**Q1.**          The value of the acid dissociation constant, *K*a, for ethanoic acid is 1.74 × 10–5 mol dm–3 at 298 K.

(a)     (i)      Write an expression for *K*a for ethanoic acid.

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(ii)     Calculate the pH at 298 K of a 0.220 mol dm–3 solution of ethanoic acid.

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**(5)**

(b)     A sample of the 0.220 mol dm–3 solution of ethanoic acid was titrated against sodium hydroxide solution.

(i)      Calculate the volume of a 0.150 mol dm–3 solution of sodium hydroxide required to neutralise 25.0 cm3 of the ethanoic acid solution.

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(ii)     From the list below, select the best indicator for this titration and explain your choice.

**Name of indicator       pH range**

bromophenol blue         3.0 – 4.6

methyl red                     4.2 – 6.3

bromothymol blue         6.0 – 7.6

thymol blue                    8.0 – 9.6

*Indicator* ..............................................................................................

*Explanation* .........................................................................................

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**(5)**

(c)     A buffer solution is formed when 2.00 g of sodium hydroxide are added to 1.00 dm3 of a 0.220 mol dm–3 solution of ethanoic acid.

Calculate the pH at 298 K of this buffer solution.

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**(6)**

**(Total 16 marks)**

**Q2.**          A 0.210 mol dm–3 solution of potassium hydroxide was added from a burette to 25.0 cm3 of a 0.160 mol dm–3 solution of ethanoic acid in a conical flask.  
Given that the value of the acid dissociation constant, *K*a, for ethanoic acid is 1.74 × 10–5 mol dm–3, calculate the pH at 25 °C of the solution in the conical flask at the following three points:

before any potassium hydroxide had been added;

after 8.0 cm3 of potassium hydroxide solution had been added;

after 40.0 cm3 of potassium hydroxide solution had been added.

**(Total 16 marks)**

**Q3.**          (a)     Methylamine is a weak Brønsted-Lowry base and can be used in aqueous solution with one other substance to prepare a basic buffer.

(i)      Explain the term *Br*ø*nsted-Lowry base* and write an equation for the reaction of methylamine with water to produce an alkaline solution.

*Brønsted-Lowry base* ..........................................................................

*Equation* ..............................................................................................

(ii)     Suggest a substance that could be added to aqueous methylamine to produce a basic buffer.

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(iii)     Explain how the buffer solution in part (a)(ii) is able to resist a change in pH when a small amount of sodium hydroxide is added.

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**(5)**

(b)     Explain why methylamine is a stronger base than ammonia.

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**(2)**

(c)     A cation is formed when methylamine reacts with a large excess of bromoethane. Name the mechanism involved in the reaction and draw the structure of the cation formed.

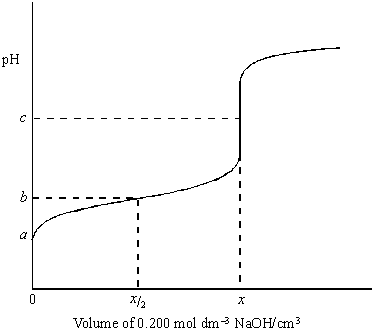
*Name of mechanism* ....................................................................................

*Structure*

**(2)**

**(Total 9 marks)**

**Q4.**          The sketch below shows the change in pH when a 0.200 mol dm–3 solution of sodium hydroxide is added from a burette to 25.0 cm3 of a 0.150 mol dm-3 solution of the weak acid HA at 25 °C.



(a)     The volume of sodium hydroxide solution added at the equivalence point is *x* cm3.  
Calculate the value of *x.*

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**(2)**

(b)     (i)      Define the term pH.

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(ii)     The pH at the equivalence point is *c*. Suggest a value for *c*.

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(iii)     Identify a suitable indicator for detecting the equivalence point of the titration.

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**(3)**

(c)     The value of *K*c for the weak acid HA at 25 °C is 2.75 × 10–5 mol dm–3.

(i)      Explain the term *weak* as applied to the acid HA.

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(ii)     Write an expression for *K*a for the acid HA.

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(iii)     Calculate the pH of the 0.150 mol dm–3 solution of acid HA before any sodium hydroxide is added, i.e. the pH at point *a*.

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**(5)**

(d)     Calculate the pH of the solution formed when cm3 of the 0.200 mol dm–3 solution of sodium hydroxide are added to 25.0 cm3 of the 0.150 mol dm–3 solution of HA, i.e. the pH at point *b*.

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**(3)**

**(Total 13 marks)**

**Q5.**          (a)     At 50°C, the ionic product of water, *K*w, has the value 5.48 × 10–14 mol2 dm–6.

(i)      Define the term *K*w

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(ii)     Define the term *pH*

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(iii)     Calculate the pH of pure water at 50 °C. Explain why pure water at 50 °C is still neutral even though its pH is not 7.

*Calculation* ..........................................................................................

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*Explanation .*.........................................................................................

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**(5)**

(b)     At 25°C, *K*w has the value 1.00 × 10–14 mol2 dm–6. Calculate the pH at 25 °C of

(i)      a 0.150 mol dm–3 solution of sodium hydroxide,

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(ii)     the solution formed when 35.0 cm3 of this solution of sodium hydroxide is mixed with 40.0 cm3 of a 0.120 mol dm–3 solution of hydrochloric acid.

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**(8)**

(c)     In a 0.150 mol dm–3 solution of a weak acid HX at 25 °C, 1.80% of the acid molecules are dissociated into ions.

(i)      Write an expression for *K*a for the acid HX.

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(ii)     Calculate the value of *K*a for the acid HX at this temperature and state its units.

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**(5)**

**(Total 18 marks)**

**Q6.**          (a)     By reference to the forces between molecules, explain why ammonia is very soluble in water.

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**(2)**

(b)     Aqueous solutions of ammonia have a pH greater than 7.

(i)      Write an equation for the reaction of ammonia with water.

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(ii)     Explain why the pH of a solution containing 1.0 mol dm–3 of ammonia is less than   
14 at 298 K.

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**(3)**

(c)     An ammonium ion in aqueous solution can behave as a Brønsted–Lowry acid. State what is meant by the term *Brønsted–Lowry acid*.

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**(1)**

(d)     State what is meant by the term *buffer solution*. Identify a reagent which could be added to a solution of ammonia in order to form a buffer solution.

*Buffer solution* ..............................................................................................

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*Reagent* ........................................................................................................

**(3)**

(e)     An acidic buffer solution is obtained when sodium ethanoate is dissolved in aqueous ethanoic acid.

(i)      Calculate the pH of the buffer solution formed at 298 K when 0.125 mol of sodium ethanoate is dissolved in 250 cm3 of a 1.00 mol dm–3 solution of ethanoic acid.  
The acid dissociation constant, *K*a, for ethanoic acid is 1.70 × 10–5 mol dm–3 at 298 K.

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(ii)     Write an ionic equation for the reaction which occurs when a small volume of dilute hydrochloric acid is added to this buffer solution.

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**(5)**

**(Total 14 marks)**

**Q7.**          (a)     The pH of a 0.120 mol dm–3 solution of the weak monoprotic acid, HX, is 2.56 at 298 K.

(i)      Write an expression for the term *pH*.

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(ii)     Write an expression for the dissociation constant, *K*a, for the weak acid HX and calculate its value at 298 K.

*Expression for K*a .................................................................................

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*Calculation* ..........................................................................................

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**(5)**

(b)     (i)      Write an expression for the ionic product of water, *K*w, and give its value at 298 K.

*Expression for K*w ................................................................................

*Value of K*w ..........................................................................................

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(ii)     Hence, calculate the pH of a 0.0450 mol dm–3 solution of sodium hydroxide at 298 K.

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**(4)**

(c)     A titration curve is plotted showing the change in pH as a 0.0450 mol dm–3 solution of sodium hydroxide is added to 25.0 cm3 of a solution of ethanedioic acid, H2C2O4The titration curve obtained has two equivalence points (end points).

(i)      Write an equation for the reaction which is completed at the **first** equivalence point.

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(ii)     When the **second** equivalence point is reached, a total of 41.6 cm3 of 0.0450 mol dm–3 sodium hydroxide has been added.  
Calculate the concentration of the ethanedioic acid solution.

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**(4)**

(d)     Draw the structure of the organic product formed in each case when, in the presence of a small amount of concentrated sulphuric acid, ethanedioic acid reacts with

(i)      an excess of methanol,

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(ii)     an equimolar amount of ethane-1,2-diol.

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**(2)**

**(Total 15 marks)**

**Q8.**          The value of the acid dissociation constant, *K*a, for the weak acid HA, at 298 K, is  
1.45 × 10–4 mol dm–3.

(a)     Write an expression for the term *K*a for the weak acid HA.

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**(1)**

(b)     Calculate the pH of a 0.250 mol dm–3 solution of HA at 298 K.

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**(4)**

(c)     A mixture of the acid HA and the sodium salt of this acid, NaA, can be used to prepare a buffer solution.

(i)      State and explain the effect on the pH of this buffer solution when a small amount of hydrochloric acid is added.

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(ii)     The concentration of HA in a buffer solution is 0.250 mol dm–3. Calculate the concentration of A– in this buffer solution when the pH is 3.59

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**(6)**

**(Total 11 marks)**

**Q9.**         (a)     The Period 3 elements, Na, Mg, Al, Si, P and S, all form oxides when the elements are burned in an excess of oxygen.

(i)      Give the formula of an oxide of **one** of these elements in which the element is not in its highest oxidation state. Give the oxidation state of the element in this oxide.

*Formula of oxide .*................................................................................

*Oxidation state of element* ..................................................................

(ii)     Write an equation for the reaction in which phosphorus(V) oxide is formed from phosphorus and oxygen.

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**(3)**

(b)     The melting points of some of the oxides formed by Period 3 elements are given in a random order below.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Oxide | **A** | **B** | **C** | **D** | **E** |
| *T*m/ °C | 2852 | –73 | 1610 | 1275 | 300 |

(i)      Using the letters **A** to **E**, give **two** oxides which have simple molecular structures.

Explain your answer.

*Oxide 1* ...............................................................................................

*Oxide 2* ...............................................................................................

*Explanation* .........................................................................................

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(ii)     Give a simple chemical test which could be used to show which of the oxides in the table is sodium oxide. State the observation you would make.

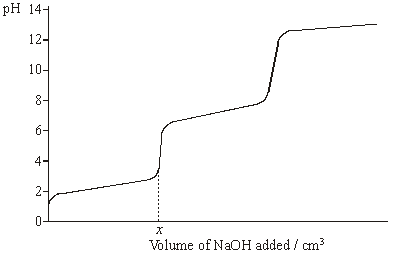
*Chemical test* .................................................................................…..

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*Observation* .........................................................................................

**(6)**

(c)     The pH curve for the titration of the weak diprotic acid H2SO3 with aqueous sodium hydroxide is shown below.



(i)      Identify the sodium salt formed from H2SO3 when *x* cm3 of NaOH have been added.

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(ii)     Write an equation for the reaction that occurs between the two end-points (equivalence points).

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(iii)     Name an indicator which could be used to determine the second end-point (equivalence point).

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**(3)**

**(Total 12 marks)**

**Q10.**          This question concerns the weak acid, ethanoic acid, for which the acid dissociation constant, *K*a, has a value of 1.74 × 10–5mol dm–3 at 25 °C.



In each of the calculations below, give your answer to 2 decimal places.

(a)     Write an expression for the term *pH*. Calculate the pH of a 0.150 mol dm–3 solution of ethanoic acid.

**(4)**

(b)     A buffer solution is prepared by mixing a solution of ethanoic acid with a solution of sodium ethanoate.

(i)      Explain what is meant by the term *buffer solution*.

(ii)     Write an equation for the reaction which occurs when a small amount of hydrochloric acid is added to this buffer solution.

**(3)**

(c)     In a buffer solution, the concentration of ethanoic acid is 0.150 mol dm–3 and the concentration of sodium ethanoate is 0.100 mol dm–3.

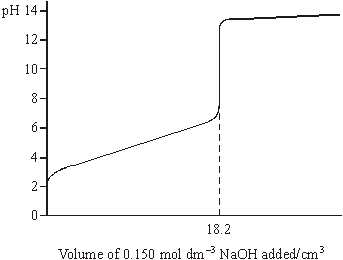
(i)      Calculate the pH of this buffer solution.

(ii)     A 10.0 cm3 portion of 1.00 mol dm–3 hydrochloric acid is added to 1000 cm3 of this buffer solution.  
Calculate the number of moles of ethanoic acid and the number of moles of sodium ethanoate in the solution after addition of the hydrochloric acid. Hence, find the pH of this new solution.

**(8)**

**(Total 15 marks)**

**Q11.**          The pH curve shown below was obtained when a 0.150 mol dm–3 solution of sodium hydroxide was added to 25.0 cm3 of an aqueous solution of a weak monoprotic acid, HA.



(a)     Use the information given to calculate the concentration of the acid.

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**(2)**

(b)     (i)      Write an expression for the acid dissociation constant, *K*a, for HA.

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(ii)     Write an expression for p*K*a

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(iii)     Using your answers to parts (b)(i) and (b)(ii), show that when sufficient sodium hydroxide has been added to neutralise half of the acid,

pH of the solution = p*K*a for the acid HA

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**(4)**

(c)     Explain why dilution with a small volume of water does not affect the pH of a buffer solution.

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**(2)**

(d)     (i)      Calculate the change in pH when 0.250 mol dm–3 hydrochloric acid is diluted with water to produce 0.150 mol dm–3 hydrochloric acid.

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(ii)     Calculate the volume of water which must be added to 30.0 cm3 of 0.250 mol dm–3  hydrochloric acid in order to reduce its concentration to 0.150 mol dm–3.

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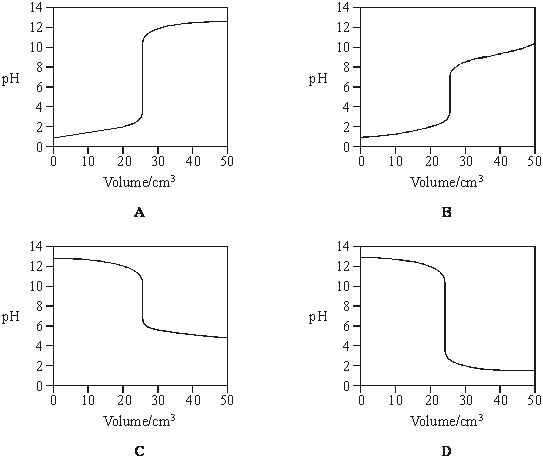
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**(4)**

**(Total 12 marks)**

**Q12.**          (a)     Titration curves labelled **A**, **B**, **C** and **D** for combinations of different acids and bases are shown below. All solutions have a concentration of 0.1 mol dm–3.



(i)      Select from **A**, **B**, **C** and **D** the curve produced by the addition of

ammonia to 25 cm3 of hydrochloric acid  ................................................

ethanoic acid to 25 cm3 of sodium hydroxide  .........................................

sodium hydroxide to 25 cm3 of hydrochloric acid  ...................................

(ii)     A table of acid–base indicators and the pH ranges over which they change colour is shown below.

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Indicator** | **pH range** |  |
|  | Thymol blue | 1.2 – 2.8 |  |
|  | Bromophenol blue | 3.0 – 4.6 |  |
|  | Methyl red | 4.2 – 6.3 |  |
|  | Cresolphthalein | 8.2 – 9.8 |  |
|  | Thymolphthalein | 9.3 – 10.5 |  |

Select from the table an indicator which could be used in the titration which produces curve **A** but not in the titration which produces curve **B**.

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**(4)**

(b)     (i)      Write an expression for the term *pH*.

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(ii)     A solution of potassium hydroxide has a pH of 11.90 at 25°C. Calculate the concentration of potassium hydroxide in the solution.

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**(4)**

(c)     The acid dissociation constant, *K*a, for propanoic acid has the value of   
1.35 × 10–5mol dm–3 at 25 °C.



In each of the calculations below, give your answer to 2 decimal places.

(i)      Calculate the pH of a 0.117 mol dm–3 aqueous solution of propanoic acid.

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(ii)     Calculate the pH of a mixture formed by adding 25 cm3 of a 0.117 mol dm–3 aqueous solution of sodium propanoate to 25 cm3 of a 0.117 mol dm–3 aqueous solution of propanoic acid.

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**(5)**

**(Total 13 marks)**

**Q13.**In this question, give all pH values to 2 decimal places.

(a)     (i)      Write expressions for the ionic product of water, *K*w, and for pH.

KW = ….................................................................................................

pH = ....................................................................................................

(ii)     At 318 K, the value of *K*w is 4.02 × 10–14 mol2 dm–6 and hence the pH of pure water is 6.70  
State why pure water is not acidic at 318 K.

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(iii)     Calculate the number of moles of sodium hydroxide in 2.00 cm3 of 0.500 mol dm–3 aqueous sodium hydroxide.

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(iv)    Use the value of *K*w given above and your answer to part (a)(iii) to calculate the pH of the solution formed when 2.00 cm3 of 0.500 mol dm–3 aqueous sodium hydroxide are added to 998 cm3 of pure water at 318 K.

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**(6)**

(b)     At 298 K, the acid dissociation constant, *K*a, for propanoic acid, CH3CH2COOH, has the value 1.35 × 10–5mol dm–3.

(i)      Write an expression for *K*a for propanoic acid.

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(ii)     Calculate the pH of 0.125 mol dm–3 aqueous propanoic acid at 298 K.

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**(4)**

(c)     Sodium hydroxide reacts with propanoic acid as shown in the following equation.

NaOH + CH3CH2COOH → CH3CH2COONa + H2O

A buffer solution is formed when sodium hydroxide is added to an excess of aqueous propanoic acid.

(i)      Calculate the number of moles of propanoic acid in 50.0 cm3 of 0.125 mol dm–3 aqueous propanoic acid.

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(ii)     Use your answers to part (a)(iii) and part (c)(i) to calculate the number of moles of propanoic acid in the buffer solution formed when 2.00 cm3 of 0.500 mol dm–3 aqueous sodium hydroxide are added to 50.0 cm3 of 0.125 mol dm–3 aqueous propanoic acid.

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(iii)     Hence calculate the pH of this buffer solution at 298 K.

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**(6)**

**(Total 16 marks)**

**Q14.**          The hydrolysis of methyl propanoate was studied in acidic conditions at 25°C and the rate equation was found to be

rate = *k*[CH3CH2COOCH3][H+]

(a)     Use the data below to calculate the value of the rate constant, *k*, at this temperature.  
Deduce its units.

|  |  |  |
| --- | --- | --- |
| Initial rate of reaction /  mol dm–3 s–1 | Initial concentration of methyl propanoate / mol dm–3 | Initial concentration of hydrochloric acid / mol dm–3 |
| 1.15 × 10–4 | 0.150 | 0.555 |

*Rate constant* ...............................................................................................

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*Units* .............................................................................................................

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**(3)**

(b)     The reaction in part (a) was repeated at the same temperature, but water was added so that the volume of the reaction mixture was doubled. Calculate the initial rate of reaction under these conditions.

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**(1)**

(c)     A third experiment was carried out at a different temperature. Some data from this experiment are shown in the table below.

|  |  |  |
| --- | --- | --- |
| Initial rate of reaction / mol dm–3 s–1 | Value of rate constant at this different temperature | Initial methyl propanoate / mol dm–3 |
| 4.56 × 10–5 | 8.94 × 10–4 | 0.123 |

Calculate the initial pH of the reaction mixture. Give your answer to two decimal places.

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**(3)**

**(Total 7 marks)**

**Q15.**          (a)     A sample of hydrochloric acid has a pH of 2.34  
Write an expression for pH and calculate the concentration of this acid.

pH ................................................................................................................

*Concentration* ..............................................................................................

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**(2)**

(b)     A 0.150 mol dm–3 solution of a weak acid, HX, also has a pH of 2.34

(i)      Write an expression for the acid dissociation constant, *K*a, for the acid HX.

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(ii)     Calculate the value of *K*a for this acid and state its units.

*Calculation* .........................................................................................

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*Units* ....................................................................................................

(iii)     Calculate the value of p*K*a for the acid HX. Give your answer to two decimal places.

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**(5)**

(c)     A 30.0 cm3 sample of a 0.480 mol dm–3 solution of potassium hydroxide was partially neutralised by the addition of 18.0 cm3 of a 0.350 mol dm–3 solution of sulphuric acid.

(i)      Calculate the initial number of moles of potassium hydroxide.

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(ii)     Calculate the number of moles of sulphuric acid added.

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(iii)     Calculate the number of moles of potassium hydroxide remaining in excess in the solution formed.

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(iv)    Calculate the concentration of hydroxide ions in the solution formed.

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(v)     Hence calculate the pH of the solution formed. Give your answer to two decimal places.

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**(6)**

**(Total 13 marks)**

**Q16.**          Buffer solutions are important in biological systems and in industry to maintain almost constant pH values.

(a)     In the human body, one important buffer system in blood involves the hydrogencarbonate ion, , and carbonic acid, H2CO3, which is formed when carbon dioxide dissolves in water.

(i)      Use the following equation to explain how this buffer maintains a constant pH of 7.41 even if a small amount of acid enters the bloodstream.

H2CO3(aq)      H+(aq)   +    (aq)

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(ii)     In a sample of blood with a pH of 7.41, the concentration of (aq) ions is 2.50 × 10–2 mol dm–3 and the concentration of H2CO3(aq) is 1.25 × 10–3 mol dm–3.  
Calculate a value for the acid dissociation constant, *K*a, for carbonic acid at this temperature.

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**(5)**

(b)     In industry, the pH of a solution used to dye cloth must be controlled or else the colour varies.

A solution of dye in a beaker is buffered by the presence of ethanoic acid and sodium ethanoate. In the solution, the concentration of ethanoic acid is 0.15 mol dm–3 and the concentration of sodium ethanoate is 0.10 mol dm–3. The value of *K*a for ethanoic acid is 1.74 × 10–5 mol dm–3 at 298 K.

(i)      A 10.0 cm3 portion of 1.00 mol dm–3 hydrochloric acid is added to 1000 cm3 of this buffered solution.

Calculate the number of moles of hydrochloric acid added.

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(ii)     Calculate the number of moles of ethanoic acid and the number of moles of sodium ethanoate in the solution after addition of the hydrochloric acid.

*Mol of ethanoic acid after addition* ......................................................

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*Mol of sodium ethanoate after addition* ..............................................

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(iii)     Hence calculate the pH of this new solution. Give your answer to 2 decimal places.

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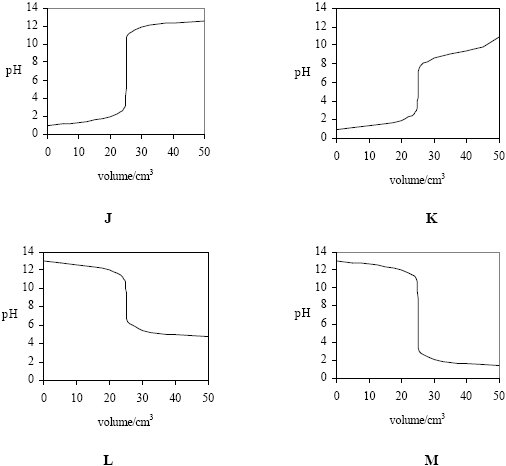
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**(6)**

**(Total 11 marks)**

**Q17.**          Indicators and pH curves can be used to determine the end point in a titration.

(a)     The pH curves labelled **J, K, L** and **M** for combinations of different acids and bases are shown below. All solutions have a concentration of 0.1 mol dm–3.



(i)      Select from **J**, **K**, **L** and **M** the curve produced by the addition of

ammonia to 25 cm3 of hydrochloric acid .............................................

ethanoic acid to 25 cm3 of sodium hydroxide ......................................

sodium hydroxide to 25 cm3 of hydrochloric acid ................................

(ii)     A table of acid–base indicators and the pH ranges over which they change colour is shown below.

|  |
| --- |
| **Indicator**                      **pH range** |
| Thymol blue                  1.2 – 2.8          Bromophenol blue        3.0 – 4.6          Methyl red                     4.2 – 6.3          Cresolphthalein             8.2 – 9.8          Thymolphthalein           9.3 – 10.5 |

Select from the list above an indicator which could be used in the titration which produces curve **J** but not in the titration which produces curve **K**.

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**(4)**

(b)     The acid dissociation constant, *K*a, for the weak acid, ethanoic acid, has a value of 1.74 × 10–5 mol dm–3 at 25 °C.

*K*a = 

(i)      Write an expression for the term pH.

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(ii)     Calculate the pH of a 0.15 mol dm–3 solution of ethanoic acid. Give your answer to   
2 decimal places.

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**(4)**

**(Total 8 marks)**

**Q18.**          In this question, give all values of pH to 2 decimal places.

(a)     (i)      Write an expression for the term pH.

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**(1)**

(ii)     Calculate the concentration, in mol dm–3, of an aqueous solution of sulfuric acid that has a pH of 0.25

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**(2)**

(b)     A student carried out a titration by adding an aqueous solution of sodium hydroxide from a burette to an aqueous solution of ethanoic acid. The end-point was reached when 22.60 cm3 of the sodium hydroxide solution had been added to 25.00 cm3 of 0.410 mol dm–3 ethanoic acid.

(i)      Write an equation for the reaction between sodium hydroxide and ethanoic acid.

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**(1)**

(ii)     Calculate the concentration, in mol dm–3, of the sodium hydroxide solution used.

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**(2)**

(iii)     A list of indicators is shown below.

|  |
| --- |
| **Indicator**                        **pH range** |
| thymol blue                       1.2–2.8 |
| bromophenol blue            3.0–4.6 |
| litmus                                5.0–8.0 |
| cresol purple                    7.6–9.2 |

Select from the list the most suitable indicator for the end-point of this titration.

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**(1)**

(iv)    Suggest why the concentration of sodium hydroxide in a solution slowly decreases when left open to air.

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**(1)**

(c)     At 298 K, the value of the acid dissociation constant, *K*a, for ethanoic acid in aqueous solution is 1.74 × 10–5 mol dm–3

(i)      Write an expression for the acid dissociation constant, *K*a, for ethanoic acid.

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**(1)**

(ii)     Calculate the pH of 0.410 mol dm–3 ethanoic acid at this temperature.

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**(3)**

(iii)     Calculate the pH of the buffer solution formed when 10.00 cm3 of 0.100 mol dm–3 potassium hydroxide are added to 25.00 cm3 of 0.410 mol dm–3 ethanoic acid.

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**(6)**

**(Total 18 marks)**

**Q19.**In this question, give all values of pH to two decimal places.

Calculating the pH of aqueous solutions can involve the use of equilibrium constants such as *K*w and *K*a

*K*w is the ionic product of water. The value of *K*w is 5.48 × 10–14 mol2 dm–6 at 50 °C.

(a)     (i)      Write an expression for pH.

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**(1)**

(ii)     Write an expression for *K*w

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**(1)**

(b)(i)      Calculate the pH of pure water at 50 °C.

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**(2)**

(ii)Suggest why this pure water is **not** acidic.

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**(1)**

(iii)Calculate the pH of 0.140 mol dm–3 aqueous sodium hydroxide at 50 °C.

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**(3)**

(c)Calculate the pH of the solution formed when 25.0 cm3 of 0.150 mol dm–3 aqueous sulfuric acid are added to 30.0 cm3 of 0.200 mol dm–3 aqueous potassium hydroxide at 25 °C. Assume that the sulfuric acid is fully dissociated.

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**(6)**

(d)(i)      Write an expression for the acid dissociation constant, *K*a, for ethanoic acid.

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**(1)**

(ii)The value of *K*a for ethanoic acid is 1.74 × 10–5 mol dm–3 at 25 °C.  
Calculate the pH of a 0.136 mol dm–3 aqueous solution of ethanoic acid at this temperature.

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**(3)**

**(Total 18 marks)**

**Q20.**          This question is about the pH of several solutions.

          Give all values of pH to 2 decimal places.

(a)     (i)      Write an expression for pH.

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**(1)**

(ii)     Calculate the pH of 0.154 mol dm–3 hydrochloric acid.

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**(1)**

(iii)     Calculate the pH of the solution formed when 10.0 cm3 of 0.154 mol dm–3 hydrochloric acid are added to 990 cm3 of water.

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**(2)**

(b)     The acid dissociation constant, *K*a, for the weak acid HX has the value  
4.83 × 10–5 mol dm–3 at 25 °C.  
A solution of HX has a pH of 2.48

Calculate the concentration of HX in the solution.

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**(4)**

(c)     Explain why the pH of an acidic buffer solution remains almost constant despite the addition of a small amount of sodium hydroxide.

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**(2)**

(d)     The acid dissociation constant, *K*a, for the weak acid HY has the value  
1.35 × 10–5 mol dm–3 at 25 °C.

A buffer solution was prepared by dissolving 0.0236 mol of the salt NaY in  
50.0 cm3 of a 0.428 mol dm–3 solution of the weak acid HY

(i)      Calculate the pH of this buffer solution.

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**(4)**

(ii)     A 5.00 × 10–4 mol sample of sodium hydroxide was added to this buffer solution.

Calculate the pH of the buffer solution after the sodium hydroxide was added.

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**(4)**

**(Total 18 marks)**

**Q21.**          This question is about the pH of some solutions containing potassium hydroxide and ethanoic acid.

Give all values of pH to 2 decimal places.

(a)     (i)      Write an expression for pH.

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**(1)**

(ii)     Write an expression for the ionic product of water, *Kw*

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**(1)**

(iii)     At 10 °C, a 0.154 mol dm–3 solution of potassium hydroxide has a pH of 13.72. Calculate the value of Kw at 10 °C.

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*(Extra space)* ......................................................................................

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**(2)**

(b)     At 25 °C, the acid dissociation constant Ka for ethanoic acid has the value  
1.75 × 10–5 mol dm–3.

(i)      Write an expression for Ka for ethanoic acid.

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**(1)**

(ii)     Calculate the pH of a 0.154 mol dm–3 solution of ethanoic acid at 25 °C.

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*(Extra space)* .......................................................................................

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**(3)**

(c)     At 25 °C, the acid dissociation constant Ka for ethanoic acid has the value  
1.75 × 10–5 mol dm–3.

(i)      Calculate the pH of the solution formed when 10.0 cm3 of 0.154 mol dm–3 potassium hydroxide are added to 20.0 cm3 of 0.154 mol dm–3 ethanoic  
acid at 25 °C.

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**(4)**

(ii)     Calculate the pH of the solution formed when 40.0 cm3 of 0.154 mol dm–3 potassium hydroxide are added to 20.0 cm3 of 0.154 mol dm–3 ethanoic acid at 25 °C.

At 25 °C, *K*w has the value 1.00 × 10–14 mol2 dm–6.

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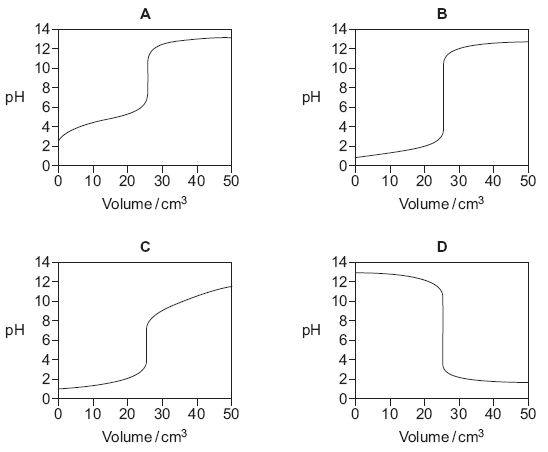
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**(4)**

**(Total 16 marks)**

**Q22.**Titration curves labelled **A**, **B**, **C** and **D** for combinations of different aqueous solutions of acids and bases are shown below.  
All solutions have a concentration of 0.1 mol dm–3.



(a)     In this part of the question write the appropriate letter in each box.

From the curves **A**, **B**, **C** and **D**, choose the curve produced by the addition of

|  |  |  |
| --- | --- | --- |
|  | ammonia to 25 cm3 of hydrochloric acid |  |
|  | sodium hydroxide to 25 cm3 of ethanoic acid |  |
|  | nitric acid to 25 cm3 of potassium hydroxide |  |

**(3)**

(b)     A table of acid.base indicators is shown below.  
The pH ranges over which the indicators change colour and their colours in acid and alkali are also shown.

|  |  |
| --- | --- |
|  | **Indicator                       pH range            Colour in acid          Colour in alkali** |
|  | Trapaeolin                     1.3 – 3.0                       red                            yellow  Bromocresol green        3.8 – 5.4                    yellow                           blue  Cresol purple                 7.6 – 9.2                    yellow                          purple  Alizarin yellow              10.1 – 12.0                  yellow                         orange |

(i)      Select from the table an indicator that could be used in the titration that produces curve **B** but **not** in the titration that produces curve **A**.

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**(1)**

(ii)     Give the colour change at the end point of the titration that produces curve **D** when cresol purple is used as the indicator.

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**(1)**

**(Total 5 marks)**

**Q23.**This question involves calculations about two strong acids and one weak acid.  
All measurements were carried out at 25 °C.

(a)     A 25.0 cm3 sample of 0.0850 mol dm–3 hydrochloric acid was placed in a beaker and 100 cm3 of distilled water were added.  
Calculate the pH of the new solution formed.  
Give your answer to 2 decimal places.

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*(Extra space)* .................................................................................................

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**(2)**

(b)     HX is a weak monobasic acid.

(i)      Write an expression for the acid dissociation constant, *K*a, for HX.

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**(1)**

(ii)     The pH of a 0.0850 mol dm–3 solution of HX is 2.79  
Calculate a value for the acid dissociation constant, *K*a, of this acid.  
Give your answer to 3 significant figures.

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**(3)**

(c)     A 25.0 cm3 sample of 0.620 mol dm–3 nitric acid was placed in a beaker and 38.2 cm3 of 0.550 mol dm–3 aqueous sodium hydroxide were added.  
Calculate the pH of the solution formed.  
Give your answer to 2 decimal places.

The ionic product of water *K*w = 1.00 × 10–14 mol2 dm–6 at 25 °C.

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**(6)**

**(Total 12 marks)**

**Q24.**Ammonia and ethylamine are examples of weak Brønsted–Lowry bases.

(a)     State the meaning of the term *Brønsted–Lowry base*.

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**(1)**

(b)     (i)      Write an equation for the reaction of ethylamine (CH3CH2NH2) with water to form a weakly alkaline solution.

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**(1)**

(ii)     In terms of this reaction, state why the solution formed is **weakly** alkaline.

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**(1)**

(c)     State which is the stronger base, ammonia or ethylamine. Explain your answer.

Stronger base ................................................................................................

Explanation ....................................................................................................

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*(Extra space)* .................................................................................................

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**(3)**

(d)     Give the formula of an organic compound that forms an alkaline buffer solution when added to a solution of ethylamine.

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**(1)**

(e)     Explain qualitatively how the buffer solution in part (d) maintains an almost constant pH when a small amount of hydrochloric acid is added to it.

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*(Extra space)* .................................................................................................

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**(2)**

**(Total 9 marks)**

**Q25.**This question is about several Brønsted–Lowry acids and bases.

(a)     Define the term *Brønsted–Lowry* acid.

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**(1)**

(b)     Three equilibria are shown below. For each reaction, indicate whether the substance immediately **above** the box is acting as a Brønsted–Lowry acid (**A**) or a Brønsted–Lowry base (**B**) by writing **A** or **B** in each of the six boxes.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| (i) | CH3COOH | + | H2O |  | CH3COO– | + | H3O+ |

**(1)**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| (ii) | CH3NH2 | + | H2O |  | CH3NH3+ | + | OH– |

**(1)**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| (iii) | HNO3 | + | H2SO4 |  | H2NO3+ | + | HSO4 – |

**(1)**

(c)     A 25.0 cm3 sample of 0.0850 mol dm–3 hydrochloric acid was placed in a beaker.  
Distilled water was added until the pH of the solution was 1.25.

Calculate the total volume of the solution formed. State the units.

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*(Extra space)* .................................................................................................

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**(3)**

(d)     At 298 K, the value of the acid dissociation constant (*K*a) for the weak acid HX in aqueous solution is 3.01 × 10–5 mol dm–3.

(i)      Calculate the value of p*K*a for HX at this temperature.  
Give your answer to 2 decimal places.

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**(1)**

(ii)     Write an expression for the acid dissociation constant (*K*a) for the weak acid HX.

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**(1)**

(iii)     Calculate the pH of a 0.174 mol dm–3 solution of HX at this temperature.  
Give your answer to 2 decimal places.

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*(Extra space)* .........................................................................................

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**(3)**

(e)     An acidic buffer solution is formed when 10.0 cm3 of 0.125 mol dm–3 aqueous sodium hydroxide are added to 15.0 cm3 of 0.174 mol dm–3 aqueous HX.  
The value of Ka for the weak acid HX is 3.01 × 10–5 mol dm–3.

Calculate the pH of this buffer solution at 298 K.  
Give your answer to 2 decimal places.

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**(6)**

**(Total 18 marks)**

**Q26.**In this question, give all values of pH to 2 decimal places.

(a)     The ionic product of water has the symbol *K*w

(i)      Write an expression for the ionic product of water.

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**(1)**

(ii)     At 42°C, the value of *K*w is 3.46 × 10−14 mol2 dm−6.

Calculate the pH of pure water at this temperature.

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**(2)**

(iii)    At 75 °C, a 0.0470 mol dm–3 solution of sodium hydroxide has a pH of 11.36.  
Calculate a value for *K*w at this temperature.

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**(2)**

(b)     Methanoic acid (HCOOH) dissociates slightly in aqueous solution.

(i)      Write an equation for this dissociation.

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**(1)**

(ii)     Write an expression for the acid dissociation constant *K*a for methanoic acid.

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**(1)**

(iii)    The value of *K*a for methanoic acid is 1.78 × 10−4 mol dm−3 at 25 °C.  
Calculate the pH of a 0.0560 mol dm−3 solution of methanoic acid.

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**(3)**

(iv)    The dissociation of methanoic acid in aqueous solution is endothermic.

Deduce whether the pH of a solution of methanoic acid will increase, decrease or stay the same if the solution is heated. Explain your answer.

Effect on pH .........................................................................................

Explanation ...........................................................................................

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*(Extra space)* ........................................................................................

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**(3)**

(c)     The value of *K*a for methanoic acid is 1.78 × 10−4 mol dm−3 at 25°C.   
A buffer solution is prepared containing 2.35 × 10−2 mol of methanoic acid and 1.84 × 10−2 mol of sodium methanoate in 1.00 dm3 of solution.

(i)      Calculate the pH of this buffer solution at 25°C.

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*(Extra space)* ........................................................................................

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**(3)**

(ii)     A 5.00 cm3 sample of 0.100 mol dm−3 hydrochloric acid is added to the buffer solution in part (c)(i).

Calculate the pH of the buffer solution after this addition.

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**(4)**

**(Total 20 marks)**

**Q27.**This question is about Brønsted-Lowry acids of different strengths.

(a)     State the meaning of the term *Brønsted–Lowry acid*.

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**(1)**

(b)    (i)      Write an expression for the acid dissociation constant *K*a for ethanoic acid.

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**(1)**

(ii)     The value of *K*a for ethanoic acid is 1.75 × 10−5 mol dm−3 at 25 °C.

Calculate the concentration of ethanoic acid in a solution of the acid that has a pH of 2.69

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**(4)**

(c)     The value of *K*a for chloroethanoic acid (ClCH2COOH) is 1.38 × 10−3 mol dm−3 at 25 °C.

(i)      Write an equation for the dissociation of chloroethanoic acid in aqueous solution.

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**(1)**

(ii)     Suggest why chloroethanoic acid is a stronger acid than ethanoic acid.

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**(2)**

(d)     **P** and **Q** are acids. **X** and **Y** are bases. The table shows the strength of each acid and base.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Acids** | | **Bases** | |
|  | strong | weak | strong | weak |
|  | **P** | **Q** | **X** | **Y** |

The two acids were titrated separately with the two bases using methyl orange as indicator.  
The titrations were then repeated using phenolphthalein as indicator.  
The pH range for methyl orange is 3.1 − 4.4  
The pH range for phenolphthalein is 8.3 − 10.0

For each of the following titrations, select the letter, **A, B, C,** or **D**, for the correct statement about the indicator(s) that would give a precise end-point.  
Write your answer in the box provided.

**A** Both indicators give a precise end-point.

**B** **Only** methyl orange gives a precise end-point.

**C** **Only** phenolphthalein gives a precise end-point.

**D** Neither indicator gives a precise end-point.

|  |  |  |  |
| --- | --- | --- | --- |
|  | (i) | Acid **P** with base **X** |  |

**(1)**

|  |  |  |  |
| --- | --- | --- | --- |
|  | (ii) | Acid **Q** with base **X** |  |

**(1)**

|  |  |  |  |
| --- | --- | --- | --- |
|  | (iii) | Acid **Q** with base **Y** |  |

**(1)**

(e)     Using a burette, 26.40 cm3 of 0.550 mol dm−3 sulfuric acid were added to a conical flask containing 19.60 cm3 of 0.720 mol dm−3 aqueous sodium hydroxide.  
Assume that the sulfuric acid is fully dissociated.

Calculate the pH of the solution formed.

Give your answer to 2 decimal places.

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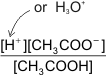
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**(6)**

**(Total 18 marks)**

**M1.**          (a)     (i)      Ka =  **(1)**

(ii)     (1)     Ka =  **(1)**

(2)     [H+] =  = 1.96 × 10–3 **(1)**

(3)     pH = -log10[H+] **(1)**

*can score independently*

(4)     pH = 2.71 **(1)**

*2 d.p. essential*

*If forget √ can score (1) and (3) for pH = 5.42*

**5**

(b)     (i)      moles acid =  **(1)** = 5.50 ×10–3

= 

 *x* = 25 ×  **or** 5.50 × 10–3 × 

       = 36.7 (or 37) cm3 (or 36.6) **(1)**

*NOT 36 NOR 37.0 units must match*

(ii)     *Indicator*:                  thymol blue **(1)***Explanation*:             weak acid – strong base **(1)**                                 equivalent at pH > 7 **(1)** or high pH

**5**

(c)     (1)     mol NaOH added =  = 0.050 **(1)**

*If wrong Mr: CE  lose marks (1) and (2) then mark on  
consequentially → max 4*

(2)     mol CH3COOH left = 0.220 – 0.050 = 0.170 **(1)**

(3)     mol CH3COO– formed = 0.050 **(1)**

(4)     [H+] = Ka  OR pH = pKa +  etc **(1)**

*If expression wrong no marks for 4 / 5 / 6*

**can score (1) to (4) in (5)**

(5)     [H+] = 1.74 × 10–5 ×  OR pH = 4.76 + log **(1)**

(6)     pH = 4.23 **(1)**

*Correct answer gets* ***(1)(1)(1)(1)(1)(1)****Mark (5) is for use of correct values of (acid moles) and  
(salt moles)  
if one wrong allow pH conseq  
if both wrong, no further marks  
e.g. if candidate forgets substitution in (2)  
he loses (2) and (5) but can score (1) (3) (4) (6) = max 4*

*for pH = 4.12 if upside down; answer 5.29 scores 3 for (1) (2) (3)*

**6**

**[16]**

**M2.**          (a)     before any KOH added: Ka =  **or  (1)**

**** Ka =  **(1)**

**** [H+] =  = 1.67 × 10–3 **(1)**

**** pH = 2.78 **(1)**

**4**

(b)     at 8 cm3 KOH:  
Moles KOH added = (8 × 10–3) × 0.210 = 1.68 × 10–3 **(1)  
** moles of CH3COO– formed = 1.68 × 10–3 **(1)**

Original moles of CH3COOH = (25 × 10–3) × 0.160 = 4.0 × 10–3 **(1)**

**** moles of CH3COOH left = (4.0 × 10–3) – (1.68 × 10–3)  
                                 = 2.32 × 10–3 **(1)**

          [H+] = Ka ×  **(1)**

= 1.74 × 10–5 ×  = 2.40 × 10–5 **(1)**

**** pH = 4.62 **(1)**

*It forget subtraction : max 5  
If Ka expression not used max 5  
if moles of CH3COOH wrong but substitution used max 5*

**7**

(c)     at 40 cm3 of KOH:  
Total moles of KOH = (40 × 10–3) × 0.21 = 8.4 × 10–3 **(1)  
** excess moles of KOH = (8.4 × 10–3) - (4.0 × 10–3)  
                                    = 4.4 × 10–3 **(1)**in total volume = 40 + 25 = 65 cm3 **(1)  
** [OH–] = 4.4 × 10–3 ×  = 0.0677 **(1)**

**** [H+] = 

*OR pOH =1.17*

= 1.477 × 10–13 **(1)  
** pH = 12.83 **(1)**

*If volume missed : max 4  
If moles of acid wrong but method includes subtraction : max 5*

*If no subtraction : max 4*

**6**

**[Max 16]**

**M3.**          (a)     (i)      H+ or proton acceptor **(1)**CH3NH2 + H2O () CH3+NH3 (+) OH– **(1)**

(ii)     CH3NH3Cl or HCl **(1)**

*Or any ammonium compound or strong acid  
name or formula*

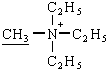
(iii)     extra OH– reacts with   
or reaction / equilibrium moves to left  
or ratio salt / base remains almost constant **(1)**

*Any 2*

**5**

(b)     lone pair (on N accepts H+) **(1)**CH3 increases electron density (on N)  
       donates / pushes electrons  
       has positive inductive effect **(1)**

**2**

(c)     nucleophilic substitution **(1)  
 (1)**

**2**

**[9]**

**M4.**          (a)     moles HA =  × 0.150 = 3.75 × 10–3 **(1)**

**** vol NaOH =  = 1.875 × 10–2 dm3 **(1)**

*or 18.75 cm3*

**2**

(b)     (i)      pH = –log10 [H+] **(1)**

(ii)     Value above 7 but below 11 **(1)**

(iii)     phenol red / thymol blue / phenolphthalein / thymolphthalein

*i.e. indicator with  7 < pKin <11*

**3**

(c)     (i)      Only slightly dissociated/ionised **(1)**

*NOT “not fully dissociated / ionised”*

(ii)     Ka =  **(1)**

*NOT *

(iii)     For weak acid alone:  
Ka =  **(1)**

**** [H+] = 

          = 2.03 × 10–3 (1)

 pH = 2.69 (1)

*pH should be given to 2 decimal places  
penalise answer to 1 d.p. once in question*

**5**

(d)     moles OH– added = 1.875 × 10–3 = moles A– = moles HA left **(1)**

**or**  [A–] = [HA]

 Ka = [H+] **or** pH = pKa **(1)**

**** pH = 4.56 (1)

**3**

**[13]**

**M5.**          Penalise pH given to 1 dp first time it would have scored only

(a)     (i)      Kw = [H+] [OH–] **(1)**

(ii)     pH = – log [H+] **(1)**

*or in words or below unless contradiction*

(iii)     *Calculation*:  [H+]  =  **(1)**

 = 2.34 × 10–7

 pH = 6.63 or 6.64 **(1)**

*Explanation*: pure water  [H+] = [OH–] **(1)**

**5**

(b)     (i)      [OH–] = 0.150             [H+] = 10–14/0.15 = 6.66 × 10–14

or pOH = 0.82

 pH = 13.18 **(1)**

or pH= 13.17

(ii)     moles OH– = (35 × 10–3) × 0.150 = 5.25 × 10–3 **(1)**a

moles H+ = (40 × 10–3) × 0.120 = 4.8(0) × 10–3 **(1)**b

 excess moles of OH– = 4.5 × 10–4 **(1)**c

 [OH–] = (4.5(0) × 10–4) × 1000/75d **(1)e**    = 6.0(0) x 10-3

[H+] =  = 1.66 × 10–12 or pOH = 2.22

 pH = 11.78 **(1)**for 11.77

**8**

(c)     (i)      Ka =  **(1)**

(ii)     [H+] = 1.80 × 10–2 × 0.150 = 2.70 × 10–3 (1)

Ka =  = 4.86 × 10–5 **(1)** mol dm–3 **(1)**

*or  = 4.95 × 10–5*

**5**

**Notes**

(a)     If Kw includes H2O allow 6.63 if seen otherwise no marks likely

(b)     (ii)     If no vol, max 4 for a, b, c, f answer = 10.65  
If wrong volume max 5 for a, b, c, e, f  
If no substraction max 3 for a, b, d  
If missing 1000 max 5 for a, b, c, d, f  answer = 8.78  
If uses excess as acid, max 4 for a, b, d, f  answer = 2.22  
If uses excess as acid and no volume, max 2 for a,  
b answer = 3.35

(c)     If wrong Ka in (i) max 2 in part (ii) for [H+] **(1)** and conseq units **(1)**

*but mark on fully from minor errors  
eg no [ ] or charges missing*

          Organic points

(1)     Curly arrows: must show movement of a pair of electrons,  
i.e. from bond to atom or from lp to atom / space  
e.g.



(2)     Structures

penalise sticks (i.e. ) once per paper



Penalise once per paper

          allow CH3– or –CH3 or  or CH3    or   H3C–

**[18]**

**M6.**          (a)     Hydrogen bonding **(1)**between H2O and NH3 **(1)**

**2**

(b)     (i)      NH3 + H2O  NH4+ + OH– **(1)**

(ii)     Ammonia is weak base **(1)**

*NOT partially ionised*

         Equilibrium to left or incomplete reaction **(1)**

**3**

(c)     A proton donor **(1)**

**1**

(d)     *Buffer solution*: A solution which resists change in pH **(1)**when small amounts of acid or base added or on dilution **(1)**

*Reagent*: NH4Cl **(1)**

*Allow a correct strong acid*

**3**

(e)     (i)      Ka = [H+] [A–] / [HA] **(1)**     = [H+] [0.125 × 4] **(1)** / 1.00  
[H+] = 1.70 × 10–5 / 0.125 × 4 = 3.40 × 10–5 **(1)**

pH = –log10 [H+] = 4.47 **(1)**

*Allow pH conseq to [H+] if 2 place decimals given*

(ii)     H+ + CH3COO– → CH3COOH **(1)**

**5**

**[14]**

**M7.**          (a)     (i)      pH = –log [H+] **(1)**

(ii)     *Expression for Ka*: Ka =  **(1)**

*Calculation*: pH = 2.56  [H+] = 2.75 × 10–3 **(1)**

Ka =  =  = 6.32 × 10–5 **(1)** (mol dm–3)

or [H+] = [X–] **(1)**

*depending on approximate made, values of Ka = 10–5 ×  
using [HX] = 0.12                             6.30 – 6.32  
using [HX] = 0.12 – 2.75...               6.45 – 6.47  
using 2.8 and [HX] = 0.12                6.53  
using 2.8 and [HX] = 0.12 – 2.8       6.69  
upside down Ka*

**5**

(b)     (i)      *Expression for Kw*: Kw = [H+] [OH–] **(1)**

*Value of Kw*: (1.0 ×)10–14 (mol2 dm–6) **(1)**

*ignore units*

(ii)     [H+] =  = 2.22 × 10–13

or pOH = 1.35 **(1)**

**** pH = 12.65 **(1)**

*must be 2dp in final answer*

**4**

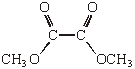
(c)     (i)      H2C2O4 + OH– → HC2O4– + H2O **(1)**

(ii)     mol OH– = (41.6 × 10–3) × 0.0450 **(1)** = 1.87 × 10–3  
 mol H2C2O4 = 9.36 × 10–4 **(1)**[H2C2O4] = 9.36 × 10–4 × 103/25  
              = 0.0374 **(1)**

*if moles of H2C2O4 not equal to half moles of OH–, no further marks gained*

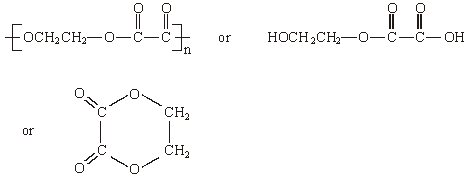
*if mol OH– = 1.9 × 10–3; hence mol H2C2O4 = 9.5 × 10–4;   
[H2C2O4] = 0.038*

**4**

(d)     (i)       **(1)**

*must be diester allow CH3OOCCOOCH3 or CH3O2CCO2CH3 and similarly in (ii)*

(ii)



**(1)**

*must be 1:1 proportion allow repeating until alone   
(i.e. n not essential)*

**2**

**[15]**

**M8.**          (a)     Ka = 

*(All three sets of square brackets needed, penalise missing brackets or missing charge once in the question)  
(Don’t penalise extra [H+]2/[HA])*

**1**

(b)     Ka    =  or [H+] = [A–]

[H+]    = 

         = 6.02 × 10–3pH = 2.22

*(must be to 2dp)  
(allow 4th mark consequential on their [H+])*

**1**

(c)     (i)      pH (almost) unchanged

*(Must be correct to score explanation)*

**1**

         H+ removed by A– forming HA  
or acid reacts with salt  
or more HA formed

**1**

(ii)     [H+]    = 10–3.59 = 2.57 × 10–4 or 2.6 × 10–4

**1**

[A–]     = 

**1**

          = 

**1**

          = 0.141 (mol dm3)

*(Allow 0.139 to 0.141 and allow 0.14)*

*(If not used 3.59, to find [H+] can only score M2 for working)*

*(If 3.59 used but [H+] is wrong, can score M2 for correct method and conseq M4)*

*If wrong method and wrong expression, can only score M1)*

**1**

(ii)     *Alternative scheme for first three marks of part (c)(ii)*

         pH = pKa  log

**1**

         pKa = 3.84

**1**

         3.59 = 3.84 – log

**1**

**[11]**

**M9.**          (a)     (i)      SO2

**1**

+4

**1**

(ii)     4P + 5O2 → 2P2O5

or      P4 + 5O2 → P4O10

**1**

(b)     (i)      B

**1**

E

**1**

They have low melting points  
or there are weak van der Waals forces between molecules

**1**

(ii)     Add water     or     heat in a flame

**1**

         Test pH           check flame colour

**1**

         13/14

yellow

**1**

(c)     (i)      NaHSO3

**1**

(ii)     NaHSO3 + NaOH → Na2SO3 + H2O

or      

**1**

(iii)     Phenolphthalein or alizarin yellow or thymol blue

**1**

**[12]**

**M10.**          (a)     pH = –log[H+]

**1**

****

**1**

[H+]= √1.74 × 10–5 × 0.15 (or 1.62 × 10–3)

**1**

pH = 2.79 (penalise 1 dp or more than 2dp once in the qu)

**1**

(b)     (i)      Solution which resists change in pH /maintains pH

**1**

despite the addition of (small amounts of) acid/base (or dilution)

**1**

(ii)     CH3COO + H+→ CH3COOH

must show an equation full or ionic in which ethanoate ions are  
converted to ethanoic acid

**1**

(c)     (i)       if rearrangement incorrect, no further marks

**1**



**1**

          (= 2.61 × 10–5)

pH = 4.58

**1**

(ii)     Ml      moles H+ added = 10 × 10-3 × 1.0 = 0.01

**1**

M2     moles ethanoic acid after addition = 0.15 + 0.01 = 0.16

**1**

M3     moles ethanoate ions after addition = 0.10 -0.01 = 0.09

**1**

M4     

**1**

          (= 3.09 ×10–5)

M5     pH     = 4.51

The essential part of this calculation is addition/subtraction of  
0.01 moles to gain marks M2 and M3. If both of these are missing,   
only mark M1 is available. Thereafter treat each mark independently,   
except if the expression in M4 is wrong, in which case both M4   
and M5 are lost.

**1**

**[15]**

*alternative scheme for part (c)(i)*



**1**

         pKa = 4.76

**1**



**1**

*alternative for penultimate mark of part (c)(ii)*



**1**

**M11.**          (a)     Concentration of acid:      m1v1 = m2v2 hence 25 × m1 = 18.2 × 0.150

OR

moles NaOH = 2.73 ×10–3;

**1**

m1 = 18.2 × 0.150/25= 0.109;

**1**

(b)     (i)      *K*a=[H+][A–]/[HA]          *not*     *K*a= [H+]2 / [HA];

**1**

(ii)     pKa = –logKa;

**1**

(iii)     [A–] = [HA];

**1**

         hence *K*a= [H+] [A–] / [HA] = [H+]

         and –logKa  = –log[H+];

**1**

(c)     ratio [A–] :         [HA] remains constant;

**1**

hence as [H+] *= K*a[HA] / [A–];              [H+] remains constant;

**1**

(d)     (i)      pH of 0.250 mol dm-3 HCl              = 0.60  
and pH of 0.150 mol dm-3 HCl       = 0.82;

**1**

pH change = 0.22;

**1**

(ii)     moles HCl = 30 × 0.250 × 10–3 = v × 0.150 × 10–3 = 7.50 × 10–3

OR

v = 30 × 0.250 × 10–3/ 0.150 × 10–3 =50;

**1**

water added = 50 – 30 = 20 cm3;

**1**

**[12]**

**M12.**          (a)     (i)      B;

**1**

         C;

**1**

         A;

**1**

(ii)     cresolphthalein

*OR*

thymolphthalein;

**1**

(b)     (i)      –log[H+];

**1**

(ii)     [H+] = 1.259 × 10–12 (or 1.26 or 1.3)

*OR*

OH = 14 – pH;

**1**

****

*OR*

= 2.10;

**1**

= 7.9(4) × 10–3;

*(if [H+] is wrong allow 1 for [OH] =  KW/[H+] or as numbers)*

**1**

(c)     (i)      Ka = [H+]2/[CH3CH2COOH]

*OR*

[H+]2/[HA]

*OR*

[H+] = [A–] etc;

**1**

[H+]    = √l.35×l0–5 × 0.117 or expression without numbers;

**1**

          = 1.257 × l0–3

pH     = 2.90;

**1**

(iii)     Ka = [H+]

*OR*

pKa    = pH;

**1**

pH = 4.87;

*(penalise 1dp once)*

**1**

**[13]**

**M13.**(a)     (i)      [H+][OH–]

**1**

– log [H+]

**1**

(ii)     [H+] = [OH–]

**1**

(iii)     (2.0 × 10–3) × 0.5 = 1.0 × 10–3

**1**

(iv)    [H+] =                     (= 4.02 × 10–11)

**1**

pH = 10.40

**1**

(b)     (i)      Ka  =  [H+][CH3CH2COO-]

          [CH3CH2COOH]

**1**

         =            [H+]

          [CH3CH2COOH]

**1**

[H+] = √(1.35 × 10–5) × 0.125      (= 1.30 × 10–3)

**1**

pH = 2.89

**1**

(c)     (i)      (50.0 × 10–3) × 0.125 = 6.25 × 10–3

**1**

(ii)     (6.25 × 10–3) – (1.0 × 10–3) = 5.25 × 10–3

**1**

(iii)     mol salt formed = 1.0 × 10–3

**1**

[H+] = Ka ×   [CH3CH2COOH]

                      [CH3CH2COO–)

**1**

= (1.35 × 10–5) × (= 7.088 × 10–5)

**1**

pH = 4.15

**1**

**[16]**

**M14.**          (a)     *k* = rate/[CH3CH2COOCH3][H+]

**1**

or

 = 

 = 1.38 × 10–3 to 1.4 × 10–3

**1**

mol–1 dm3 s–1

**1**

(b)     ans = rate constant × (½ × 0.150) × (½ × 0.555)

*ignore units*

      = rate constant × 0.0208

2.88 × 10–5 (1.38 × 10–3 gives 2.87 × 10–5)

*Allow 2.87 – 2.91 × 10–5 (1.4 × 10–3 gives 2.91 × 10–5)*

**1**

(c)     [H+] = rate/ k[CH3COOCH2CH3]

**1**

= 

= 0.415 (0.4146)

**1**

pH = 0.38 mark independently

*[H+] = 0.41 gives pH = 0.39*

**1**

**[7]**

**M15.**          (a)     –log [H+]

*ecf if [ ] wrong and already penalised*

**1**

4.57 × 10–3

*allow 4.6 × 10–3*

*ignore units*

**1**

(b)     (i)      Ka =  allow HA etc

*not  but mark on*

*If expression wrong allow conseq units in (ii)   
but no other marks in (ii)*

**1**

(ii)     = 

*If use 4.6 × 10–3*

**1**

*Ka = 1.4(1) × 10–4 and pKa = 3.85*

= 1.39 × 10–4

*allow 1.39 – 1.41 × 10–4 mol dm–3*

**1**

(iii)     *pK*a = 3.86

*Penalise dp of final answer < or > 2 in pH once in paper*

**1**

(c)     (i)       × 0.480 = 0.0144 or 1.4(4) ×10–2

*Mark is for answer (M1)*

**1**

(ii)      × 0.350 = 0.0063 or 6.3 × 10–3

*Mark is for answer (M2)*

**1**

(iii)     0.0144 – 2(0.0063) = 1.80 × 10–3

*M3 is for (i) – 2(ii)*

*If x 2 missed, CE i.e. lose M3 and the next mark gained*

**1**

(iv)    1.80 × 10–3 ×  = 0.0375 (0.038)

*M4 is for answer*

If vol is not 48 × 10–3 (unless AE) lose M4 and next mark gained  
If multiply by 48 - this is AE - i.e. lose only M4  
If multiply by 48 × 10–3 this is AE - i.e. lose only M4

**1**

(v)     10–14 / 0.0375         (10–14 / 0.038)

*M5 for Kw/[OH–]*

**1**

(= 2.66 × 10–13)     (= 2.63 × 10–13)

*or pOH*

or pOH = 1.426    (or pOH = 1.420)

*If no attempt to use Kw or pOH lose both M5 and M6*

**1**

pH = 12.57           (12.58)                 M6

*Allow M6 conseq on AE in M5 if method OK*

**1**

**[13]**

**M16.**          (a)     (i)      addition of small amounts of acid send eqm to left or extra H+removed by reaction with HCO3–

**1**

ratio [H2CO3]/[HCO3–] remains constant hence [H+] and  
pH remain const

**1**

(ii)     pH = 7.41  [H+] = 3.89 × 10–8 mol dm–3

**1**

*K*a = 

**1**

=  = 7.78 × 10–8 mol dm–3

*allow error carried forward mark. Do not penalise twice.*

**1**

(b)     (i)      moles H+ added = 10 × 10–3 × 1.0 = 0.01

**1**

(ii)     moles ethanoic acid after addition = 0.15 + 0.01 = 0.16

**1**

         moles ethanoate ions after addition = 0.10 – 0.01 = 0.09

**1**

(iii)     [H+] = 

**1**

= 1.74 × 10–5 × 

**1**

pH = 4.51

**1**

**[11]**

**M17.**          (a)     (i)      **B**                                                                                                             1

**C**

**1**

**A**

**1**

(ii)     cresolphthalein or thymolphthalein

**1**

(b)     pH = -log[H+]

**1**

Ka =  or [H+] = [A–]

**1**

[H+] = √1.74 × 10–5 × 0.15 (or 1.62 × 10–3)

**1**

pH = 2.79 (penalise 1 dp or more than 2dp once in the qu)

**1**

**[8]**

**M18.**          (a)     (i)      –log[H+]

*or log1/[H+]  
penalise ( )*

**1**

(ii)     [H+] = 0.56

*mark for the answer; allow 2dp or more*

**1**

[H2SO4] = ½ × 0.56 = 0.28

**1**

(b)     (i)      CH3COOH + NaOH → CH3COONa + H2O

***OR***

CH3COOH + OH– → CH3COO– + H2O

*Allow CH3CO2H etc*

**1**

(ii)     mol acid = (25.0 × 10–3) × 0.41 = 1.025 × 10–2 or 1.03 × 10–2

**1**

[NaOH] = 1.025 × 10–2/22.6 × 10–3 = 0.45(4)

*mark for answer  
if not 0.454 look back for error*

**1**

***OR***

[NaOH] = 1.03 × 10–2/22.6 × 10–3 = 0.456 or 0.46

(iii)     cresol purple

**1**

(iv)    NaOH reacts with carbon dioxide (in the air)

**1**

(c)     (i)      Ka = 

allow molecular formulae or minor slip in formulae

*penalise ( )  
allow H3O+not allow HA etc*

**1**

(ii)     Ka =  or with numbers

**1**

*allow HA etc here  
This can be scored in part (c)(i) but doesn’t score there.*

[H+] = (√(1.74 × 10–5 × 0.410) = √(7.13 × 10–6)) = 2.67 × 10–3

**1**

*mark for 2.67 × 10–3 or 2.7 × 10–3 either gives 2.57*

pH = 2.57          can give three ticks here for (c)(ii)  
                          penalise decimal places < 2 >

**1**

*pH mark conseq on their [H+]*

*so 5.15 gets 2 marks where square root not taken*

(iii)     **M1** mol OH– = (10.0 × 10–3) × 0.10 = 1.0 × 10–3

*If no subtraction or other wrong chemistry the max score is 3 for M1, M2 and M4*

**1**

**M2** orig mol HA = (25.0 × 10–3) × 0.41 = 0.01025

**1**

or 1.025 × 10–2 or 1.03 × 10–2

**M3** mol HA in buffer = orig mol HA – mol OH–

**1**

  = 0.00925 or 0.0093

*If A– is wrong, max 3 for M1, M2 and M3 or use of  
pH = pKa – log [HA]/[A–]*

**M4** mol A– in buffer = mol OH– = 1.0 × 10–3

*Mark is for insertion of correct numbers in correct expression for [H+]*

**1**

**M5** [H+] = 

**1**

****

(= 1.61 × 10–4 or 1.62 × 10–4)

**M6** pH = 3.79  can give six ticks for 3.79

*if [HA]/[A–] upside down lose M5 & M6*

*If wrong method e.g. [H+]2/[HA] max 3 for M1, M2 and M3*

*Some may calculate concentrations  
[HA] = 0.264 and [A–] = 0.0286 and rounding this to 0.029 gives pH = 3.80 (which is OK)*

NB Unlike (c)(ii), this pH mark is NOT awarded conseq to their  
[H+] unless following AE

*BEWARE: using 0.01025 wrongly instead of 0.00925 gives pH = 3.75  
(this gets 3 for M1, M2 & M4)*

**1**

**[18]**

**M19.**(a)     (i)      –log[H+]

*Penalise missing [ ] here* ***and not elsewhere***

**1**

(ii)     [H+][OH–]

**1**

(b)     (i)      [H+] = 2.34 × 10–7

**1**

pH = 6.63

*Penalise fewer than 3 sig figs but allow more than 2 dp*

**1**

(ii)     [H+] = [OH–]

**1**

(iii)     **M1**    [H+] = Kw/[OH–]

*if upside down or CE, allow M3 only for correct use of their [H+]*

**1**

**M2**    (= 5.48 × 10–14/0.140) = 3.91 × 10–13

**1**

**M3** pH = 12.4(1)

*not 12.40 (AE from 12.407)*

**1**

*Penalise fewer than 3 sig figs but allow more than 3 sfs  
For values above 10, allow 3sfs - do not insist on 2 dp.  
For values below 1, allow 2dp – do not insist on 3 sig figs*

*Not allow pH = 14 – pOH but can award M3 only for pH = 13.1(46)  
Can award all three marks if pKw = 13.26 is used*

(c)     **M1** mol NaOH = mol OH– = (30 × 10–3) × 0.20 = 6.0 × 10–3

*mark for answer*

**1**

**M2**    mol H2SO4 = (25 × 10–3) × 0.15 = 3.75 × 10–3

*mark for answer*

**1**

**M3**    mol H+ = (25 × 10–3) × 0.15 × 2 = 7.5 ×10–3OR XS mol H2SO4 = 0.75 × 10–3

*if factor of 2 missed or used wrongly, CE - lose M3 and next mark gained. In this case they must then use Kw to score any more.  
see examples below*

**1**

**M4**    XS mol H+ = 1.5 × 10–3

**1**

**M5** [H+] = (1.5 × 10–3) × (1000/55) = 0.0273

*if no use or wrong use of volume, lose M5 and M6 except if 1000 missed  
AE –1 (pH = 4.56)*

**1**

**M6** pH = 1.56

*Penalise fewer than 3 sig figs but allow more than 3 sfs  
For values above 10, allow 3sfs - do not insist on 2 dp.  
For values below 1, allow 2dp – do not insist on 3 sig figs*

**1**

(d)     (i)      Ka = 

*Must have all 3 brackets but don’t penalize ( )  
see note to (a)(i)*

*not HA  
This mark could score in (d) (ii)*

**1**

(ii)     Ka =  or with numbers or [H+] = [CH3COO–]

*allow HA here*

**1**

*This mark could score in (d) (i)*

[H+] = (√(1.74 × 10–5 × 0.136) = √(2.366 × 10–6=) 1.54 × 10–3

**1**

pH = 2.81        can give three marks here for (d)(ii)

*Do not insist on 2 dp  
Penalise fewer than 3 sig figs but allow more than 3 sfs  
For values below 1, allow 2dp – do not insist on 3 sig figs*

*mark for answer if 1.5 × 10–3 penalise here*

*pH = 2.82 conseq*

*if miss √ but it is shown, AE -1 so allow 2 for pH = 5.63*

**1**

**[18]**

**M20.**          (a)     (i)      – log[H+] or log 1/[H+]

*penalise missing square brackets here only*

**1**

(ii)     0.81

*2dp required, no other answer allowed*

**1**

(iii)     **M1** mol H+ = 1.54 × 10–3

*if wrong no further mark  
if 1.5 × 10–3 allow M1 but not M2 for 2.82*

**1**

**M2** pH = 2.81

*allow more than 2dp but not fewer*

**1**

(b)     **M1** [H+] = 3.31 × 10–3

**1**

**M2** Ka = or  or using numbers

*do not penalise ( ) or one or more missing [ ]*

**1**

**M3** [HX] = 

*allow conseq on their [H+]2/(4.83 × 10–5) (AE)  
if upside down, no further marks after M2*

**1**

**M4** [HX] = 0.227

*allow 0.225 – 0.23*

**1**

(c)     **M1** extra/added OH– removed by reaction with H+ or the acid

**1**

**M2** correct discussion of equn shift i.e. HX  H+ + X– moves to right

**1**

**OR**

ratio  remains almost constant

(d)     (i)      **M1** mol HY = (50 × 10–3) × 0.428 = 0.0214

***OR*** [Y] = .0236 × 

*mark for answer*

**1**

**M2** [H+] = 1.35 × 10–5 × 

***OR*** 1.35 × 10–5 = [H+] × 

***OR*** [H+] = 1.35 × 10–5 × 

***OR*** 1.35 × 10–5 = [H+] × 

*must be numbers not just rearrangement of Ka expression*

*If either HY value or Y– value wrong, (apart from AE -1) lose M2 and M3*

**1**

**M3** [H+] = 1.22 ×10–5

*mark for answer*

**1**

**M4** pH = 4.91

*allow more than 2dp but not fewer*

***allow M4 for correct pH calculation using their [H+] (this applies in (d)(i) only)***

**1**

**If Henderson Hasselbalch equation used:**

**M1** mol HY = (50 × 10–3) × 0.428 = 0.0214

**OR** [Y] = .0236 × 

*mark for answer*

**1**

**M2** p*K*a = 4.87

**1**

**M3** log = –0.043

          log = –0.043

*If either HY value or Y– value wrong, (apart from AE-1) lose M3 and M4*

**1**

**M4** pH = 4.87 – (– 0.043) = 4.91

*allow more than 2dp but not fewer*

**1**

(ii)     Can score full marks for correct consequential use of their  
HY and Y– values from d(i)

**M1** Mol HY after adding NaOH = 0.0214 – 5.0 × 10–4 = 0.0209

*AE in subtraction loses just M1  
If wrong initial mol HY (i.e. not conseq to part d(i)) or no subtraction or subtraction of wrong amount, lose M1 and M3*

**1**

**M2** Mol Y– after adding NaOH = 0.0236 + 5.0 × 10–4 = 0.0241

*AE in addition loses just M2  
If wrong mol Y– (i.e. not conseq to part d(i)) or no addition or addition of wrong amount lose M2 and next mark gained*

**1**

**M3** [H+] = 1.35 × 10–5 ×  (= 1.17 × 10–5)

          if convert to concentrations

          [H+] = 1.35 × 10–5 ×  (= 1.17 × 10–5)

**1**

*if HY/Y– upside down, no further marks*

**M4** pH = 4.93

*allow more than 2dp but not fewer*

*NOT allow M4 for correct pH calculation using their [H+] (this allowance applies in (d)(i) only)*

**1**

**If Henderson Hasselbalch equation used:**

*Can score full marks for correct consequential use of their HY and Y– values from d(i)*

**M1** Mol HY after adding NaOH = 0.0214 – 5.0 ×10–4 = 0.0209

*AE in subtraction loses just M1  
If wrong initial mol HY (i.e. not conseq to part d(i)) or no subtraction or subtraction of wrong amount lose M1 and M3*

**1**

**M2** Mol Y– after adding NaOH = 0.0236 + 5.0 × 10–4 = 0.0241

*AE in addition loses just M2  
If wrong mol Y– (i.e. not conseq to part d(i)) or no addition or addition of wrong amount lose M2 and next mark gained*

**1**

**M3** log  = –0.062

*if HY/Y–– upside down, no further marks*

**1**

**M4** pH = 4.87 – (– 0.062) = 4.93

*allow more than 2dp but not fewer*

**1**

**[18]**

**M21.**          (a)     (i)      - log[H+]

*penalise missing [ ] here* ***and not elsewhere***

**1**

(ii)     [H+][OH–]

*Allow ( ) brackets, but must have charges*

**1**

(iii)     Mark independently from a(ii)

[H+] = 10-13.72 = 1.905 × 10–14

*If wrong no further mark*

**1**

Kw = 1.905 × 10–14 × 0.154 = = (2.93 – 2.94) × 10–15

**1**

(b)     (i)      Ka = 

*Must have charges and all brackets, allow ( )*

*Acid/salt shown must be CH3COOH not HA*

*and correct formulae needed*

**1**

(ii)     **In pH values penalise fewer than 3 sig figs each time  
but allow more than 2 dp  
For values above 10, allow 3sfs - do not insist on 2 dp**

Ka = 

*Allow HA*

**1**

([H+]2 = 1.75 × 10–5 × 0.154 = 2.695 × 10–6 = 2.70 × 10–6)

*If √ shown but not done gets pH = 5.57 (scores 2)*

[H+] = 1.64 × 10–3

*Allow mark for pH conseq to their [H+]* ***here only***

**1**

pH = 2.78 or 2.79

**1**

(c)     (i)      **In pH values penalise fewer than 3 sig figs each time but  
allow more than 2 dp**

**For values above 10, allow 3sfs - do not insist on 2 dp**

**M1** Initially

mol OH– = (10 × 10–3) × 0.154 **and**

mol HA = (20 × 10–3) × 0.154

**or** mol OH– = 1.54 × 10–3 **and** mol HA = 3.08 × 10–3

**1**

**M2** [H+] = Ka 

or with numbers

*Allow Henderson Hasselbach*

*pH = pKa + log *

**M3** mol ethanoic acid left = (mol ethanoate ions) = 1.54 × 10–3

Ka = [H+] **or** pH = pKa scores **M1**, **M2** and **M3**

*1 If either mol acid in mixture or mol salt wrong*

*- max 2 for M1 and M2*

*Any mention of [H+]2 - max 2 for M1 and M3*

**1**

**M4** pH (= - log 1.75 × 10–5) = 4.76 or 4.757

*Not 4.75*

**1**

If no subtraction (so mol ethanoic acid in buffer = original mol)  
pH = 4.46 scores 2 for **M1** and **M2**If [H+]2 used, pH = 3.02 scores 2 for **M1** and **M3**

(ii)     **In pH values penalise fewer than 3 sig figs each time but  
allow more than 2 dp  
For values above 10, allow 3sfs - do not insist on 2 dp**

**M1** XS mol KOH (= (20 × 10–3) × 0.154) = 3.08 × 10–3

*If no subtraction: max 1 for correct use of volume*

*No subtraction and no use of volume scores zero*

*If wrong subtraction or wrong moles*

*Can only score* ***M2*** *and* ***M3*** *for process*

**1**

**M2** [OH-] = 3.08 × 10–3 ×  = 0.0513(3)

*Mark for dividing their answer to* ***M1*** *by correct volume (method mark)*

*If no volume or wrong volume or multiplied by volume, max 2 for* ***M1*** *and* ***M3*** *process*

**1**

**M3** [H+] =  (= 1.948 × 10–13 to 1.95 × 10–13)

**or** pOH = 1.29

*Mark for Kw divided by their answer to* ***M2***

*If pOH route, give one mark for 14 – pOH*

**1**

**M4** pH = 12.7(1)

*Allow 3sf but not 12.70*

**1**

If no subtraction and no use of volume (pH = 11.79 scores zero)  
If no subtraction, max 1 for correct use of volume, (60cm3)  
(pH = 13.01 scores 1)  
If volume not used, pH = 11.49 (gets 2)  
If multiplied by vol, pH = 10.27 (gets 2)

**[16]**

**M22.**(a)     C

**1**

A

**1**

D

**1**

(b)     (i)      Bromocresol green

*Allow wrong spellings*

**1**

(ii)     Purple to yellow

*Must have both colours:*

*Purple start – yellow finish*

**1**

**[5]**

**M23.**(a)     **M1**    [H+] = 0.0170

**1**

**M2**    pH = 1.77

*2 dp*

***Allow M2 for correct pH calculation from theirwrong [H+] for this pH calculation only***

**1**

(b)     (i)              Ignore 

*Penalize missing [ ] here* ***and not elsewhere***

*Allow HA instead of HX*

**1**

(ii)     **M1**    [H+] = 10–2.79 OR 1.6218… ×10–3

*If [H+] wrong, can only score M2*

**1**

**M2**         OR     

*Allow HA instead of HX*

**1**

**M3**    Ka = 3.09 ×10–5   3sfs min         (allow 3.10 ×10–5 if 1.6218 rounded to 1.622)         Ignore units

*If [HX] used as (0.0850 –1.62 ×10–3 )*

*this gives Ka = 3.15 ×10–5*

*(0.0016)2/0.085 = 3.01 ×10–5 scores 2 for AE*

**1**

(c)     **M1**    mol OH– (= (38.2 × 10–3) × 0.550 )

= 2.10(1) × 10–2 or 0.0210(1)

*Mark for answer*

**1**

**M2**    Mol H+ (= (25.0 × 10–3) × 0.620 )

= 1.55 × 10–2 or 0.0155

*Mark for answer*

**1**

**M3**    excess mol OH– = 5.5(1) × 10–3

*Allow conseq for M1 – M2*

***If wrong method*** *e.g. no subtraction or use of √*

***can only score max of M1, M2, M3 and M4.***

**1**

**M4**    [OH− ] = 5.51 × 10−3 ×     [ = 0.08718   (0.0872)]

***OR***    [OH− ] = 5.5 × 10−3 ×  = 0.0870(2)

*(M1 – M2) / vol in dm3 mark for dividing by volume*

*(take use of 63.2 without 10–3 as AE so 9.94 scores 5)*

*If no use or wrong use of vol lose M4 & M6*

*Can score M5 for showing (10–14/ their XS alkali)*

**1**

**M5**    [H+] =  = 1.147 × 10−13

***OR***     = 1.149 × 10−13

***OR***    pOH = 1.06

*If no use or wrong use of Kw or pOH no further marks*

**1**

**M6**    pH = 12.9(4)   allow 3sf

*If vol missed score max 4 for 11.7(4)*

*If acid– alkali reversed max 4 for pH = 1.06*

*Any excess acid – max 4*

**1**

**[12]**

**M24.**(a)      Proton acceptor

**1**

(b)     (i)     CH3CH2NH2   +   H2O      CH3CH2NH3+   +   OH–

*allow eq with or without   *

*allow C2H5NH2 and C2H5NH3+ (plus can be on N or H or 3)*

*allow RHS as C2H5NH3OH*

**1**

(ii)     Mark independently of (b)(i)

*Allow*

*Ethylamine is only partly/slightly dissociated*

*OR*

*Ethylamine is only partly/slightly ionized*

reaction/equilibrium lies to left or low [OH–] ***OR*** little OH– formed

***OR*** little ethylamine has reacted

*Ignore “not fully dissociated” or “not fully ionized”*

*Ignore reference to ionisation or dissociation of water*

**1**

(c)     **M1**    Ethylamine

*If wrong no marks in (c)*

**1**

**M2**    alkyl group is electron releasing/donating

***OR*** alkyl group has (positive) inductive effect

**1**

**M3**    increases electron density on N(H2)

***OR*** increased availability of lp

***OR*** increases ability of lp (to accept H(+))

*Mark M3 is independent of M2*

**1**

(d)     CH3CH2NH3Cl

*Or any amine hydrochloride*

allow name (ethylammonium chloride or ethylamine hydrochloride) or other halide  
for Cl

*or a strong* ***organic*** *acid*

***NOT*** *NH4Cl*

**1**

(e)     Mark independently of (d)

Extra H+ reacts with ethylamine or OH–

*Or makes reference to Equilibrium (in (b)(i)) with amine on LHS*

**1**

***OR***   CH3CH2NH2   +   H+      CH3CH2NH3+

***OR***   H+   +   OH–      H2O

Equilibrium shifts to RHS

***OR***   ratio [CH3CH2NH3+]/[ CH3CH2NH2] remains almost constant

**1**

**[9]**

**M25.**(a)     Proton donor or H+ donor

*Allow donator*

**1**

(b)     (i)      B B

*Both need to be correct to score the mark*

**1**

(ii)     A A

*Both need to be correct to score the mark*

**1**

(iii)     B A

*Both need to be correct to score the mark*

**1**

(c)     **M1**    [H+] = 10–1.25 OR 0.05623

**1**

**M2**    mol HCl = (25 × 10–3) × 0.0850 (= 2.125 × 10–3)

*Mark for Working*

**1**

**M3**    vol   = 0.0378 dm3 or 37.8 cm3

allow 0.0375 – 0.038 dm3 or 37.5 – 38 cm3

*Units and answer tied*

*Lose M3 if total given as (25 + 37.8) = 62.8 cm3*

*Ignore “vol added = 12.8 cm3 ” after correct answer*

**1**

(d)     (i)      4.52

*Must be 2dp*

**1**

(ii)     Ka =        ignore =  but this may score M1 in (d)(iii)

*Must have all brackets but allow ( ) Allow HA etc*

***NO*** *mark for 10–pKa*

**1**

(iii)     **M1**    Ka =  or with numbers

*Allow [H+] = √(Ka × [HA]) for M1*

**1**

**M2**    [H+] = (√(3.01 ×10–5 × 0.174) = √(5.24 ×10–6) )  
= 2.29 ×10–3 - 2.3 ×10–3

*Mark for answer*

**1**

**M3**    pH = 2.64             (allow more than 2dp but not fewer)

***Allow 1 for correct pH from their wrong [H+]***

*If square root forgotten, pH = 5.28 scores 2 for M1 and M3*

**1**

(e)     **M1**    mol OH– = (10.0 × 10-3) × 0.125 = 1.25 × 10–3

*Mark for answer*

**1**

**M2**    orig mol HX = (15.0 × 10–3) × 0.174 = 2.61 × 10×3

*Mark for answer*

**1**

**M3**    mol HX in buffer = orig mol HX – mol OH–

*Mark for answer*

= 2.61 × 10–3 – 1.25 × 10–3 = 1.36 × 10–3

*Allow conseq on their (M2 – M1)*

([HX] = 1.36 × 10–3/25 × 10–3 = 0.0544)

*If no subtraction, max 3 for M1, M2 & M4 (pH = 4.20)*

*If [H+] = [X–] & √used, max 3 for M1, M2 & M3 (pH = 2.89)*

**1**

**M4**    mol X– in buffer = mol OH– = 1.25 × 10–3

([X–] = 1.25 × 10–3/25 × 10–3 = 0.05)

*May be scored in M5 expression*

**1**

**M5**    [H+]   

*If use Ka =  no further marks*

=    OR 

(= 3.27 × 10–5)

*If either value of HX or X– used wrongly or expression upside down, no further marks*

**1**

**M6**    pH = 4.48 or 4.49   (allow more than 2dp but not fewer)

*Do* ***not*** *allow M6 for correct calculation of pH using their [H+] - this only applies in (d)(iii) - apart from earlier AE*

**1**

**[18]**

**M26.**(a)     (i)      [H+][OH−] ***OR*** [H3O+][OH−]

*Ignore (aq)*

*Must have [ ] not ( )*

**1**

(ii)     3.46 × 10−14 (= 1.86 × 10−7)

*If no square root, CE=0*

**1**

pH = 6.73

***Must be 2dp***

**1**

(iii)    [H+] = 10−11.36 (= 4.365 × 10−12 OR 4.37 × 10−12)

*Mark for working*

**1**

*Kw* = [4.365 × 10−12 ***OR*** 4.37 × 10−12 × 0.047] = 2.05 × 10−13

*Allow 2.05 × 10−13 − 2.1 × 10−13*

*Mark for answer*

*Ignore units*

**1**

(b)     (i)      HCOOH    HCOO− +   H+

*Must have  but ignore brackets.*

***OR***   HCOOH + H2O     HCOO− +   H3O+

*Allow HCO2− or CHOO− ie minus must be on oxygen, so penalise COOH−*

**1**

(ii)      

*Must have all brackets but allow ( )*

*Must be HCOOH etc.*

*Allow ecf in formulae from (b)(i)*

**1**

(iii)    M1



*Allow HA or HX etc.*

*Allow [H+] = (Ka × [HA]) for M1*

**1**

M2    [H+] = 3.16 × 10−3

*Mark for answer*

**1**

M3    pH = 2.50     allow more than 2 dp but not fewer

***Allow correct pH from their wrong*** *[H+]* ***here only*** *If square root shown but not taken, pH = 5.00 can score max 2 for M1 and M3*

**1**

(iv)    M1    Decrease     **Mark M1 independently**

**1**

M2    Eqm shifts / moves to RHS  ***OR*** more H+    ***OR***    *Ka* increases      
***OR*** more dissociation

**1**

M3    To reduce temperature or oppose increase / change in temperature

***Only award M3 following correct M2***

**1**

(c)     (i)      M1    

*If [HX]/[X-] upside down, no marks*

**1**

M2    

         (= 2.27 × 10−4)

**1**

M3    pH = 3.64      allow more than 2 dp but not fewer

***pH calc NOT allowed from their wrong [H+] here***

**1**

(ii)     M1    Mol H+ added = 5.00 × 10−4

*Mark on from AE in moles of HCl (eg 5 × 10−3 gives pH = 3.42 scores 3)*

**1**

M2    Mol HCOOH = 2.40 × 10−2 **and**   Mol HCOO– = 1.79 × 10−2

*If either wrong no further marks except AE (−1) OR if ECF in mol acid and / or mol salt from (c)(i), can score all 4*

**1**

M3    

*If [HX]/[X-] upside down here after correct expression in (c)(i), no further marks*



*If [HX]/[X-] upside down here and is repeat error from (c)(i), max 3 (pH = 3.88 after 3.86 in (c)(i))*

**1**

M4    pH = 3.62      allow more than 2 dp but not fewer

***pH calc NOT allowed from their wrong [H+] here***

**1**

**[20]**

**M27.**(a)    Proton donor or H+ donor

**1**

(b)     (i)      

*If Ka wrong, can only score M1 below.*

*Must be ethanoic acid not HA*

*Must have square brackets (penalise here only) but mark on in (b)(ii).*

**1**

(ii)     M1  [H+] = 10−2.69 ***OR*** 2.042 × 10−3 (mol dm−3)

**1**

M2  

*Ignore ( )*

*Mark for correctly rearranged expression incl [H+]2*

**1**

M3



*If M2 wrong no further marks.*

**1**

M4  = 0.238 (mol dm−3) Allow 0.229 − 0.24

**1**

(c)    (i)      ClCH2COOH      ClCH2COO− + H+***OR*** ClCH2COOH + H2O      ClCH2COO− + H3O+

*Allow *

*Allow ClCH2CO2H and ClCH2CO 2−*

**1**

(ii)     M1  Cl is (more electronegative so) withdraws electrons  
       ***OR*** negative inductive effect of Cl

*Ignore electronegativity.*

*Ignore chloroethanoic acid has a lower Ka value.*

*Allow Cl reduces +ve inductive effect of methyl group.*

**1**

M2  Weakens O–H bond  
       ***OR*** O–H bond is more polar  
       ***OR*** reduces negative charge on COO−       ***OR*** stabilizes COO− (more)

*M1 & M2 are independent marks.*

*Ignore H+ lost more easily.*

**1**

(d)     (i)      **A**

**1**

(ii)     **C**

**1**

(iii)    **D**

**1**

(e)     M1  Mol NaOH = mol OH− = (19.6 × 10–3) × 0.720 = 1.41(1) × 10−2

*Mark for answer.*

**1**

M2  Mol H2SO4 = (26.4 × 10−3) × 0.550 = 1.45(2) × 10−2

*Mark for answer.*

**1**

M3  Mol H+ added = **2 ×** (1.452 × 10−2) = 2.90(4) × 10−2       ***OR***       XS mol H2SO4 = 7.46(4) × 10−3

*If factor × 2 missed completely (pH = 2.05)*

*or used wrongly later,*

*can score max 4 for M1, M2, M5 & M6*

**1**

M4  XS mol H+ = 0.0149(3)

**1**

M5  For dividing by volume  
       [H+ ] = 0.0149(3) × (1000 / 46.0) = 0.324 − 0.325 mol dm−3

*If no use or wrong use of volume lose M5 and M6*

*ie can score 4 for pH = 1.83 (no use of vol)*

*Treat missing 1000 as AE (−1) & score 5 for pH = 3.49*

**1**

M6  pH = 0.49

***2dp*** *(penalise more or less).*

*If × 2 missed & vol not used, pH = 3.39 scores M1 & M2 only.*

**1**

**[18]**