
# Determining an equilibrium constant by Experiment

Pupil’s Book

**From an esterification**

It is possible to determine experimentally the equilibrium constant for the reaction between methanol, CH­3­.OH, and ethanoic acid, CH­3.COOH, to form the ester methyl ethanoate, (CH3.CO.OCH3), and water.

The esterification is catalysed by hydrogen ions.

The reaction is reversible and proceeds slowly towards an equilibrium. It is therefore necessary to set up the experiment and leave it for a week before the calculation is to be completed.

 After this period of time, the number of moles of ethanoic acid in the equilibrium mixture is determined by titration with a standardised 1 mol l-1 sodium hydroxide solution.

If the initial number of moles of the methanol and ethanoic acid are known, the equilibrium constant can then be calculated.

**Esterification Route Procedure**

You will need:

|  |  |
| --- | --- |
| A selection of 150 cm3 conical flasks or similar with stoppers to fit | Some parafilm |
| A balance (accurate to 2 d.p.) | A bottle of methanol |
| A bottle of glacial ethanoic acid | A bottle of standardised hydrochloric acid solution (1 mol l-1) |
| A bottle of standardised sodium hydroxide solution (1 mol l-1) | Three burettes |
| Filter funnels | Distilled water |
| A 25 cm3 measuring cylinder | Thymol blue indicator |

**Record all your measurements on the results sheet provided**

1. Weigh a 100cm3 flask. From a burette, add 3.7cm3 of methanol and reweigh.
2. From a burette, add 2.5cm3 of glacial (pure) ethanoic acid and again reweigh the flask.
3. From a burette, add 6.2cm3 of a standardised 1 mol l-1 hydrochloric acid solution.
4. Stopper the flask and wrap the neck in parafilm.
5. Set up a second identical flask, recording all the weights as before.
6. Shake the flasks to mix the contents.

**Now leave the flasks for one week** to allow equilibrium to be attained.

**Shake both flasks each day.**

The flasks have been set up and left for one week to attain equilibrium. Carry out the following experiment on one of the flasks numbered 1-10.

1. Consult the Record Sheet to obtain the mass of methanol and ethanoic acid used to set up the experiment in the flask you have chosen. The sheet will also give the volume of hydrochloric acid added, and the concentrations of the hydrochloric acid and the sodium hydroxide solutions.
2. Record these figures on your Results sheet.
3. Add 25cm3 of distilled water to the flask, followed by 2 drops of Thymol blue indicator.
4. Titrate at once with a standardised sodium hydroxide solution (~1 mol l-1 ) and record the volume of alkali added to the flask. The indicator will turn from violet to yellow to blue at the end-point.
5. Record this value on your results sheet.
6. Use the values you have to calculate the equilibrium constant for the esterification. Use the ‘The Calculation – Esterification Route’ sheet to help you.

**Esterification Record Sheet**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Added | Flsk 1 | Flask 2 | Flask 3 | Flask 4 | Flask 5 | Flask 6 | Flask 7 | Flask 8 | Flask 9 | Flask 10 |
| Mass of methanol |  |  |  |  |  |  |  |  |  |  |
| Mass of glacial ethanoic acid |  |  |  |  |  |  |  |  |  |  |
| Volumeof HCl(aq) |  |  |  |  |  |  |  |  |  |  |
| Concentrationof HCl(aq) |  |  |  |  |  |  |  |  |  |  |
| Concentrationof NaOH(aq) |  |  |  |  |  |  |  |  |  |  |

**The calculation – Esterification Route**

1. Calculate the mass of methanol used and hence the number of mol of methanol originally present.

 (Let this equal ***a***)

1. Calculate the mass of ethanoic used and hence the number of mol of ethanoic acid originally present.

 (Let this equal ***b***)

1. If M is the concentration of the hydrochloric, calculate the number of mol of acid added. Let this equal***c*** mole where

***c*** = 6.20 x M

 1000

1. Now calculate the number of mol of water originally present. Let this be ***d*** molwhere

***d*** = mass of acid solution (6.20g) – mass of HCl (36.5 x **c** g)

Mass of one mol of water (18g)

1. Therefore the **initial** concentrations in the reaction are

 ***a*** mol ***b*** mole ***none*** ***d*** mol

1. From the volume of sodium hydroxide titrated, calculate the number of mol of hydrogen ions in the equilibrium mixture. (Let this equal ***e*** mol).

This is the total from the ethanoic and hydrochloric acids.

1. Therefore the number of mol of **ethanoic acid** in the equilibrium mixture is (***e*** – ***c***) mol.
2. Therefore the number of mol of ethanoic acid which reacted to form the ester is

[***b*** - (***e*** – ***c***)] mol. This will be the number of mol of ester. (Let this equal ***f*** mol).

Therefore at equilibrium we have the following quantities present:

 (***a*** – ***f***) mol (***e*** – ***c***) mol ***f*** mol (***d*** + ***f*** ) mol

1. The equilibrium constant can be calculated by inserting these figures in the equilibrium rate expression:

Determining an equilibrium constant by Experiment

#### From the hydrolysis of an ester:

It is possible to determine experimentally the equilibrium constant for the hydrolysis of the ester methylethanoate.

The hydrolysis is catalysed by hydrogen ions.

The reaction is reversible and proceeds slowly towards an equilibrium. It is therefore necessary to set up the experiment

and leave it for a week before the calculation is to be completed.

After this period of time, the concentration of ethanoic acid

in the equilibrium mixture is determined by titration with a standardised 1 mol l-1 sodium hydroxide solution.

If the initial concentration of the methylethanoate is known, the equilibrium concentrations of all species can be found and hence the equilibrium constant calculated for the reaction

You will need:

|  |  |
| --- | --- |
| A selection of 150 cm3 conical flasks or similar with stoppers to fit | Some parafilm |
| A balance (accurate to 2 d.p.) | A bottle of methylethanoate |
| A bottle of standardised hydrochloric acid solution (1 mol l-1) | A bottle of standardised sodium hydroxide solution (1 mol l-1) |
| Burettes | Filter funnels |
| Distilled water | A 25 cm3 measuring cylinder |
| Thymol blue indicator |  |

**Record all your measurements on the results sheet provided**

1. Weigh a 100cm3 flask. From a burette, add 3.2cm3 of methylethanoate and reweigh.
2. From a burette, add 6.2cm3 of a standardised 1 mol l-1

hydrochloric acid solution.

1. Stopper the flask and wrap the neck in parafilm.
2. Set up a second identical flask, recording all the

weights as before.

1. Shake the flasks to mix the contents.

**Now leave the flasks for one week** to allow equilibrium to be attained.

**Shake both flasks each day.**

1. At the end of one week, add 25cm3 of distilled water to each flask, followed by 2 drops of Thymol blue indicator.
2. Titrate at once with a 1 mol l-1 standardised sodium hydroxide solution and record the volume of alkali added to each flask. The indicator will turn from violet to yellow to blue at the end-point.
3. Use the ‘The Calculation – Hydrolysis Route’ sheet to work out the equilibrium constant from your results.

The flasks have been set up and left for one week to attain equilibrium. Carry out the following experiment on one of the flasks labelled A-J.

1. Consult the Record Sheet to obtain the mass of methylethanoate used to set up the experiment in the flask you have chosen. The sheet will also give the volume of hydrochloric acid added, and the concentrations of the hydrochloric acid and the sodium hydroxide solutions.
2. Record these figures on your Results sheet.
3. Add 25cm3 of distilled water to the flask, followed by 2 drops of Thymol blue indicator.
4. Titrate at once with a standardised sodium hydroxide solution (~1 mol l-1 ) and record the volume of alkali added to the flask. The indicator will turn from violet to yellow to blue at the end-point.
5. Record this value on your results sheet.
6. Use the values you have to calculate the equilibrium constant for the esterification.
7. Use the ‘The Calculation – Hydrolysis Route’ sheet to help you.

**Hydrolysis Record Sheet**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Added | Flask A | Flask B | Flask C | Flask D | Flask E | Flask F | Flask G | Flask H | Flask I | Flask J |
| Mass of methylethanoate |  |  |  |  |  |  |  |  |  |  |
| Volume of HCl(aq) |  |  |  |  |  |  |  |  |  |  |
| Concentration of HCl(aq) |  |  |  |  |  |  |  |  |  |  |
| Concentration of NaOH(aq) |  |  |  |  |  |  |  |  |  |  |

### The calculation – Hydrolysis Route

1. Calculate the mass of methylethanoate used and hence the number of mol of methylethanoate originally present.

 (Let this equal ***m***)

1. If M is the concentration of the hydrochloric, calculate the number of mol of acid added.

 Let this equal***n*** mole where

***n*** = 6.20 x M

 1000

1. Now calculate the number of mol of water originally present. Let this be ***p*** molwhere

***p*** = mass of acid solution (6.20g) – mass of HCl (36.5 x **n** g)

Mass of one mol of water (18g)

1. Therefore the initial concentrations in the reaction are

 ***none*** ***none*** ***m*** mol ***p*** mol

1. From the volume of sodium hydroxide titrated, calculate the number of mol of hydrogen ions in the equilibrium mixture. (Let this equal ***q*** mol).

 This is the total from the ethanoic and hydrochloric acids.

1. Therefore the number of mol of **ethanoic acid** in the equilibrium mixture is (***q*** – ***n***) mol.
2. Therefore the number of mol of ester in the equilibrium mixture is [***m*** - (***q*** – ***n***)] mol.
3. The number of moles of water in the equilibrium mixture is

[***p*** - (***q*** – ***n***)] mol.

9. Therefore at equilibrium we have the following quantities present:



 (***q*** – ***n***) mol (***q*** – ***n***) mol [***m*** - (***q*** – ***n***)] mol [***p*** - (***q*** – ***n***)] mol

1. The equilibrium constant can be calculated by inserting these figures in the equilibrium rate expression:

