NCEA exam questions on titration curves

**2017**

A titration was carried out by adding 0.112 mol L–1 sodium hydroxide solution, NaOH(*aq*), to 20.0 mL of ethanoic acid solution, CH3COOH(*aq*).

The equation for the reaction is:

CH3COOH(*aq*) + NaOH(*aq*) → CH3COONa(*aq*) + H2O(l) *K*a(CH3COOH) = 1.74 × 10–5



**(a)** With reference to the titration curve above, put a tick next to the indicator most suited to identify the equivalence point.



(b) (i) The ethanoic acid solution, CH3COOH(*aq*), has a pH of 2.77 before any NaOH is added.

Show by calculation that the concentration of the CH3COOH solution is 0.166 mol L–1.

(ii) Calculate the pH of the solution in the flask after 10.0 mL of 0.112 mol L–1 NaOH has been added to 20.0 mL of ethanoic acid solution, CH3COOH(*aq*).

(c) The equivalence point pH for the titration of ethanoic acid with sodium hydroxide is 8.79.

(i) Identify the chemical species present at the equivalence point, other than water.

(ii) In a second titration, a 0.166 mol L–1 methanoic acid solution, HCOOH(*aq*), is titrated with the NaOH

solution. The equivalence point pH for this titration is 8.28.

The equivalence point pH for the CH3COOH titration is 8.79.

Compare and contrast the pH values at the equivalence point for both titrations.

*K*a(HCOOH) = 1.82 × 10–4 *K*a(CH3COOH) = 1.74 × 10–5

*No calculations are necessary.*

**2016**

20.00 mL of 0.320 mol L–1 ammonia, NH3, is titrated with 0.640 mol L–1 hydrochloric acid, HCl.

The equation for this reaction is:

NH3 + HCl → NH4+ + Cl– p*K*a(NH4+) = 9.24

The curve for this titration is given below.



(a) Explain why the pH at the equivalence point (point C) is not 7.

(b) Show, by calculation, that the pH at the equivalence point (point C) is 4.96.

(c) Explain, in terms of the species present, why the pH at B (half way to the equivalence point) is 9.24.

(d) Explain, in terms of the species present, why the pH of the solution at point C is 4.96.

*No calculations are necessary.*

**2015**

20.0 mL of 0.258 mol L–1 hydrofluoric acid, HF, solution is titrated with a sodium hydroxide, NaOH, solution.

The equation for the reaction is:

HF + NaOH → NaF + H2O p*K*a(HF) = 3.17

The titration curve is given below:



(a) (i) Identify the species in solution at the equivalence point.

(ii) Explain why the pH at the equivalence point is greater than 7.

Include an equation in your answer.

(iii) After a certain volume of NaOH solution has been added, the concentration of HF in the solution will

be twice that of the F–.

Calculate the pH of this solution, and evaluate its ability to function as a buffer.

(iv) Determine by calculation, the pH of the solution after 24.0 mL of 0.258 mol L–1 NaOH solution has been added.

(b) In a second titration, a 0.258 mol L–1 ethanoic acid, CH3COOH, solution was titrated with the NaOH

solution.

Contrast the expected pH at the equivalence point with the HF titration. p*K*a(CH3COOH) = 4.76

No calculations are necessary.

**2014**

A titration was carried out by adding hydrobromic acid, HBr, to 20.0 mL of aqueous methylamine, CH3NH2, solution.

The equation for the reaction is: CH3NH2 + HBr → CH3NH3+ + Br–

*K*a(CH3NH3+) = 2.29 × 10–11

The curve for this titration is given below:



(a) Explain why the pH does not change significantly between the addition of 5 to 15 mL of HBr (around

point **A** on the curve). Include any relevant equation(s) in your answer.

(b) The aqueous methylamine, CH3NH2, solution has a pH of 11.8 before any HBr is added.

Show by calculation that the concentration of this solution is 0.0912 mol L–1.

(c) (i) Write the formulae of the four chemical species, apart from water and OH–, that are present at the point marked **B** on the curve

(ii) Compare and contrast the solution at point **B** with the initial aqueous methylamine solution.

In your answer you should include:

• a comparison of species present AND their relative concentrations

• a comparison of electrical conductivity linked to the relevant species present in each solution

• equations to support your answer.

**2013**

20.0 mL of 0.0896 mol L–1 ethanoic acid is titrated with 0.100 mol L–1 sodium hydroxide.

p*K*a (CH3COOH) = 4.76

(a) Calculate the pH of the ethanoic acid before any NaOH is added.

(b) Halfway to the equivalence point of the titration, the pH = p*K*a of the ethanoic acid.

Discuss the reason for this.

(c) (i) Discuss the change in the concentration of species in solution, as the first 5.00 mL of NaOH is added

to the 20.0 mL of ethanoic acid. Your answer should include chemical equations.

No calculations are required.

(ii) Calculate the pH of the titration mixture after 5.00 mL of NaOH has been added.

**2012**

A titration was carried out with methanoic acid and sodium hydroxide.

The equation for the reaction is: HCOOH + NaOH → HCOONa + H2O p*K*a (HCOOH) = 3.74

The curve for this titration is given below:



25.0 mL of methanoic acid solution is titrated with 0.180 mol L–1 sodium hydroxide.

(a) (i) Show that the concentration of the HCOOH solution is 0.288 mol L–1.

(ii) Calculate the initial pH of the 0.288 mol L–1 HCOOH solution.

(b) Discuss the pH of the reaction mixture, in terms of the species present, after 20 mL of NaOH has been

added. *No calculations are necessary.*

(c) Some indicators and their p*K*a values are shown in the table below.



Discuss the suitability of **each** of these indicators for this titration.

In your answer you should include:

• an identification of the most suitable indicator(s)

• the consequences of choosing an unsuitable indicator

• an explanation of the significance of the p*K*a in selecting an indicator.

**2011**

Below is the titration curve for 10.0 mL of 0.100 mol L–1 ethanoic acid being titrated with 0.100 mol L–1 sodium hydroxide. Ethanoic acid can be represented by the symbol HEt.



(a) With reference to the point marked A on the graph, discuss:

• the species present, and their relative concentrations

• an estimate of the p*K*a value for ethanoic acid

• the effect of adding small amounts of strong acid or strong base to the solution.

*Include relevant equations in your answer. No calculations are necessary.*

(b) With reference to the point marked B on the graph, discuss the species present, and their effect on the

pH at the equivalence point.

*Include relevant equations in your answer. No calculations are necessary.*

**2010**

20.00 mL of 0.160 mol L–1 ammonia is titrated with 0.230 mol L–1 hydrochloric acid.

The equation for the reaction is

NH3 + HCl → NH4+ + Cl–

p*K*a(NH4+) = 9.24, *K*a = 5.75 × 10–10

The curve for this titration is given below.



(a) Explain, in terms of species present, why the pH at B (half way to the equivalence volume) is 9.24.

(b) Calculate the pH at point A.

(c) Discuss the pH of the reaction mixture at point **C**, in terms of the species present.

**2009**

25.0 mL of 0.0500 mol L–1 benzoic acid solution (C6H5COOH) is titrated with 0.0500 mol L–1 sodium hydroxide solution. The equation for the reaction is:

C6H5COOH(*aq*) + NaOH(*aq*) → C6H5COONa(*aq*) + H2O(*ℓ*)

The titration curve for the reaction is:



**a)** Write the formulae of the four chemical species, apart from water and H3O+, that are present at the equivalence point.

**b)** Explain why the solution in the titration flask has buffering properties after 9.80 mL of the NaOH solution has been added, but not when 25.0 mL has been added.

**c)** Some indicators are shown in the table below.



Discuss the suitability of these indicators for this titration.

Your discussion should include:

• identification of the most suitable indicator(s)

• consideration of how indicators are chosen for a titration

 • the consequences of choosing an unsuitable indicator.

**2008**

The following titration curve shows the addition of aqueous 0.100 mol L–1 sodium hydroxide to a solution of hydrazoic acid, HN3.

p*K*a(HN3) = 4.72



(a) (i) Draw a cross (X) on the titration curve to indicate the pH at the equivalence point of the titration.

(ii) Complete the titration curve to show how the pH changes as more aqueous sodium hydroxide is added.

(b) The initial pH of the hydrazoic acid (HN3) is 2.6. Calculate the concentration of the HN3 solution used

in the titration.

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