Determining an equilibrium constant essay sample

Science, Chemistry



Objective

To find out the equilibrium constant, Kc, for the reaction below, using acid hydrolysis:

CH3COOC2H5 + H2O⇔ CH3COOH + C2H5OH

Theory

although the hydolysis of ethyl ethanoate is very slow, by using dilute hydrochloric acid as catalyst which can be used to alter the time required to reach the equilibrium as the catalyst increases both the forward and backward reaction to the same extent, the above equilibrium can be attained in 48 hours. After 48 hours, the reaction mixture can then be titrated with standard sodium hydroxide solution. Finally the equilibrium concentration of four components below and hence, Kc,, of hydrolysis of CH3COOC2H5 can then be calculated by the equilibrium law:

Kc = image00. png

The experiment can be divided into two parts:

In part A: mixtures containing different proportions of the two reactants are added with a fixed amount of dilute hydrochloric acid as a catalyst. In part B: after the mixtures have reached equilibrium at room temperature, each one is titrated with sodium hydroxide.

Controlled variables

Independent variables

Dependent variable

Temperature

Concentration of CH3COOC2H5

Concentration of NaOH

volume of HCl added

same electronic balance

volume of CH3COOC2H5 added

Volume of water added

The volume of NaOH

Safety Precautions

Ethyl ethanoate -General Hazards

Flammable

Keep the liquid away from naked flame

Keep the stopper on the bottle as much as possible

Hydrochloric acid -General Hazards

irritant

wear gloves and safety googles

Sodium hydroxide -General Hazards

corrosive

wear gloves and safety googles

Special Handling Information

Wear gloves

Avoid skin contact with the chemicals

Apparatus and Reagents Used (Part A)

Safety spectacles

10 specimen tubes with well-fitting caps

Labels for tubes and stoppers

Access to a balance

Pipette, 5 cm3, and safety filler

Dilute hydrochloric acid, 2M HCl

2 measuring cylinders, 10 cm3

Distilled water

Ethyl ethanoate, CH3COOC2H5

Procedures ???? PART A)

Ten specimen tubes were labeled with 1a, 1b, 1c, 1d, 2a, 2b, 3a, 3b, 4a, 4b.

the stoppers were labeled too, so that they do not get misplaced.

each tube is weight, with its stopper, and the masses are recorded in a copy of Results table 1

A pipette and safety filler are used, 5 cm3 of 2Mhydrochloric acid is carefully added to each tube, the stoppers are replaced.

Each stoppered tube is weight and the masses are recorded.

A dry measuring cylinder is selected, and is used to add to tubes 2a, 2b, 3a,

3b, 4a, 4b the volumes of ethyl ethanoate shown in results table 1, the stoppers are replaced.

The stoppered tubes 2a, 2b, 3a, 3b, 4a, 4b. The masses are recorded. a second measuring cylinder is used to add to tubes 3a, 3b, 4a, 4b the volumes of distilled water shown in results table 1, the stoppers are replaced.

The stoppered tubes 3a, 3b, 4a, 4b is weight. The masses are recorded. the tubes are shaken gently and are set aside for at least 48 hours. during this time, the tubes are shaken occasionally.

Results Table 1

Tube Number

1a 1b 1c 1d 2a 2b 3a 3b 4a 4b

Mass of empty tube /g

- 20. 46
- 20. 31
- 20. 43
- 19.95
- 20.03
- 19.80
- 19.40
- 19.56
- 19.64
- 19.57

Volume of HCl(aq) added /cm3

5. 0 5. 0 5. 0 5. 0 5. 0

5. 0
5.0
5.0
5.0
5.0
Mass of tube after addition /g
25. 65
25. 43
25. 68
25.01
25. 18
24. 87
24. 61
24. 74
24. 76
24. 53

Volume of ethyl ethanoate added /cm3

- -
- _
- -
- 5.0
- 5.0
- 4.0
- 4.0
- 2.0
- 2.0

Mass of tube after addition /g

- _
- _
- _
- -

29.74

28. 29 28.35 26.60 26.34

Volume of water added /cm3

- _
- -
- _
- _
- _
- 1.0
- 1.0
- 3.0
- 3.0

_

Mass of tube after addition /g

https://assignbuster.com/determining-an-equilibrium-constant-essay-sample/

- -
- -
- -
- 29.34
- 29.30
- 29.60
- 29. 33

Mass of ethyl ethanoate added /g

_ _ _ _ 4. 56 4. 52 3. 68

- 3.61 1.84 1.81 Mass of HCI(aq) added /g 5.19 5.12 5.25 5.06 5.15 5.07 5.21 5.18
- 5.12
- 4.96

Mass of water added /g

-

_

- -
- -
- _
- _
- 1. 05
- 0.95
- 3
- 2.99

Apparatus and Reagents Used (Part B)

Safety spectacles

5 conical flasks, 250 cm3

Wash-bottle of distilled water

Phenolphthalein indicator

Burette, stand and white tile

Small funnel

Sodium hydroxide solution, 1M NaOH(standardised)

Procedures :(PART B)

A burette is rinsed and filled with standardized sodium hydroxide solution.

The contents of tube 1a into a conical flask. The tube is rinsed into the flask

three times with distilled water.

two to three drops of phenolphthalein indicator solution is added and the acid is titrated against sodium hydroxide solution. The burette reading is recorded in a copy of results table 2.

steps 2 and 3 for each of the other tubes is repeated.

Results Table 2

Solution in flask

Equilibrium Mixture

Solution in burette

Sodium Hydroxide 0. 970 mol dm-3

Indicator

Tube Number

1a 1b 1c 1d 2a 2b 3a 3b

4a

4b

Final burette reading

- 10.60
- 20.60
- 31. 15
- 41. 15
- 26.70
- 34.75
- 23.85
- 26.65
- 21.70
- 24.10

Initial burette reading

0.10

20. 60		
31. 15		
0. 05		
7. 25		
0. 00		
3. 45		
0. 00		
0. 05		
Titre/cm3		
10. 50		
10		
10. 55		
10		
26. 65		
27. 50		
23. 85		
23. 20		

24.05

Calculation and results

Result Table 3

Tube Number

2a

- 2b
- Зa
- 3b
- 4a
- 4b
- 1.

Amount of HCl /mol

0.0097

- 0.0097
- 0.0097

0.0097

2.

Total amount of acid at eqm. /mol

- 0.0259
- 0.0267
- 0.0231
- 0.0225
- 0.0210
- 0.0233
- 3.

Eqm. amount of ethanoic acid /mol

- 0.0170
- 0.0134
- 0.0128
- 0.0113

4.

Eqm. amount of ethanol /m

- 0.0162
- 0.0170
- 0.0134
- 0.0128
- 0.0113
- 0.0136
- 5.

Initial amount of ethyl ethanoate /mol

- 0.0518
- 0.0514
- 0.0418
- 0.0410
- 0.0209
- 0.0206

Eqm. amount of ethyl ethanoate /mol

0.0356

0.0344

0.0284

0.0282

0.0096

0.0070

7.

Mass of pure HCl /g

- 0.354
- 0.354
- 0.354
- 0.354
- 0.354
- 0.354

Mass of water in HCl(aq) /g

- 4.796
- 4.716
- 4.856
- 4.826
- 4.766
- 4.606

9.

Initial amount of water /mol

- 0.2664
- 0.2620
- 0.3281
- 0.3210
- 0.4314
- 0.4220

10.

Eqm. amount of water /mol

0. 2503
0. 2450
0. 3147
0. 3082
0. 4201
0. 4084
11.
Eqm. constant, Kc
0. 0292
0. 0342
0. 02
0. 0188
0. 0317
0. 065
12
Mean Value of Kc

image06. png

Calculation ???? Set 2a)

amount of acid:

since HCl and NaOH react in equimolar amounts, so,

```
amount of HCl added = concentration of NaOH X volume of NaOH added in1a
```

= 0. 970 X image07. png0. 0097mol

Total amount of acid at equilibrium:

- = number of moles of HCl added+ CH3COOH formed
- = concentration of NaOH X volume of NaOH added in 2a
- = 0. 970 X image08. png0. 0259mol

equilibrium amount of ethanoic acid

= Total amount of acid at equilibrium- amount of acid

=(2)-(1)

equilibrium amount of ethanol:

= equilibrium amount of ethanoic acid

=(3)

= 0. 0162mol

Initial amount of ethyl ethanoate: image09. png

```
= image10. png
```

equilibrium amount of ethyl ethanoate

= Initial amount of ethyl ethanoate- equilibrium amount of ethanoic acid

=(5)-(4)

- = 0. 0518-0. 0162
- = 0. 0356mol

Mass of pure HCI:

= amount of acid X molar mass of HCl

=(1)X36.5

= 0. 354g

Mass of water in HCl(aq)

- = mass of HCl added-mass of pure HCl
- = 5. 15-0. 354
- = 4. 796g

Initial amount of water

= image11. png

= image12. png

equilibrium amount of water

- = Initial amount of water- equilibrium amount of ethanoic acid
- =(9)-(3)
- = 0. 2664-0. 01615
- = 0. 2503mol

equilibrium constant, Kc

Kc = image00. png

= image02. png

Discussion on Errors

Error: the weighting measurement of tubes may not be accurate due to the air current

https://assignbuster.com/determining-an-equilibrium-constant-essay-sample/

Impovement: close the window before measurement.

Error: some deionized water used to rinse the test tubes may retain inside the bottles. By lechatelier's principle, the increase in[H2O]promote the equilibrium shifts rightward.

Improvement: allow some time to dry them

Error: vaporization of CH3COOC2H5 will decrease [CH3COOC2H5] and hence affects Kc

Improvement: the test tube should be sealed besides stopped.

Error: shake the test tubes too vigorously so that the mixture will be contaminated by the stoppers. Also if we shake it too vigorously, this will increase kinetic energy of chemicals and affects Kc

Improvement: shake the test tubes gently.

Error: the surrounding temperature is not constant thus this will alter Kc

since Kc is temperature-dependent.

Improvement: place the test tubes under electronic water bath.

Error: Due to some measuring error, the amount of HCl is not the same so equilibrium

amount of ethanoic acid obtained are not accurate which in turn affect Kc Improvement: use instrument with smaller graduation.

Questions and answers

By Le Chatelier's principle, when a system at equilibrium is disturbed by a change in conditions (external factors), the equilibrium position shifts to the direction which tends to reduce the disturbance. Addiction of water, which in turn pushes the equilibrium shifting to the right so as to remove the

additional water. Furthermore, one of the products is removed due to the neutralization of the equilibrium mixture with sodium hydroxide. The equilibrium position will shift rightward, producing more products so as to reduce more reactant.

Since the reaction is kinetically slow (even in the presence of the catalyst). The reaction is slow enough at room temperature so that the orders of mixing, temperature fluctuations over two days of reaction time, and even a final titration with a strong base have little effect on the reaction. It is possible to measure the ethanoic acid by titration with standard NaOH which remove ethanoic acid and catalyst hydrochloric acid without significantly disturbing the equilibrium position.

Conclusion

Since equilibrium constant cannot be easily affected by physical factors, except for temperature. Hence equilibrium of a reaction can be obtained by many methods, e. g. colorimetrical method. The one used in this experiment is titrimetric one since the hydrolysis is kinetically slow. By finding both equilibrium expression of products and reactants and follow the equation Kc = image00. png, equilibrium constant is found.

Comments

The value of equilibrium constant I obtained is 0.027 which is much lower than the theoretical one-0. 25. It is because the theoretical value of the equilibrium constant is calculated from standard conditions and therefore cannot be wholly compared with the

value obtained from the room temperature and air pressure present in the laboratory. Since equilibrium constant is temperature-dependent. This experiment is carried out under cold weather; the rate of reaction is slow, after 48 hours, less products are formed, total amount of acid at equilibrium decrease, in turn decrease in equilibrium amount of ethanoic acid thus Kc decrease. Besides low temperature, we also don't shake it occasionally, after 48hours; the reaction may even not reach the equilibrium, so after calculation there is a large deviation with the theoretical one. To find out whether the reaction reaches equilibrium of not after 48hours we can prepare one more tube during doing the experiment. Put the tube for 1 more week. Repeat the experiment again to see if there is more ethanoic acid

produced. If so, the tubes used for calculation before have not reached the equilibrium.

There are five characteristics of a dynamic equilibrium

Occurs in a closed system

since the reaction above involves only liquids, no liquids can escape from the reaction mixture, it can be regarded as a closed system. equilibrium can be reached from either side

Chemical equilibrium are dynamic

he forward reaction and backward reaction do not stop even if the equilibrium has been reached. The reactant particles keep on collide to give the product particles and the product keep on collide to give reactant particles. When the rate of the forward reaction is equal to that of the

backward reaction, a state of dynamic equilibrium is reached. the microscopic processes continue, no overall macroscopic changes occur.

Change in conditions would result in a shift of equilibrium position temperature: depends on ΔH of the reaction. Equilibrium shift to right, if the forward reaction is endothermic. Equilibrium shift to left, if the forward reaction is exothermic.

Concentration: increase the concentration of reactants shifts the equilibrium position to the right. Increase the concentration of products shifts the equilibrium position to the left.

Pressure: the increase in pressure does not affect the concentration of solid and liquid since the compressibility is rather low in solid and liquid state. A catalyst does NOT affect the equilibrium position.

A catalyst speeds up the rate of both the forward and reverse reactions. The initial slope of the concentration vs time lines will be steeper for both reactants and products. Reactants disappear faster while products are formed faster. At equilibrium the concentrations of reactants and products for the catalysed reaction are the same as for the uncatalysed reaction.

The formation of ethyl ethanoate is particularly well-suited to the determination of the equilibrium constant. Since there is a homogeneous reaction with the same number of moles of reactants and products, the equilibrium constant, Kc which generally expressed in terms of Molarity can be calculated in terms of moles alone and this add convenience. Since the equilibrium law expression of this reaction is independent of the volume. Ethanoic acid is a weak acid and therefore dissociates partially. The equilibrium is far to the right; this therefore means that the concentrations of the products of this reaction are assumed to be lower than they actually are.

Modification of experiment:

After calculating the equilibrium constant, we can determine ΔH of the reaction. Repeating the experiment of one set of data under different temperature, the corresponding equilibrium constant at certain temperature are calculated, then plot a graph InK against 1/T

By $lnK = -\Delta H/RT + C$

the slope $=-\Delta H/R$

by finding the slope we can find the ΔH too.