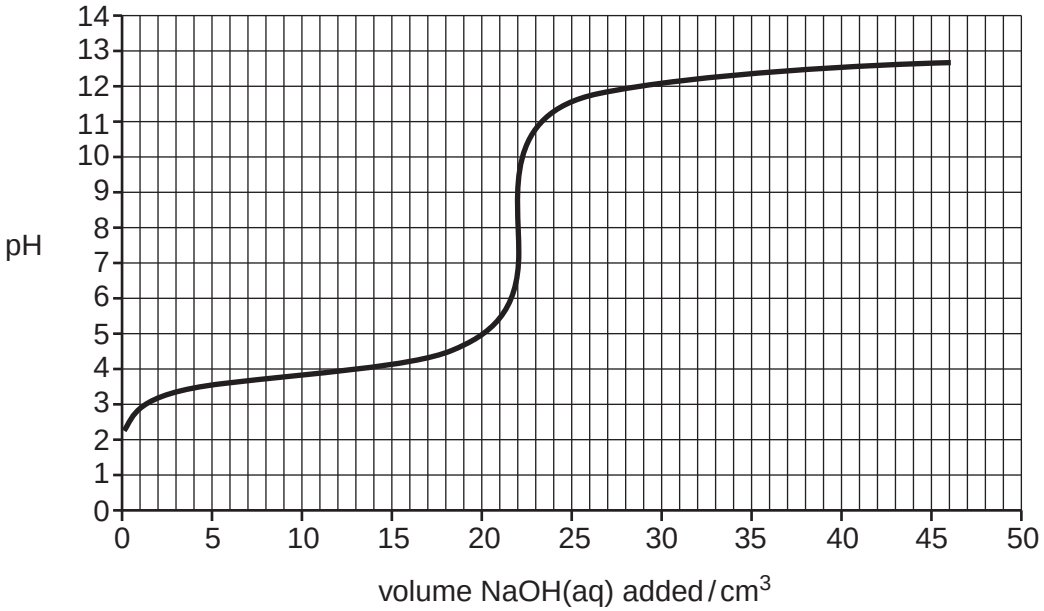
1 Glycolic acid, $HOCH_2COOH$, and thioglycolic acid, $HSCH_2COOH$, are weak acids.

(a) Glycolic acid reacts with bases, such as aqueous sodium hydroxide, NaOH(aq), to form salts.

A student pipetted 25.0 cm^3 of 0.125 mol dm^{-3} glycolic acid into a conical flask. The student added NaOH(aq) from a burette. A pH meter and data logger were used to measure continuously the pH of the contents of the conical flask.

The pH curve that the student obtained is shown below.



1 mol of glycolic acid reacts with 1 mol of sodium hydroxide.

(i) Write the equation for the reaction that takes place in the titration.

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

(ii) Determine the concentration, in mol dm^{-3}, of the NaOH.

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

(iii) The student decided to carry out this titration using an acid–base indicator.

What important factor does the student need to consider when deciding on the most suitable indicator to use for this titration?

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.....

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

(b) The 0.125 mol dm^{-3} glycolic acid had a pH of 2.37.

(i) What is the expression for the acid dissociation constant, K_a, of glycolic acid?

[1]

(ii) Calculate K_a for glycolic acid.

K_a = …… units …… **[3]**

(iii) Calculate the percentage molar dissociation of the glycolic acid.

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

(c) A buffer of glycolic acid and ammonium glycolate is used in a facial cleanser.

Explain, using equations,

- how a solution containing glycolic acid and glycolate ions can act as a buffer
- how this buffer could be prepared from ammonia and glycolic acid.

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

[7]

(d) Ammonium thioglycolate, $HSCH_2COONH_4$, is the ammonium salt of thioglycolic acid, $HSCH_2COOH$.

When ammonium thioglycolate is dissolved in water, an acid–base equilibrium is set up. The equilibrium lies well to the left-hand side.

$HSCH_2COO^-(aq)$ + $NH_4^+(aq)$ $\rightleftharpoons$ $HSCH_2COOH(aq)$ + $NH_3(aq)$

…… …… …… ……

In the spaces above,

- label one conjugate acid–base pair as '**Acid 1**' and '**Base 1**'
- label the other conjugate acid–base pair as '**Acid 2**' and '**Base 2**'. **[2]**

(e) Ammonium thioglycolate is used by hairdressers to perm hair.

Hair is a protein and its shape is largely the result of cross-linked disulfide bonds, –S–S–. The formula of the protein in hair can be represented as R–S–S–R.

Perming of hair involves two stages.

Stage 1

- Hair is first wound around curlers and a solution of ammonium thioglycolate is applied to the hair.
- In this process, each disulfide bond is broken by two thioglycolate ions to form two molecules containing thiol groups, –S–H, and one other product.

Stage 2

- After 15–30 minutes, the hair is rinsed with a weak solution of hydrogen peroxide, H_2O_2.
- The hydrogen peroxide reforms disulfide bonds that lock the hair in the shape of the curlers. The hair is now 'permed'.

Suggest equations for the two processes that take place during perming.
In your equations, use R–S–S–R to represent the protein in hair.

Stage 1

Stage 2

[2]

[Total: 20]

2 The dissociation of water is a reversible reaction.

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

The ionic product of water, K_w, measures the extent of dissociation of water.

K_w varies with temperature. Therefore, it is always important to quote the temperature at which measurements are being taken.

Fig. 6.1 shows the variation of K_w between 0 °C and 60 °C.

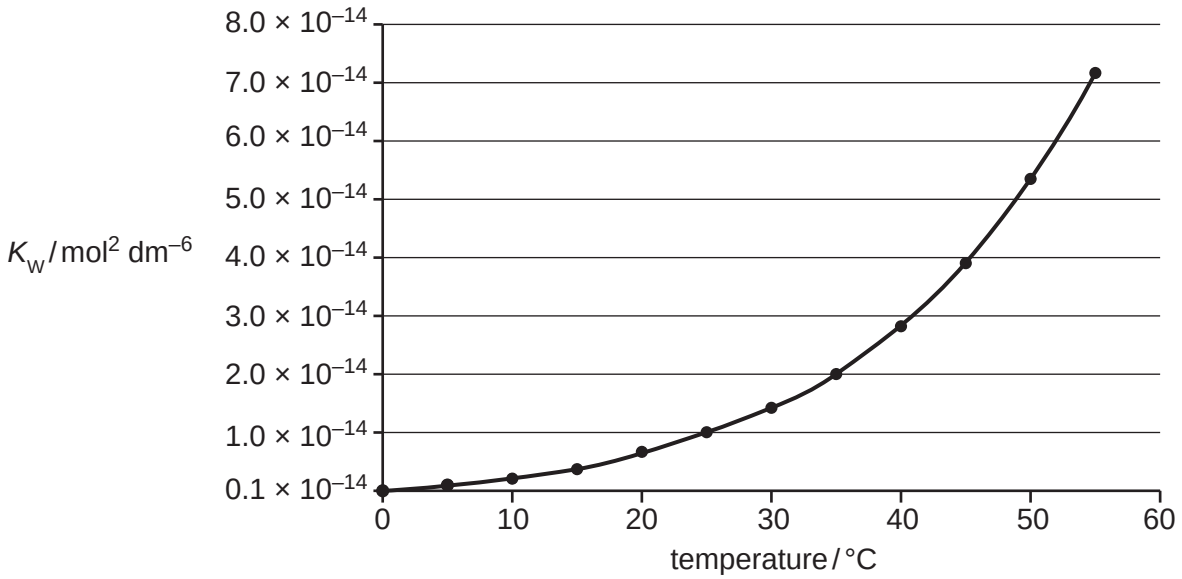

Fig. 6.1

(a) (i) Write the expression for K_w.

.....

[1]

(ii) Calculate the $OH^-(aq)$ concentration in an aqueous solution of hydrochloric acid with a pH of 4.37 at 25 °C.

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

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

(b) (i) Using **Fig. 6.1**, explain whether the dissociation of water is an exothermic or endothermic process.

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

(ii) Determine the pH of pure water at body temperature, 37 °C.

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

(iii) Many experimental measurements use published data, such as K_w, measured at 25 °C. Often these measurements have been taken at different temperatures, especially in experimental work carried out at body temperature.

What is the consequence of this for published scientific work?

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

(c) The reverse reaction of the dissociation of water is called neutralisation.

Plan an experiment that a student could carry out to measure the enthalpy change of neutralisation.

In your answer you should explain how the enthalpy change of neutralisation could be calculated from the experimental results.

.... **[6]**

(d) When dissolved in water, the enthalpy change of solution of the salt potassium fluoride, KF, is $-15\,kJ\,mol^{-1}$.

The salt rubidium fluoride, RbF, has an enthalpy change of solution in water of $-24\,kJ\,mol^{-1}$.

Suggest reasons for the difference between the enthalpy changes of solution of KF and RbF.

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

(e) A student hurt his ankle whilst playing football. The physiotherapist applied a cold pack to soothe the pain.

The cold pack is made of two separated compartments, one containing ammonium nitrate crystals, NH_4NO_3, the other containing water. The pack is activated by breaking the barrier between the two compartments. The crystals dissolve spontaneously in the water causing the temperature of the pack to drop.

Explain why ammonium nitrate in the cold pack dissolves spontaneously in water even though this process is endothermic.

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

[Total: 20]