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 $\mathbf{HPO_4^{2-}}$. (6)

Ammonium hydroxide ($\mathbf{NH_4OH}$) is produced by dissolving gaseous ammonia in water.

Calculate the pH of an ammonium hydroxide solution that contains 7.0 g $\mathbf{NH_4OH}$ per litre.
The value of the base dissociation constant (K_b) for ammonium hydroxide is 1.8×10^{-5}. (12)

2012

Section B - Question 11 B

1. A student determined the concentration of a hydrochloric acid solution by titration with 25.0 cm^3 portions of a 0.05 M <u>primary standard</u> solution of anhydrous sodium carbonate. The portions of sodium carbonate solution were measured into a conical flask using a 25 cm^3 pipette. The hydrochloric acid solution was added from a burette. The mean titre was 20.8 cm^3.

   The balanced equation for the titration reaction was:

$$\mathbf{2HCl + Na_2CO_3 \longrightarrow 2NaCl + H_2O + CO_2}$$

(*a*) Explain the underlined term. (5)

(*b*) Describe how the student should have prepared 500 cm^3 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 (**Na_2CO_3**) 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 cm^3 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.

$$\underset{\text{green}}{\mathbf{HIn}} \rightleftharpoons \mathbf{H^+} + \underset{\text{purple}}{\mathbf{In^-}}$$

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)

2011

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 6.3×10^{-5} mol l^{-1}.

What is the concentration of a sulfuric acid solution that has the same pH? (14)

2010

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:

$$\mathbf{HX} \rightleftharpoons \mathbf{H^+} + \mathbf{X^-}$$

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 cm^3 of 0.1 M **NaOH** solution is added slowly to 25 cm^3 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)

2008

Section A - Question 1

1. To determine the concentration of ethanoic acid, $\mathbf{CH_3COOH}$, 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, $\mathbf{NaOH}$. 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:

$$\mathbf{CH_3COOH} \quad + \quad \mathbf{NaOH} \quad \longrightarrow \quad \mathbf{CH_3COONa} \quad + \quad \mathbf{H_2O}$$

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 °C is 1.0×10^{-14}. Show that the pH of pure water is 7.0 at 25 °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)

2007

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**):

$$\mathbf{HNO_2} \quad + \quad \mathbf{H_2O} \quad \rightleftharpoons \quad \mathbf{NO_2^-} \quad + \quad \mathbf{H_3O^+} \qquad (6)$$

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)

2006

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 (**$Na_2CO_3.xH_2O$**). An 8.20 g sample of the crystals was weighed accurately on a clock glass and then made up to 500 cm^3 of solution in a volumetric flask. A pipette was used to transfer 25.0 cm^3 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 cm^3.

The titration reaction is described by the equation:

$$Na_2CO_3 \quad + \quad 2HCl \quad \longrightarrow \quad 2NaCl \quad + \quad CO_2 \quad + \quad H_2O$$

(*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 **$Ca(HCO_3)_2$**. Explain in words <u>or</u> 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 cm^3 of a 0.1 M sodium hydroxide (**NaOH**) solution is added slowly to 25 cm^3 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)

2005

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.

$$\mathbf{H_2F^+ \quad + \quad Cl^- \quad \rightleftharpoons \quad HCl \quad + \quad HF} \qquad (6)$$

(*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)