



Acids, Bases & PH Calculations
Chemistry Past Exam Questions
Higher Level

2013

Section B - Question 11 - Part b

(b) Define a base according to (i) the Arrhenius theory, (ii) the Brønsted-Lowry theory. (7)

Give (i) the conjugate acid, (ii) the conjugate base, of HPO_4^{2-} . (6)

Ammonium hydroxide (NH_4OH) is produced by dissolving gaseous ammonia in water.

Calculate the pH of an ammonium hydroxide solution that contains 7.0 g NH_4OH per litre.

The value of the base dissociation constant (K_b) for ammonium hydroxide is 1.8×10^{-5} . (12)

Section B - Question 11 B

1. A student determined the concentration of a hydrochloric acid solution by titration with 25.0 cm³ portions of a 0.05 M primary standard solution of anhydrous sodium carbonate. The portions of sodium carbonate solution were measured into a conical flask using a 25 cm³ pipette. The hydrochloric acid solution was added from a burette. The mean titre was 20.8 cm³.

The balanced equation for the titration reaction was:



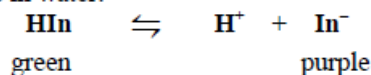
- (a) Explain the underlined term. (5)
- (b) Describe how the student should have prepared 500 cm³ of the 0.05 M primary standard solution from a known mass of pure anhydrous sodium carbonate, supplied on a clock glass. (12)
- Calculate the exact mass of anhydrous sodium carbonate (Na₂CO₃) required to prepare this solution. (6)
- (c) (i) Describe how the liquid level in the burette was adjusted to the zero mark.
(ii) Why was a pipette filler used to fill the pipette with 25.0 cm³ of the sodium carbonate solution? (6)
- (d) Name a suitable indicator for this titration.
State the colour change observed at the end point. (9)
- (e) Calculate, correct to two decimal places, the concentration of the hydrochloric acid solution in
(i) moles per litre,
(ii) grams per litre. (12)
-

Section B - Question 10 B

- (b) Define *an acid* in terms of the Brønsted-Lowry theory.

What is a *conjugate pair*? (7)

A certain water soluble acid-base indicator represented by **HIn** is a weak acid which dissociates as follows in water.



State and explain the colour observed when a few drops of a solution of the indicator are added to a 0.5 M NaOH solution. (6)

Calculate the pH of (i) the 0.5 M NaOH solution, (ii) a 0.1 M solution of the indicator, given that its K_a value is 2.0×10^{-5} . (12)

Section B - Question 7

7. Sulfuric acid is a strong dibasic acid. The formula **HA** represents a weak monobasic acid.
- (a) How do strong acids differ from weak acids in their behaviour in water according to (i) the Arrhenius theory, (ii) the Brønsted-Lowry theory? (12)
- (b) What is the conjugate base of (i) sulfuric acid, (ii) the weak acid **HA**? Which of these conjugate bases is the stronger? Explain. (12)
- (c) Explain, by giving a balanced equation for its dissociation in water, that the conjugate base of sulfuric acid is itself an acid. (6)
- (d) Define pH. (6)
- Calculate the pH of a 0.2 M solution of a weak acid, **HA**, the value of whose acid dissociation constant, K_a , is $6.3 \times 10^{-5} \text{ mol l}^{-1}$.
- What is the concentration of a sulfuric acid solution that has the same pH? (14)
-

Section B - Question 8

8. (a) Define (i) acid, (ii) conjugate acid, according to the Brønsted-Lowry theory. (8)

In acting as an acid-base indicator methyl orange behaves like a weak acid. Letting **HX** represent methyl orange, it dissociates as follows:



In aqueous solution, the undissociated form (**HX**) is red and the dissociated form (**X⁻**) is yellow.

Distinguish between a strong acid and a weak acid. (6)

What is the conjugate base of **HX**? (3)

- (b) State and explain the colour observed when a few drops of the methyl orange solution is added to (i) a 0.1 M solution of **HCl**, (ii) a 0.1 M solution of **NaOH**. (12)

- (c) Calculate the pH of (i) a 0.1M solution of **NaOH**, (ii) a 0.004 M solution of methyl orange, if methyl orange has a K_a value of 3.5×10^{-4} . (9)

Draw a clearly labelled diagram of the pH curve you would expect to obtain when 50 cm³ of 0.1 M **NaOH** solution is added slowly to 25 cm³ of a 0.1 M **HCl** solution. Explain by referring to the curve why almost any acid-base indicator can be used in this titration. (12)

Section A - Question 1

1. To determine the concentration of ethanoic acid, CH_3COOH , in a sample of vinegar, the vinegar was first diluted and then titrated against 25.0 cm^3 portions of a previously standardised 0.10 M solution of sodium hydroxide, NaOH . One rough and two accurate titrations were carried out.

The three titration figures recorded were 22.9 , 22.6 and 22.7 cm^3 , respectively.

- (a) Why was the vinegar diluted? (5)
- (b) Describe the correct procedures for measuring exactly 25.0 cm^3 of vinegar and diluting it to exactly 250 cm^3 using deionised water. (15)
- (c) The equation for the titration reaction is:
- $$\text{CH}_3\text{COOH} + \text{NaOH} \longrightarrow \text{CH}_3\text{COONa} + \text{H}_2\text{O}$$
- Name an indicator suitable for this titration. Justify your choice of indicator.
State the colour change at the end point. (12)
- (d) Calculate the concentration of the diluted solution of ethanoic acid in
(i) moles per litre, (ii) grams per litre.
State the concentration of ethanoic acid in the original vinegar sample in grams per litre.
Express this concentration in terms of % (w/v). (15)
- (e) Ethanoic acid is a carboxylic acid. Identify the carboxylic acid which occurs in nettles and stinging ants. (3)

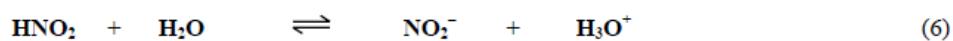
Section B - Question 8

8. (a) (i) Write an expression for the self-ionisation of water. (5)
- (ii) Define K_w , the ionic product of water.
The value of K_w at $25 \text{ }^\circ\text{C}$ is 1.0×10^{-14} . Show that the pH of pure water is 7.0 at $25 \text{ }^\circ\text{C}$. (12)
- (iii) Calculate the pH of a 0.5 M solution of a strong monobasic (monoprotic) acid.
Calculate the pH of a 0.5 M solution of a weak monobasic acid with a K_a value of 1.8×10^{-5} . (12)
- (b) (i) Explain clearly how suspended solids are removed in the treatment of water for drinking. (9)
- (ii) Identify two chemicals added at the final stages of the treatment of water for drinking.
State the purpose of adding each chemical you have identified. (12)
-

Section B - Question 7

7. (a) Define (i) *acid*, (ii) *conjugate pair*, according to the Brønsted-Lowry theory. (8)

Identify the two conjugate pairs in the following dissociation of nitrous acid (HNO_2):



Distinguish between a strong acid and a weak acid. (6)

- (b) Calculate the pH of 0.1 M nitrous acid (HNO_2); the value of the acid dissociation constant (K_a) for nitrous acid is 5.0×10^{-4} .
What is the pH of a nitric acid (HNO_3) solution of the same concentration? (15)
- (c) *Eutrophication* in water may result from the addition of large quantities of nitrate fertilizers to it. Describe the processes occurring in the water leading to eutrophication. (9)
- (d) Explain how heavy metal ions are removed from large quantities of water. (6)

Section A - Question 1

1. An experiment was carried out to determine the percentage water of crystallisation and the degree of water of crystallisation, x , in a sample of hydrated sodium carbonate crystals ($\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$). An 8.20 g sample of the crystals was weighed accurately on a clock glass and then made up to 500 cm³ of solution in a volumetric flask. A pipette was used to transfer 25.0 cm³ portions of this solution to a conical flask. A previously standardised 0.11 M hydrochloric acid (HCl) solution was used to titrate each sample. A number of accurate titrations were carried out. The average volume of hydrochloric acid solution required in these titrations was 26.05 cm³.

The titration reaction is described by the equation:



- (a) Identify a primary standard reagent which could have been used to standardise the hydrochloric acid solution. (5)
- (b) Name a suitable indicator for the titration and state the colour change observed in the conical flask at the end point. Explain why not more than 1 – 2 drops of indicator should be used. (12)
- (c) (i) Describe the correct procedure for rinsing the burette before filling it with the solution it is to deliver.
(ii) Why is it important to fill the part below the tap of the burette? (12)
- (d) From the titration figures, calculate the concentration of sodium carbonate (Na_2CO_3) in the solution in
(i) moles per litre,
(ii) grams per litre. (9)
- (e) Calculate the percentage water of crystallisation present in the crystals and the value of x , the degree of hydration of the crystals. (12)

Section B - Question 8

8. (a) (i) What is *hard water*? (5)
(ii) A supply of hard water is treated for domestic use by ion-exchange. You may assume that all the hardness is due to $\text{Ca}(\text{HCO}_3)_2$. Explain in words or using a balanced equation how a cation exchange resin, represented by RNa , softens this water supply. (6)
(iii) In the treatment of water for drinking, what is meant by the term *flocculation*?
Name a flocculating agent. (9)
(iv) What substance is added to water to adjust the pH if the water is too acidic? Why is it undesirable to have the pH of drinking water below 6? (6)
- (b) (i) Explain how an acid-base indicator, which is itself a weak acid, and may be represented by HX , functions. (9)
(ii) Draw a clearly labelled diagram of the titration curve you would expect to obtain when 50 cm³ of a 0.1 M sodium hydroxide (NaOH) solution is added slowly to 25 cm³ of a 0.1 M ethanoic acid (CH_3COOH) solution. (9)
(iii) Explain with reference to your diagram why phenolphthalein is a suitable indicator for a titration of sodium hydroxide with ethanoic acid. (6)

Section B - Question 8

8. (a) Define (i) *acid*, (ii) *base*, according to the Brønsted-Lowry theory. (8)
- (b) Identify **one** species acting as an acid, and also identify its conjugate base, in the following system. (6)
- $$\text{H}_2\text{F}^+ + \text{Cl}^- \rightleftharpoons \text{HCl} + \text{HF}$$
- (c) Calculate the pH of a 0.002 M solution of methanoic acid (**HCOOH**).
The value of K_a for methanoic acid is 1.8×10^{-4} . (12)
- (d) What is meant by the *biochemical oxygen demand (BOD)* of a water sample? (6)
- (e) Describe clearly the processes involved in the primary and secondary stages of urban sewage treatment. What substances are removed by tertiary treatment of sewage? (18)