IB · DP · Chemistry

2 hours 14 questions

Structured Questions: Paper 2

18.1 Further Aspects of Acids & Bases

Easy (5 questions)	/42
Medium (5 questions)	/63
Hard (4 questions)	/35
Total Marks	**/140**

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Easy Questions

1 (a) Define the terms Lewis acid and Lewis base and state the type of bond formed between a Lewis acid and base.

(3 marks)

(b) Identify which of the following are Lewis acids, Lewis bases or neither:

NH_3, K^+, SO_4^{2-}, CH_4, BCl_3,

(5 marks)

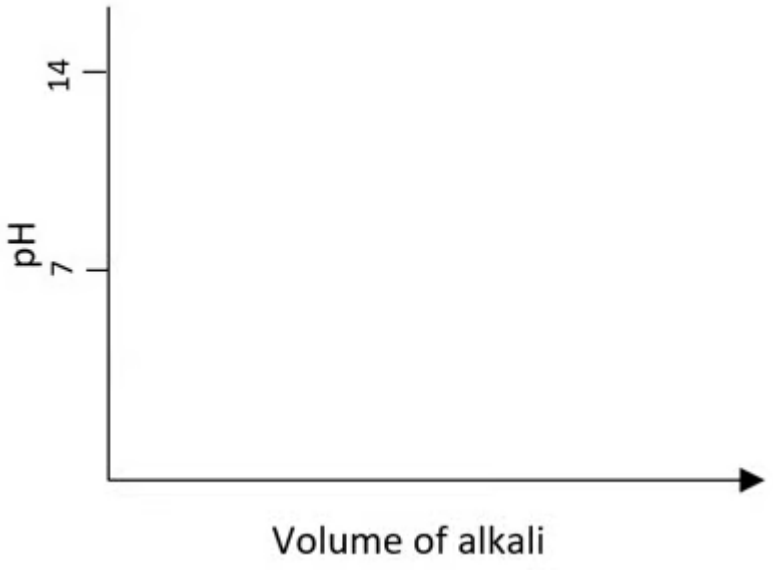
(c) Explain why aqueous ions of transition metals can act as Lewis acids.

(2 marks)

(d) State an alternative name for a species that acts as a Lewis base in organic chemistry mechanisms.

(1 mark)

2 (a) On the axes below, draw a sketch graph to show the neutralisation of ethanoic acid by sodium hydroxide:



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(2 marks)

(b) Write an equation for the reaction between ethanoic acid and sodium hydroxide and identify the species acting as a Lewis base in the reaction.

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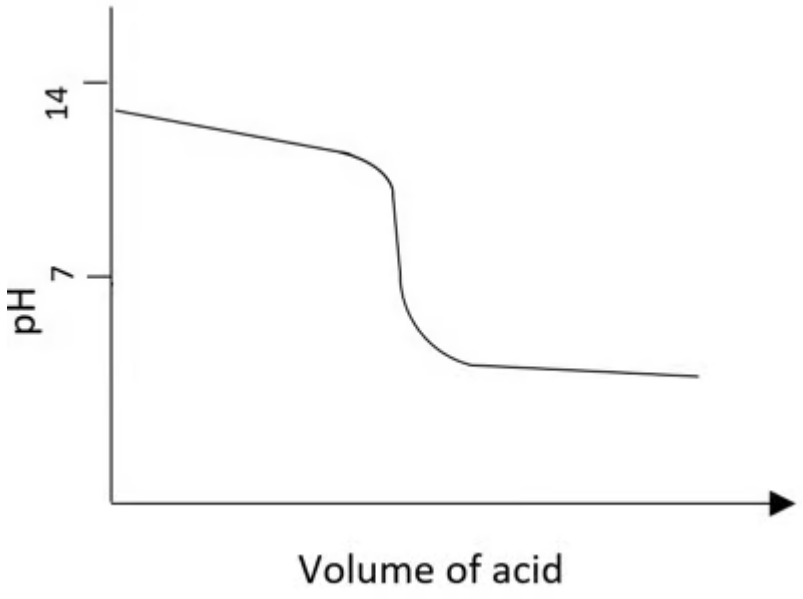
(2 marks)

(c) Identify the type of titration taking place from the curve and indicate where the buffer region is found on this curve.



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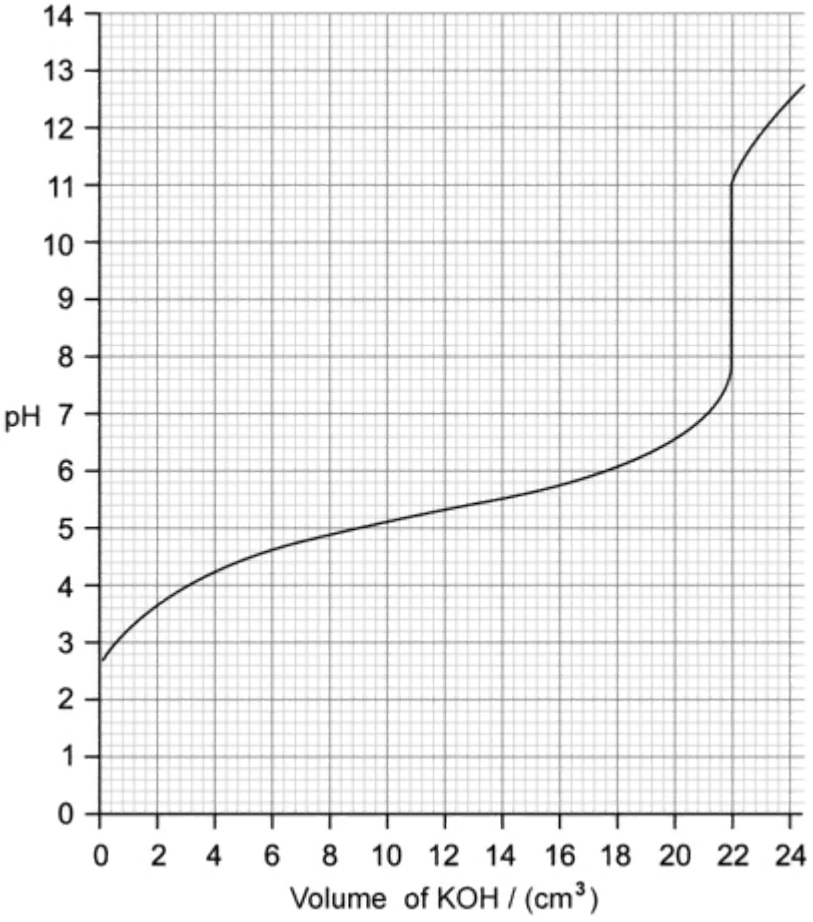
(2 marks)

(d) Identity on the graph the point at which pK_a= pH and find the pK_a of the acid.



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(2 marks)

3 (a) Explain how an acid-base indicator works.

(3 marks)

(b) Phenolphthalein, $C_{20}H_{14}O_4$, is an acid-base indicator. State the formula and colour of the conjugate base of phenolphthalein.

(2 marks)

(c) Explain how suitable indicators are chosen for titrations.

(3 marks)

4 (a) Outline what is meant by a buffer solution.

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(1 mark)

(b) Outline how a buffer solution can be made starting from 1.0 mol dm^{-3} ethanoic acid and 1.0 mol dm^{-3} sodium hydroxide.

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(2 marks)

(c) Use suitable equations to explain how the buffer in b) functions when a small quantity of acid is added.

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(4 marks)

(d) State the composition of a basic buffer

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(1 mark)

5 (a) Explain what is meant by the term *hydrolysis* in acids and bases.

(1 mark)

(b) Salts can be acidic, basic or neutral. Explain how you can predict whether a salt is likely to be acidic. Include an equation in your answer.

(3 marks)

(c) Deduce which of the following salts are acidic, basic or neutral:

CH_3COONa; NH_4Cl; KCl

(3 marks)

Medium Questions

1 (a) Iron(III) ions can react with cyanide ions to form ferricyanide ion via the following equation

$$Fe^{3+} + 6CN^{-} \rightarrow [Fe(CN)_6]^{3-}$$

State which of the reactants is behaving as a Lewis base and justify your answer.

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(2 marks)

(b) State the definition of a Brønsted-Lowry acid and the equation which demonstrates how ethanoic acid, CH_3COOH (aq) , behaves as a Brønsted-Lowry acid when reacting with ammonia, NH_3 (aq).

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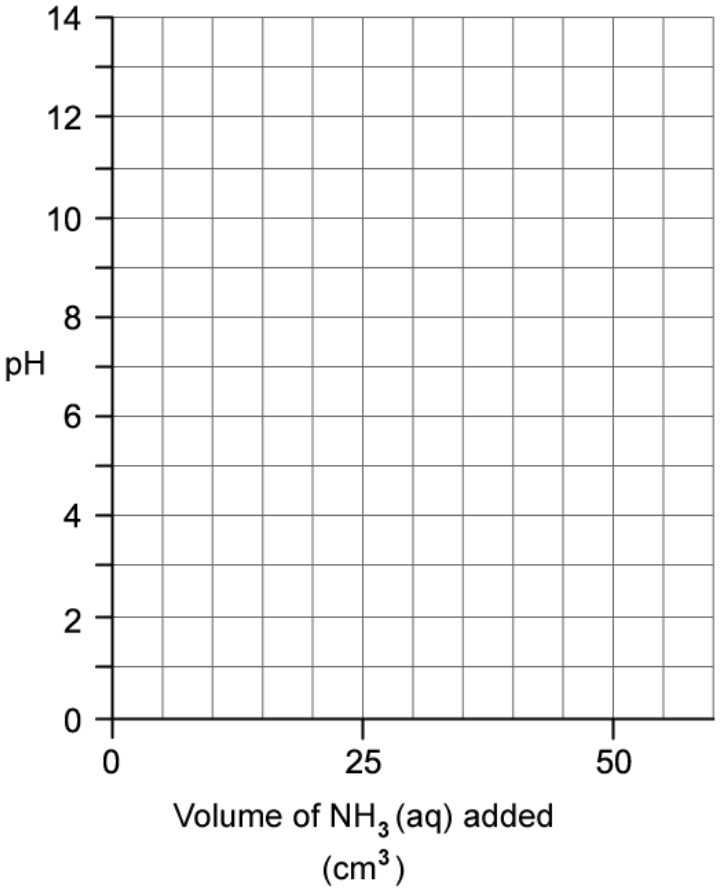
(2 marks)

(c) Sketch a graph to indicate the change in pH during a titration of 25.0 cm^3 of 0.100 mol dm^{-3} hydrochloric acid, HCl (aq) , with 0.100 mol of ammonia, NH_3 (aq).



(2 marks)

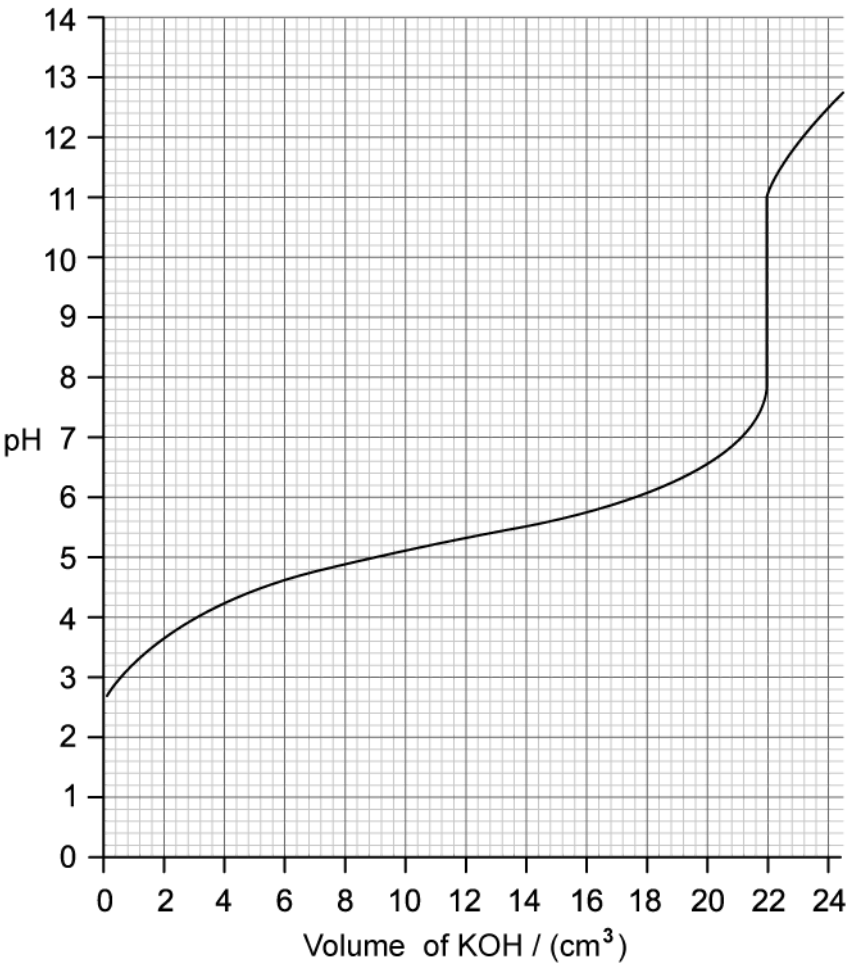
(d) The end point in a titration can be identified using a suitable indicator.

i) Using Section 22 of the Data Booklet, select a suitable indicator that could be used for this titration and justify your choice.

ii) Describe how an acidic indicator works.

(5 marks)

2 (a) Ethanoic acid, CH_3COOH (aq) , is titrated with 0.16 mol dm^{-3} potassium hydroxide and the following graph is obtained.



Explain why the equivalence point is greater than pH 7 for this titration.

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(3 marks)

(b) Explain what is meant by a buffer solution and describe where the 'buffer region' on the graph would occur.

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(2 marks)

(c) Explain the shape of the pH curve up to the equivalence point.

(4 marks)

(d) Explain why potassium hydroxide can act as a Brønsted-Lowry base and Lewis base.

(3 marks)

3 (a) This question is about Brønsted-Lowry acids and bases.

i) Give the meaning of the term Brønsted-Lowry acid.

ii) Explain the term weak acid.

(3 marks)

(b) When an acid and a base react they produce a conjugate base and a conjugate acid.

$$\text{acid} + \text{base} \rightleftharpoons \text{conjugate base} + \text{conjugate acid}$$

Write an equation to show how hydrochloric acid behaves as a strong acid when it reacts with water, and state the role of water in this reaction.

(2 marks)

(c) Ethanoic acid is a weak acid. Hydrogen carbonate ions can also act as a weak acid if in an aqueous solution.

i) Write equations for each of these weak acids at equilibrium.

ii) A solution was made up containing sodium hydrogen carbonate and sodium carbonate. Explain how this solution would act as a buffer if a small amount of acid was added to it.

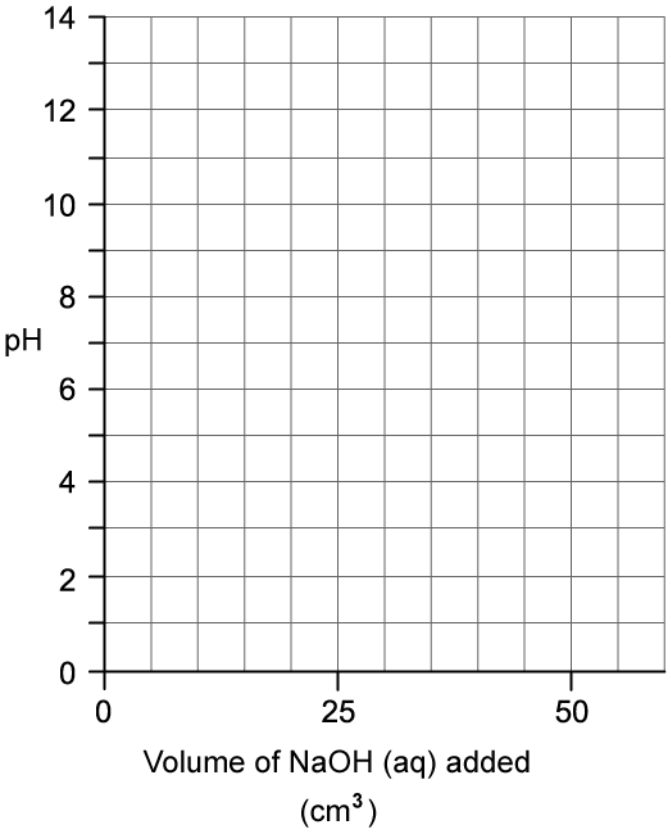
(4 marks)

(d) Explain how a solution containing ethanoic acid and ethanoate ions can act as a buffer.

(4 marks)

4 (a) A student performed a titration of 25.0 cm^3 of 0.100 mol dm^{-3} hydrochloric acid, HCl (aq) , with 0.100 mol of sodium hydroxide, NaOH (aq).

i) Draw the expected pH curve on the graph and indicate the equivalence point for this.



ii) Explain why the salt produced in this reaction is neutral.

(5 marks)

(b) The student repeated the titration using two different chemicals, 25.0 cm^3 of 0.100 mol dm^{-3} nitric acid, HNO_3 (aq) , and 0.100 mol dm^{-3} ammonia, NH_3 (aq).

i) State the equation for this reaction.

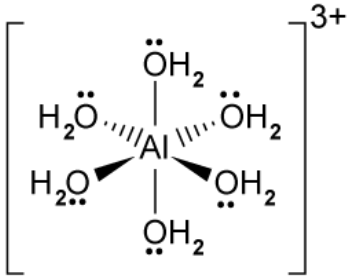
ii) Explain why the salt produced in this reaction is acidic.

(5 marks)

(c) State the equation for reaction between nitric acid and water, this reaction and identify the conjugate acid formed in the reaction.

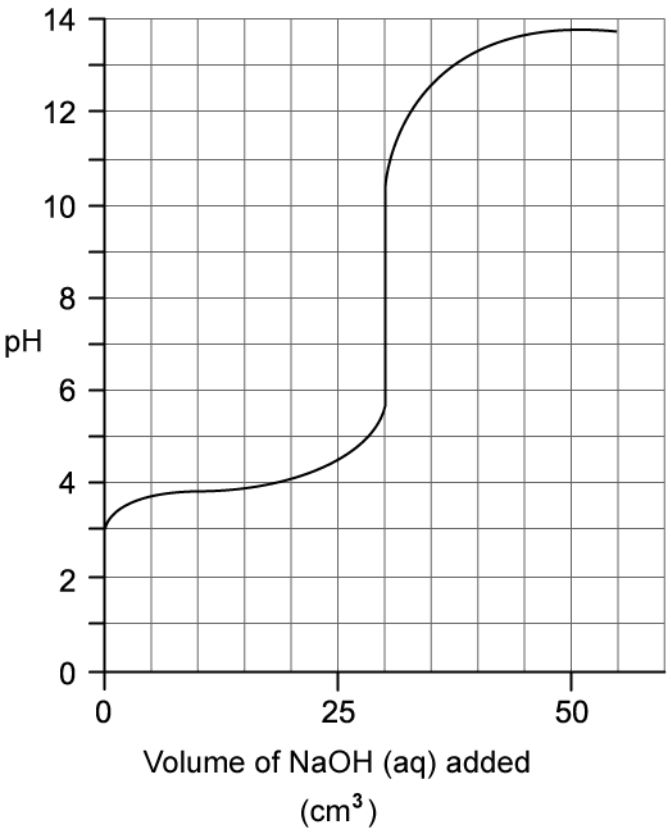
(2 marks)

(d) The image below shows the hexaaquaaluminium ion, $[Al(H_2O)_6]^{3+}$. Explain why this can behave as an acid.



(3 marks)

5 (a) 25.0 cm^3 of 0.100 mol dm^{-3} propanoic acid, CH_3CH_2COOH (aq) , is titrated with of 0.100 mol dm^{-3} sodium hydroxide. The pH curve for this titration is shown below.



i) Label the equivalence point and half equivalence point on the curve

ii) Explain what is meant by the half equivalence point.

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(3 marks)

(b) The student used the pH range of the indicators to determine which was the best one to use for this titration.

i) Using Section 22 of the Data Booklet highlight on the graph the pH range of bromocresol green for this titration.

ii) Using Section 22 of the Data Booklet suggest a suitable choice of indicator for this titration and state the colour change you would expect to see.

(3 marks)

(c) The end point of an indicator depends on its pK_a

i) Explain the connection between the pH range of an indicator that is a weak acid and
the value of pK_a for the indicator.

ii) Explain how the student can calculate the K_a of propanoic acid by using the pH curve.

(5 marks)

(d) A buffer solution contains a mixture of propanoic acid and its salt. A small amount of nitric acid is added to the buffer.

Write an equation, including state symbols, showing how this buffer can resist the change in pH.

(1 mark)

Hard Questions

1 (a) Ammonia reacts with boron trifluoride to form an adduct, a molecule made from the combination of two others.

$$NH_3 + BF_3 \rightarrow NH_3BF_3$$

Identify the Lewis acid and base and the type of bond formed between a Lewis acid and base.

(2 marks)

(b) Explain the role of water, in terms of Lewis acid-base theory, in the following equations:

$$NH_3\,(aq) + H_2O\,(l) \rightleftharpoons NH_4^+\,(aq) + OH^-\,(aq)$$
$$HCl\,(aq) + H_2O\,(l) \rightarrow H_3O^+\,(aq) + Cl^-\,(aq)$$

(2 marks)

(c) 'All Brønsted-Lowry acids are Lewis acids but not all Lewis acids are Brønsted Lowry acids.'

Evaluate whether this statement is true, giving an appropriate example.

(4 marks)

(d) In the nitration of benzene, identify a species which acts as a Lewis base.

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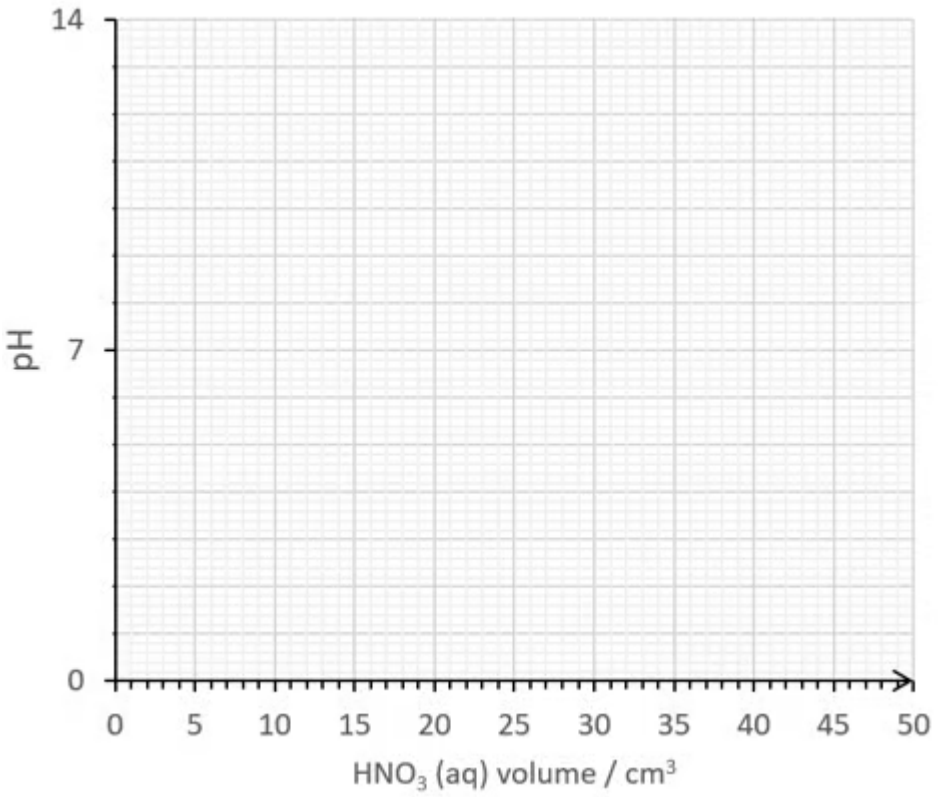
(1 mark)

2 (a) Sketch the titration curve when 50 cm^3 of 0.1 mol dm^{-3} HNO_3 (aq) is titrated against 25 cm^3 of 0.1 mol dm^{-3} NH_3 (aq).



(4 marks)

(b) Select a suitable indicator for the titration from table 22 of the Data booklet.

(1 mark)

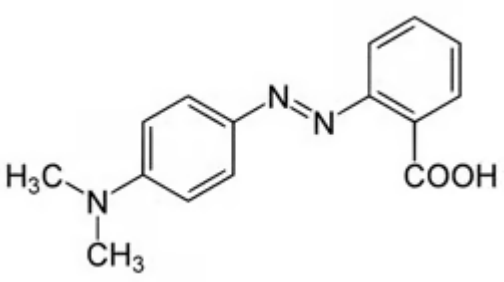
(c) Calculate the pH of 0.1 mol dm^{-3} ammonia using section 21 of the Data booklet.

(5 marks)

(d) Deduce, using section 21 of the Data booklet whether the pH of 0.1 mol dm^{-3} ethylamine would be higher or lower than 0.1 mol dm^{-3} ammonia solution.

(1 mark)

3 (a) Indicators are solutions of weak acids or bases. Methyl red has the molecular formula $C_{15}H_{15}N_2O_2$.



Draw the structure of the conjugate base of methyl red.

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(1 mark)

(b) What will be seen if a few drops of methyl red are added during a titration of 50 cm^3 of 0.1 mol dm^{-3} HCl (aq) against 25 cm^3 of 0.1 mol dm^{-3} NaOH (aq).

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(1 mark)

(c) The pKa of methyl red is 5.1. Explain how this relates to the acid-base character of methyl red when added to water.

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(3 marks)

4 (a) Using section 21 of the Data booklet, discuss the relationship between the chemical structures and acidity of chloroethanoic acid, dichloroethanoic acid and trichloroethanoic acid.

(3 marks)

(b) This question is about acid buffers.

i) Explain how you could make a buffer given a supply of the following:
20 cm^3 of 0.10 mol dm^{-3} chloroethanoic acid
20 cm^3 of 0.10 mol dm^{-3} potassium hydroxide

[3]

ii) Determine the new concentration of each reactant in the buffer.

[1]

(4 marks)

(c) 20 cm^3 of 0.05 mol dm^{-3} dichloroethanoic acid was reacted with 10 cm^3 of 0.10 mol dm^{-3} sodium hydroxide. Suggest, with a reason, a pH value for the resulting solution.

(3 marks)