18.2 Calculations Involving Acids & Bases

Question Paper

Course	DP IB Chemistry
Section	18. Acids & Bases (HL only)
Topic	18.2 Calculations Involving Acids & Bases
Difficulty	Medium

Time allowed: 80

Score: /61

Percentage: /100

Question 1a

a)
At 298K, water molecules dissociate into equal quantities of ions, and the pH is 7.

i)
Write an equation to show the dissociation of water.

ii)
At 313 K, the pH of water is 6.77. Explain why water is still neutral with a pH of 6.77.

[2 marks]

Question 1b

b)
The ionic product of water, K_w, can be used to find the pH of a strong base. Changing the temperature will affect the value for K_w.

i)
Give the expression and units for the ionic product of water, K_w

ii)
As temperature is increased, the value for K_w also increases. Explain why.

[5 marks]

Question 1c

c)
Determine the pH of pure water at 40 °C.

K_w of pure water at 40 °C is 2.92×10^{-14} $mol^2 dm^{-3}$

[3 marks]

Question 1d

d)
Strong bases fully ionise in water, as shown by the equation of dissociation of sodium hydroxide:

$$NaOH\,(aq) \rightarrow Na^+\,(aq) + OH^-\,(aq)$$

At 298K, K_w is 1×10^{-14} $mol^2 dm^{-6}$.

Calculate the pH of a 0.05 mol dm^{-3} solution of NaOH at 298 K.

[3 marks]

Question 2a

a)
Weak acids do not fully ionise in solution. The acid dissociation constant, K_a is used to determine the hydrogen ion concentration.

Write an expression for the acid dissociation constant, K_a for the acid HA.

[1 mark]

Question 2b

b)
The pH of a 0.15 mol dm^{-3} solution of HCN is 5.08 at 298 K. Calculate the value of K_a for HCN at 298 K.

Give your answer to two decimal places.

[3 marks]

Question 2c

c)
A sample of 0.01 mol dm^{-3} butanoic acid has a K_a value of 1.51×10^{-5} mol dm^{-3}.

i)
Write an expression for the acid dissociation constant, K_a, for butanoic acid.

ii)
Calculate the pH of the 0.01 mol dm^{-3} butanoic acid. Give your answer to two decimal places.

[4 marks]

Question 2d

d)
0.50 moles of ammonia was dissolved in water to make a 1.00 dm^3 solution. This solution has a hydroxide ion concentration of 6.40×10^{-3} mol dm^{-3}.

i)
Write an expression for the base dissociation constant, K_b, of ammonia.

ii)
Calculate a value for pK_b for ammonia.

[4 marks]

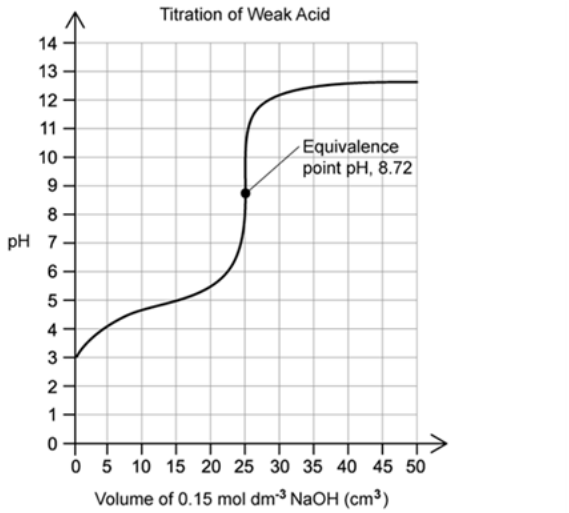
Question 3a

a)

The pH curve shown below was obtained when a 0.150 mol dm^{-3} solution of sodium hydroxide was added to 25.0 cm^3 of an aqueous solution of ethanoic acid. The half equivalence point is where half of the volume of sodium hydroxide required for neutralisation has been added to the ethanoic acid.

i)

Label the graph with an X to show the position of the half equivalence point.



ii)

When half of the ethanoic acid solution has been neutralised, the remaining ethanoic acid concentration is equal to that of the sodium ethanoate that had formed. Calculate the pH at this point.

K_a of ethanoic acid = 1.75 x 10^{-5} mol dm^{-3}.

[3 marks]

Question 3b

b)

A different titration was performed using 0.100 mol dm^{-3} ammonia solution, NH_3 (aq) and 25.00 cm^3 of 0.100 nitric acid, HNO_3 (aq).

Using Section 21 of the Data Booklet, calculate the pH of the ammonia solution before it was added to the nitric acid.

[6 marks]

Question 3c

c)
The titration is repeated using 0.200 mol dm^{-3} sodium hydroxide, NaOH (aq), instead of ammonia.

Determine whether the salt formed in this titration will be acidic, basic or neutral.

[2 marks]

Question 3d

d)
Determine the pH of the solution if 150 cm^3 of 0.30 mol dm^{-3} sodium hydroxide, NaOH (aq), is mixed with 200 cm^3 0.10 mol dm^{-3} of nitric acid, HNO_3 (aq).

[5 marks]

Question 4a

a)
Monochloroacetic acid, ClH_2COOH, is a skin irritant that is used in "chemical peels" intended to remove the top layer of dead skin from the face and ultimately improve the complexion.

Write an expression for the acid dissociation constant, K_a, of monochloroacetic acid.

[1 mark]

Question 4b

b)
Calculate the pH of a 0.05 M solution of monochloric acid.

The value of K_a for monochloroacetic acid is 1.35×10^{-3} mol dm^{-3}

[4 marks]

Question 4c

c)
Using Section 2 of the Data Booklet, calculate the value of $[OH^-]$ for the solution of monochloric acid.

[2 marks]

Question 4d

d)
Calculate the percentage dissociation for the solution of monochloric acid.

[2 marks]

Question 5a

a)
State the relationship between the following expressions for conjugate acid-base pair

i)
K_a and K_b

ii)
pKa and pK_b

[2 marks]

Question 5b

b)
Using Section 21 of the Data Booklet, calculate the following for the conjugate bases at 298 K.

i)
pK_b of $CH_3CH_2COO^-$

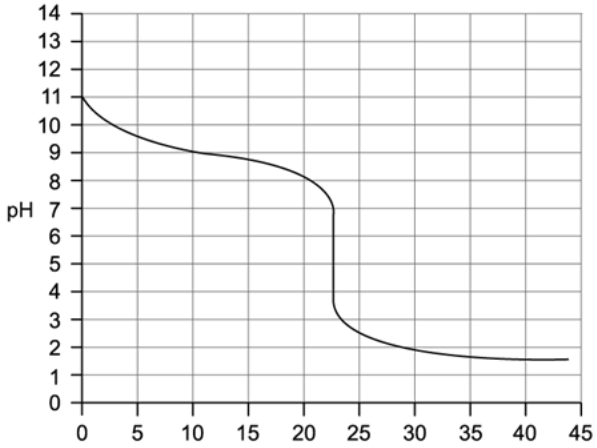
ii)
K_b of $CH(CI_2)COO^-$

iii)
K_a of $CH(CH_2)_2COO^-$

[4 marks]

Question 5c

c)
A student performs a titration using a 0.10 mol dm^{-3} ammonia, NH_3 (aq), and a hydrochloric acid and 0.10 hydrochloric acid, HCl (aq).



i)
State the equation for the overall reaction that is occurring.

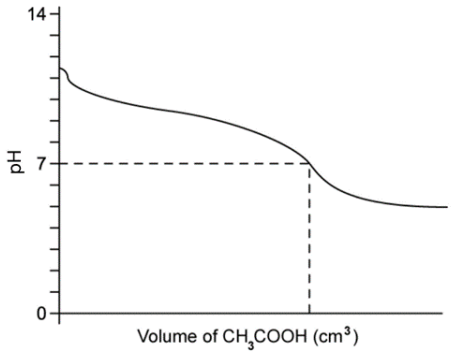
ii)
Mark on the curve the point at which the pOH is equal to pK_b of the weak base and deduce the pK_b of the acid.

[4 marks]

Question 5d

d)

The student repeats the titration with 0.10 mol dm^{-3} ethanoic acid, CH_3COOH (aq) which has a pK_a value of 4.76. A sketch of the pH curve obtained is shown below.



Explain why it is difficult to determine the equivalence point for this reaction accurately.

[1 mark]