the buffer solution would respond to the added $NH_3(aq)$.

-- **[2]**

iii. The student adds 6.075 g Mg to 1.00 dm^3 of this buffer solution.

Calculate the pH of the new buffer solution.

Give your answer to **two** decimal places

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

16(a). Ethanoic acid, CH_3COOH, is a weak Brønsted—Lowry acid.

An acid—base equilibrium is set up when ethanoic acid is added to water.

Write the equation for the equilibrium that would be set up and label the two conjugate acid—base pairs.

.... + ... $\rightleftharpoons$ .... + ...

....

[2]

(b). An aqueous solution of CH_3COOH has a pH of 3.060.
This solution contains both hydrogen ions and hydroxide ions.

i. How can an aqueous solution of an acid contain hydroxide ions?

--- **[1]**

ii. Calculate the concentration of hydroxide ions in this solution of ethanoic acid.

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

(c). A student adds an excess of aqueous ethanoic acid to solid calcium carbonate.
The resulting solution is able to act as a buffer solution.

i. Write a full equation for the reaction between ethanoic acid and solid calcium carbonate.

--- **[1]**

ii. Explain why this buffer solution has formed.

--- **[1]**

iii. Explain how this buffer solution controls pH when either 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.

[5]

(d). A biochemist plans to make up a buffer solution with a pH of 5.000.
The biochemist adds solid sodium ethanoate, CH_3COONa, to 400 cm^3 of 0.200 mol dm^{-3} ethanoic acid.
K_a for ethanoic acid = 1.75×10^{-5} mol dm^{-3}

Calculate the mass of sodium ethanoate that the biochemist needs to dissolve in the ethanoic acid to prepare this buffer solution.

Assume that the volume of the solution remains constant at 400 cm^3 on dissolving the sodium ethanoate.

[5]

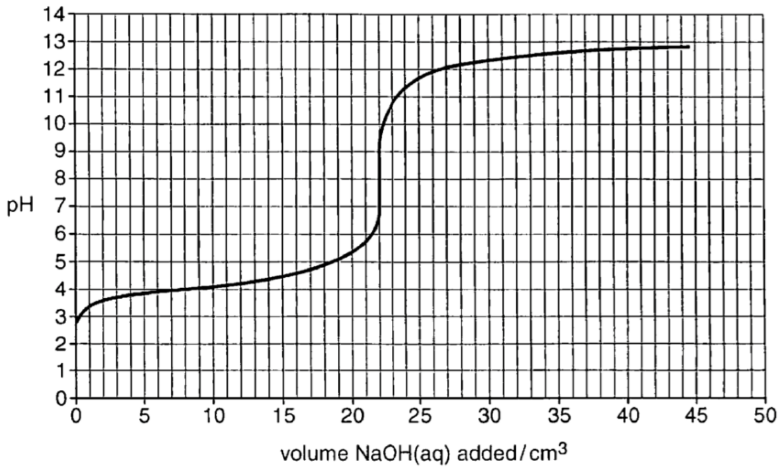
17(a). This question is about different weak acids.

A student carries out a titration to determine the concentration of a solution of ethanoic acid.

The method is outlined below.

- A 25.0 cm^3 sample of $CH_3COOH(aq)$ is pipetted into a conical flask.
- The $CH_3COOH(aq)$ is titrated by adding 0.125 mol dm^{-3} NaOH from a burette.
- The pH of the solution is measured continuously, with stirring, as the NaOH(aq) is added.

The pH titration curve is shown below.



i. How could the student measure the pH continuously as the NaOH(aq) is added?

-- **[1]**

ii. Determine the unknown concentration, in mol dm^{-3}, of the $CH_3COOH(aq)$.
Show your working.

concentration of $CH_3COOH(aq)$ = ...mol dm^{-3} **[2]**

(b). The table shows the pH ranges of four indicators.

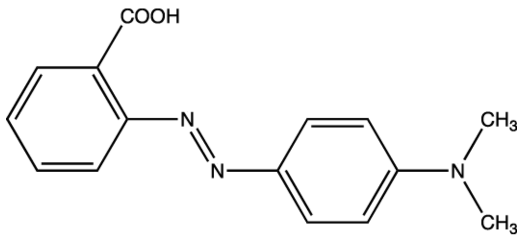
Indicator	congo red	methyl red	brilliant yellow	alizarin yellow R
pH range	3.0–5.0	4.4–6.2	6.6–7.8	10.1–12.0

i. Choose, with a reason, the indicator from the table that is most suitable for the student's titration in **(a)**.

---**[1]**

ii. An indicator is a weak acid, HA, which has a different colour from its conjugate base, A^-.

For methyl red, the HA form is red and the A^- form is yellow.
The structure of methyl red is shown below.



methyl red

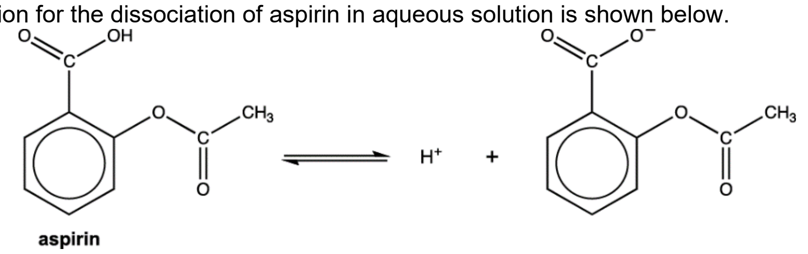
Draw the structure of the conjugate base of methyl red and explain, in terms of equilibrium, the colours of methyl red at low pH, at high pH, and at the end point of a titration. You can use HA and A^- in your explanation.

explanation: ---

---**[4]**

(c). Aspirin is a weak acid with a pK_a value of 3.40 and a solubility in water of 1.00×10^{-2} g cm^{-3} at body temperature (37 °C).

The equation for the dissociation of aspirin in aqueous solution is shown below.



i. Calculate the pH of a saturated solution of aspirin in water at body temperature.

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

ii. 'Soluble aspirin' is usually sold as the sodium or calcium salt of aspirin.

Suggest why salts of aspirin are more soluble than aspirin in water.

-- **[1]**

iii. The stomach contains hydrochloric acid at a pH of about 1–3.

Explain why swallowing soluble aspirin may lead to irritation of the stomach lining.

-- **[2]**

18(a). A student investigates the reactions of two weak monobasic acids: 2-hydroxypropanoic acid, $CH_3CH(OH)COOH$, and butanoic acid, $CH_3CH_2CH_2COOH$.

The student wants to prepare a standard solution of 2-hydroxypropanoic acid that has a pH of 2.19.

Plan how the student could prepare 250 cm^3 of this standard solution from solid 2-hydroxypropanoic acid.

In your answer you should provide detail of the practical procedure that would be carried out, including appropriate quantities and necessary calculations.

K_a for 2-hydroxypropanoic acid is 1.38×10^{-4} mol dm^{-3} at 25 °C.

--- **[8]**

(b). 2-Hydroxypropanoic acid is a slightly stronger acid than butanoic acid. The two acids are mixed together and an acid–base equilibrium is set up.

Suggest the equilibrium equation and identify the conjugate acid–base pairs.

$CH_3CH(OH)COOH + CH_3CH_2CH_2COOH \rightleftharpoons$ ....

[2]

(c). To prepare a buffer solution, 75.0 cm^3 of 0.220 mol dm^{-3} butanoic acid is reacted with 50.0 cm^3 of 0.185 mol dm^{-3} sodium hydroxide.

K_a for butanoic acid is 1.5×10^{-5} mol dm^{-3} at 25 °C.

i. Calculate the pH of 0.185 mol dm^{-3} sodium hydroxide at 25 °C.

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

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

ii. Calculate the pH of the buffer solution at 25 °C.

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

Show **all** your working.

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

19. Methanoic acid is added to water. An acid−base equilibrium is set up containing two acid−base pairs.

Suggest a mechanism for the forward reaction in this equilibrium.

Your mechanism should use displayed formulae and curly arrows, and show all species present at equilibrium.

[2]

20. The complex ion, $[Fe(H_2O)_6]^{3+}$, behaves as a weak Brønsted−Lowry acid in aqueous solution. The equation below represents the dissociation of aqueous $[Fe(H_2O)_6]^{3+}$ ions, together with the K_a value.

$$[Fe(H_2O)_6]^{3+}(aq) \rightleftharpoons [Fe(H_2O)_5OH]^{2+}(aq) + H^+(aq) \qquad K_a = 6.00 \times 10^{-3}\ mol\ dm^{-3}$$

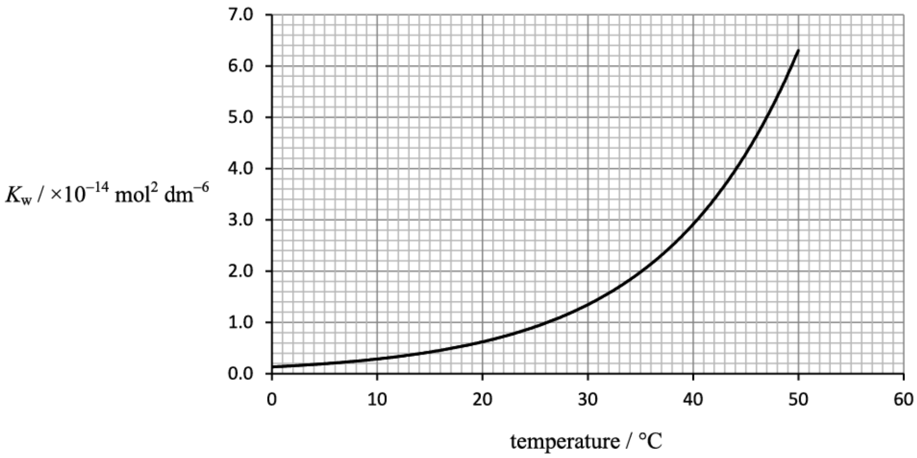
i. Write the expression for the acid dissociation constant, K_a, for $[Fe(H_2O)_6]^{3+}$.

[1]

ii. Calculate the pH of a 0.100 mol dm^{-3} solution of $[Fe(H_2O)_6]^{3+}$ to **two** decimal places.

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

21. The dissociation of water is measured by the ionic product of water, K_w. The value of K_w varies with temperature as shown in the graph below.



Calculate the pH of water at body temperature, 37 °C.

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

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

Nitric acid, HNO_3, and nitrous acid, HNO_2, are two Brønsted–Lowry acids containing nitrogen.

A student measures the pH of 0.0450 mol dm^{-3} solutions of HNO_3 and HNO_2 (pK_a = 3.35) and found that the acids had different pH values.

i. Explain why the pH values are different.

____

____ **[1]**

ii. Calculate the pH value of 0.0450 mol dm^{-3} HNO_3 to **two** decimal places.

Show your working.

pH = ... **[1]**

iii. Calculate the pH value of 0.0450 mol dm^{-3} HNO_2 to **two** decimal places.

Show your working.

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

(b). Rubidium hydroxide, RbOH, is a strong alkali. A technician is asked to prepare a 250.0 cm^3 solution of RbOH with a pH of 12.500.

Calculate the mass of RbOH that the technician needs to use.

mass = ...g **[4]**

END OF QUESTION PAPER