The extraction and purification of paracetamol essay

Analysing the Quantity and Purity of Paracetamol Present in Different Formulations of the Commercial Medicine

Aim

The aim of this investigation was to determine the percentage by mass of pure paracetamol in formulations of branded paracetamol in 500mg tablets. Two techniques were used so as to determine this:

-Extraction and purification of tablets by filtration and recrystallisation. -Hydrolysis of the drug under reflux followed by titration against ammonium cerium sulphate.

In addition to this, the purity of the paracetamol was investigated by determination of melting point of the respective brands of paracetamol.

Findings

Using the extraction and purification procedure it was found that Tesco had the greatest percentage by mass of the active ingredient, paracetamol, at 46. 8%. Morrisons tablet percentage by mass was 44. 6% while Superdrug had a percentage by mass of 37. 8%.

Using the reflux and titration procedure it was found that Superdrug had the greatest percentage by mass of the active ingredient, paracetamol at 20. 0%. The Tesco percentage by mass was 19. 6% while Morissons was 18. 5%.

The melting point procedure concluded that all three crude samples had similar purity of paracetamol with melting point at 156oC. The melting point of the Morrisons recrystallised paracetamol was 168oC, Superdrug had a melting point of 165oC while Tesco had a melting point of 164oC. This shows

that Morrisons had the highest purity of pure paracetamol followed by Superdrug and then Tesco.

Underlying Chemistry
History and Uses

Paracetamol (C8H9NO2) (or acetaminophen) is the most common over the counter painkiller in the world. It was discovered in 1852 by Charles Fredric Gerhardt who later went on to discover aspirin. The drug is so popular due to the few side effects it has on the body and does not irritate the stomach like other commonly used drugs such as aspirin. The structure is as shown:

Paracetamol is used for relief of headaches, fever, menstrual pain, back pain, toothache and other general pain; however it is ineffective against muscle pain as it possesses no anti-inflammatory properties. “ Non-opioid analgesics work by inhibiting an enzyme known as cyclooxygenase (COX). COX is a catalyst for the conversion of a fatty acid contained in cell walls—arachidonic acid—to substances known as prostaglandins.” (tuftsjournal. tufts. edu.) Prostaglandins have many functions including the induction of pain. By reducing the production of prostaglandins the pain is relieved. Paracetamol does not affect the cause of the pain but rather combats the biochemical pathway which results in the feeling of pain.

Prostaglandins also affect the hypothalamus in the brain, the centre which is responsible for the maintenance of our bodies’ internal environment despite changes to the external environment, i. e. homeostasis. The prostaglandins cause the body to raise its temperature, and hence by taking paracetamol the body temperature is lowered. Paracetamol is therefore classed as

antipyretic as it lowers the body temperature. Due to these properties the drug is commonly used to combat flu and cold symptoms. The range of pain combatted by paracetamol alongside the fact that it has very few side effects has resulted in it being the most commonly used painkiller.

Paracetamol is also popular because of the rate at which pain subsides from its use due to the rapid uptake in the body. “ Absorption: Rapidly and almost completely absorbed from the G. I. tract. Peak plasma concentrations are reached in 10-60 minutes.”(labmed. yale. edu)

Methodology

Two techniques were used in the determination of the mass of active ingredient present in the tablets. The first was the extraction and purification of paracetamol from tablets. The second was an acid catalysed hydrolysis under reflux followed by titrations against ammonium cerium sulphate.

The use of the melting point allowed the purity of the paracetamol to be determined.

The extraction and purification of paracetamol

This procedure extracted paracetamol from the tablets by crystallisation. The paracetamol tablets were crushed and dissolved in propanone at a raised temperature; this decreased the time required for the paracetamol to dissolve. The binding agents and fillers in the tablet are insoluble in propanone however the paracetamol is soluble. This results in the paracetamol forming a solution in the propanone while the other components of the tablet are left as insoluble residue. The solution was

filtered to remove the residue. The filtrate was left to evaporate forming crystals of paracetamol.

These crystals were then dissolved in hot water and then filtered through cotton wool to remove any binding agents left. This filtrate was left in the fridge and shards of paracetamol formed. This relies on the fact that paracetamol has a high solubility in hot water but a low one in cold water. This allows shards of paracetamol to form. “ The soluble impurities are only present to the level of a few percent and so never reach their limit of solubility and thus stay in solution.” (Ellis, 2002)

The pure recrystallised paracetamol was then dried and its mass measured. The percentage by mass was then calculated.

Reflux and titrations

This procedure required the paracetamol to be boiled under reflux for one hour with sulphuric acid. This acid catalysed hydrolysis broke down the paracetamol (an amide) into an amine (4-aminophenol) and a carboxylic acid (ethanoic acid.) The raised temperature was used so as thermally accelerate the reaction. The reaction is shown below:

(Overall reaction)

This reaction mechanism may be found in the appendix.

The use of reflux apparatus ensured that the reaction vessel never boiled dry. This is because any vapour formed from heating in the reaction vessel was turned back into a liquid by condensation. The benefit of using a heating

mantle was that it ensured that a constant temperature, heating the round bottomed flask over a greater surface area.

This procedure produced 4-aminophenol. This has a hydroxyl group on carbon 1 and an amine group on the carbon 1. Since the nitrogen is attached to only one carbon it is a primary amine. The 4-aminophenol can then be oxidised using ammonium cerium sulphate, involving the loss of hydrogen from the 4-aminophenol using ferroin as an indicator. This produced iminoquinone. “ Only after all the 4-aminophenol has been oxidised will the cerium (IV) reagent oxidise the ferroin indicator from Fe2+ to Fe3+ (ferriin).” (Ellis, 2002) This resulted in the colour change from red to yellow, as the red ferroin is oxidised to ferriin which is blue. This is shown in the diagram below When mixed with the ammonium cerium sulphate this produced a yellow colour which indicated the end point of the titration.

A titration was also carried out without the test material being present and the difference between the values with the test species present and absent accounted for the mass of paracetamol present. The difference in volumes of titre required for the colour change is directly proportional to the mass of paracetamol present in the tablet (0. 007560g per 1cm3 equivalent titre.)

Melting Point

By measuring the melting points of the given formulations, the purity of the paracetamol was able to be determined. Melting point apparatus worked by heating the species in a capillary tube which itself was inserted into a heating block. By looking through a lens at the species, the moment at which

the species melted could be seen and then at this moment the reading on the thermometer could be viewed.

When a substance is heated, there is an increase in entropy as the species is thermally excited. If enough energy is put into the substance, it results in a change of state, in this case solid to liquid.

The three brands of paracetamol melting points were measured for the tablet, the crude and the recrystallised samples. “ Pure paracetamol is a white crystalline solid which melts at 169-171oC. (Ellis 2002).

The impurities in the samples lower the melting points. The sample which was closest to the given melting point represents the purest sample of paracetamol.

Procedures

The Extraction and Purification of Paracetamol

Please note this experiment was carried out twice for each brand and an average taken. This was then duplicated so as to improve the reliability. (This is shown in results as the replicate.)

Paracetamol was extracted from three brands of paracetamol; Morrisons, Superdrug and Tesco. These procedures represent the procedure used for each brand.

Two tablets were weighed using a balance (accurate to 2 D. P.) then crushed using a mortar and pestle. The ground tablets were placed in a beaker. 50cm3 of propanone was measured using a pipette. The propanone was used to rinse the mortar and pestle before adding it to the beaker. The

beaker was left on a brisk stir at a low heat until the tablet was dissolved as far as possible. The insoluble material was the binding agents and fillers. Initially 20cm3 of propanone was used however it was found that the tablets did not dissolve fully.

A Buchner Funnel was set up as shown (see left.)

The insoluble material (binding agents and fillers) collects in the filter paper.

The filtrate (propanone and paracetamol) is collected in the filtering flask.

A little propanone was run through the filter paper so as to create a seal between the filter paper and the base as shown on the above diagram. This prevented the insoluble material from passing through the holes in the funnel. The content of the beaker was passed through the funnel and a little propanone was used to rinse the beaker. The filtrate was left in an evaporating basin overnight in an oven. This formed crude paracetamol crystals. The mass of the crystals was taken.

The crystals were placed in a beaker and 20cm3 of hot water was added. The beaker was heated on a brisk stir until the paracetamol had dissolved. This was passed through a warmed wet piece of cotton wool in a warmed glass funnel. This was to prevent the paracetamol from recrystallising in the cotton during filtration. The filtrate was passed directly into a basin. The basin was placed in the fridge overnight to cool and to allow the crystals to form. These crystals were white.

The recrystallised paracetamol in water was passed through a piece of fluted filter paper to collect the crystals. (Initially the paracetamol was filtered out

of the water using a sintered glass crucible however this produced a lower yield as crystals were lost when using this technique. See table 22.) The filter paper and crystals were placed in an oven at room temperature overnight to allow the crystals to dry. These crystals were white. The dry mass of the crystals was measured. This procedure was replicated for each brand of paracetamol.

Reflux and titrations

Please note that this procedure was carried out once for each brand of paracetamol. This was then duplicated so as to improve the reliability. (This is shown in the results as the replicate.)

The first stage of this procedure involved the acid hydrolysis of paracetamol:

15cm3 of 2 molar solution of sulphuric acid and 25cm3 of water were measured using a pipette and placed in a 100ml round bottomed flask. To this 0. 30g of crushed (using mortar and pestle) paracetamol tablet was added, having measured the paracetamol using a balance (accurate to 2 D. P.) This was swirled and warmed until the tablet was dissolved. This was then boiled under reflux for one hour in a heating mantle as shown below:

The paracetamol and sulphuric acid were placed nn the round bottomed flask.

The solution turned from colourless to a light golden colour. The solution was cooled and 100cm3 of water was added.

20cm3 of the resulting solution was pipetted into a conical flask with 15cm3 of 2 molar Hydrochloric acid, 40cm3 of water and precisely 8 drops of ferroin indicator. This was then titrated against 0. 1 molar solution of ammonium cerium sulphate until colour changed from a pink/peach colour to a cloudy yellow colour. (The colour change was not very obvious during this procedure. Therefore previous titration colours were kept beside the species to try to standardize the colour at which the end point of the titration was determined.) The titrations were repeated until two results were within 0. 1cm3 of each other i. e. until two concordant results were obtained. The apparatus is as shown overleaf:

The burette was filled with the yellow ammonium cerium sulphate solution and the conical flask contained the paracetamol acid mixture.

This procedure was also repeated without the test material present.

Melting Point

During this procedure, the melting points of the recrystallised, crude and unaltered tablet forms of paracetamol were investigated.

The sample of species was crushed into a powder using a mortar and pestle. Capillary tubes (1mm diameter, 10cm long) were sealed at one end using a Bunsen burner. This provided a place to hold the paracetamol when using the melting point apparatus. The capillary tube was placed turned open-side-down and pressed onto the paracetamol formulations. Then the closed end of the capillary tubes was gently tapped on the table to allow the paracetamol to fall to the closed end. This was then placed open-side-up into

the metal heating block alongside a thermometer. The temperature was slowly increased using the thermostat on the melting point apparatus while the paracetamol was viewed through the magnifying glass on the apparatus. The point at which the paracetamol melted was then recorded.

Results

Initial

Extraction and purification

The crystals of the crude and recrystallised paracetamol were both white. The crude crystals were prismatic shaped while the recrystallised paracetamol formed long shards.

Table 1 shows the mass of crude paracetamol from each tablet:

Table 1

Brand

Mass (g)

Sample 1

Sample 2

Average

Tesco

0. 94

1. 00

0. 97

Morrisons

1. 01

1. 00

1. 01

Superdrug

0. 97

0. 92

0. 95

Table 2 shows the mass of recrystallised paracetamol from each tablet:

Table 2

Brand

Mass (g)

Sample 1

Sample 2

Average

Tesco

0. 58

0. 49

0. 54

Morrisons

0. 44

0. 49

0. 47

Superdrug

0. 36

0. 48

0. 42

Table 3 shows the percentage by mass of crude paracetamol compared to the mass of two tablets (1. 10g):

Table 3

Brand

Percentage of Crude Paracetamol (%)

Tesco

88. 2

Morrisons

91. 8

Superdrug

86. 4

(Calculations may be found in the appendix)

Table 4 shows the mass of recrystallised paracetamol compared to the respective mass of two tablets (1. 10g):

Table 4

Brand

Percentage of pure Paracetamol (%)

Tesco

49. 1

Morrisons

42. 7

Superdrug

38. 2

(Calculations may be found in the appendix)

Reflux and titrations

Table 5 shows the volume of Ammonium Cerium sulphate required for the colour change from red to yellow to occur without the test species present (paracetamol):

Table 5

Titration

Initial Titre

(cm3)

Final Titre

(cm3)

Volume of ammonium cerium (IV) sulphate needed for the colour change (cm3)

Rough

0. 0

0. 5

0. 5

First

0. 5

1. 0

0. 5

Second

1. 0

1. 5

0. 5

Average Titre = (0. 5+0. 5)/2 = 0. 5cm3

Table 6 shows the volume of Ammonium Cerium sulphate required for the colour change from red to yellow to occur using Tesco paracetamol:

Table 6

Titration

Initial Titre

(cm3)

Final Titre

(cm3)

Volume of ammonium cerium (IV) sulphate needed for the colour change (cm3)

Rough

0. 0

8. 6

8. 6

First

8. 6

15. 8

7. 2

Second

15. 8

23. 1

7. 3

Average volume = (7. 2+7. 3)/2 = 7. 25cm3

Amended titre = 7. 25-0. 5 = 6. 75cm3

As 1 cm3 of ammonium cerium (IV) sulphate = 0. 007560g of Paracetamol

6. 75 x 0. 007560 = 0. 05103g

So, if 0. 3g of tablet 0. 05103g of pure Paracetamol

Then, 0. 55g of tablet 0. 093555g of pure Paracetamol

Percentage by mass (0. 093555/0. 55) x 100 = 17. 0%

Table 7 shows the volume of Ammonium Cerium sulphate required for the colour change from red to yellow to occur using Morrisons paracetamol:

Table 7

Titration

Initial Titre

(cm3)

Final Titre

(cm3)

Volume of ammonium cerium (IV) sulphate needed for the colour change (cm3)

Rough

0. 0

7. 4

7. 4

First

7. 4

14. 4

7. 0

Second

14. 4

21. 5

7. 1

Average volume = (7. 0+7. 1)/2 = 7. 05cm3

Amended titre = 7. 05-0. 5 = 6. 55cm3

As 1 cm3 of ammonium cerium (IV) sulphate = 0. 007560g of Paracetamol

6. 55 x 0. 007560 = 0. 049518g

So, if 0. 3g of tablet 0. 049518g of pure Paracetamol

Then, 0. 55g of tablet 0. 090783g of pure Paracetamol

Percentage by mass (0. 090783/0. 55) x 100 = 16. 5%

Table 8 shows the volume of Ammonium Cerium sulphate required for the colour change from red to yellow to occur using Superdrug paracetamol:

Table 8

Titration

Initial Titre

(cm3)

Final Titre

(cm3)

Volume of ammonium cerium (IV) sulphate needed for the colour change

(cm3)

Rough

0. 0

9. 7

9. 7

First

9. 7

18. 6

8. 9

Second

18. 8

27. 8

9. 0

Average volume = (8. 9+9. 0)/2 = 8. 95cm3

Amended titre = 8. 95-0. 5 = 8. 45cm3

As 1 cm3 of ammonium cerium (IV) sulphate = 0. 007560g of Paracetamol

8. 45 x 0. 007560 = 0. 063882g

So, if 0. 3g of tablet 0. 063882g of pure Paracetamol

Then, 0. 55g of tablet 0. 117117g of pure Paracetamol

Percentage by mass (0. 117117/0. 55) x 100 = 21. 3%

Table 9 shows the melting points of the paracetamol:

Table 9

Brand

Melting Point (0C)

Tablet Sample

Crude Sample

Recrystallised Sample

Tesco

140

155

163

Morrisons

145

157

167

Superdrug

139

159

164

Replicate

Extraction and purification

The crystals of the crude and recrystallised paracetamol were both white. The crude crystals were prismatic shaped while the recrystallised paracetamol formed long shards.

Table 10 shows the mass of crude paracetamol from each tablet:

Table 10

Brand

Mass (g)

Sample 1

Sample 2

Average

Tesco

1. 00

0. 98

0. 99

Morrisons

1. 00

1. 04

1. 02

Superdrug

1. 01

0. 97

0. 99

Table 11 shows the mass of recrystallised paracetamol from each tablet:

Table 11

Brand

Mass (g)

Sample 1

Sample 2

Average

Tesco

0. 51

0. 46

0. 49

Morrisons

0. 53

0. 49

0. 51

Superdrug

0. 40

0. 42

0. 41

Table 12 shows the percentage by mass of crude paracetamol compared to the mass of two tablets (1. 10g)

Table 12

Brand

Percentage of crude Paracetamol (%)

Tesco

90. 0

Morrisons

92. 7

Superdrug

90. 0

(Calculations may be found in the appendix)

Table 13 shows the mass of recrystallised paracetamol compared to the mass of two tablets (1. 10g):

Table 13

Brand

Percentage of pure Paracetamol (%)

Tesco

44. 5

Morrisons

46. 4

Superdrug

37. 3

(Calculations may be found in the appendix)

Reflux and titrations

Table 14 shows the volume of Ammonium Cerium sulphate required for the colour change from red to yellow to occur without the test species present (paracetamol):

Table 14

Titration

Initial Titre

(cm3)

Final Titre

(cm3)

Volume of ammonium cerium (IV) sulphate needed for the colour change (cm3)

Rough

0. 0

0. 5

0. 5

First

0. 5

1. 1

0. 6

Second

1. 1

1. 6

0. 5

Average volume = (0. 5+0. 6)/2 = 0. 55 cm3

Table 15 shows the volume of Ammonium Cerium sulphate required for the colour change from red to yellow to occur using Tesco paracetamol:

Table 15

Titration

Initial Titre

(cm3)

Final Titre

(cm3)

Volume of ammonium cerium (IV) sulphate needed for the colour change

(cm3)

Rough

0. 0

10. 6

10. 6

First

10. 6

20. 0

9. 4

Second

20. 0

29. 3

9. 3

Average volume = (9. 3+9. 4)/2 = 9. 35cm3

Amended titre = 9. 35-0. 55 = 8. 8cm3

As 1 cm3 of ammonium cerium (IV) sulphate = 0. 007560g of Paracetamol

8. 8 x 0. 007560 = 0. 066528g

So, if 0. 3g of tablet 0. 066528g of pure Paracetamol

Then, 0. 55g of tablet 0. 121968g of pure Paracetamol

Percentage by mass (0. 121968/0. 55) x 100 = 22. 2%

Table 16 shows the volume of Ammonium Cerium sulphate required for the colour change from red to yellow to occur using Morrisons paracetamol:

Table 16

Titration

Initial Titre

(cm3)

Final Titre

(cm3)

Volume of ammonium cerium (IV) sulphate needed for the colour change

(cm3)

Rough

21. 5

30. 5

9. 0

First

30. 5

39. 5

9. 0

Second

39. 5

47. 6

8. 1

Third

0. 00

8. 6

8. 6

Fourth

8. 6

17. 3

8. 7

Average volume = (8. 7+8. 6)/2 = 8. 65cm3

Amended titre = 8. 65-0. 55 = 8. 1cm3

As 1 cm3 of ammonium cerium (IV) sulphate = 0. 007560g of Paracetamol

8. 1 x 0. 007560 = 0. 061236g

So, if 0. 3g of tablet 0. 061236g of pure Paracetamol

Then, 0. 55g of tablet 0. 112266g of pure Paracetamol

Percentage by mass (0. 112266/0. 55) x 100 = 20. 4%

Table 17 shows the volume of Ammonium Cerium sulphate required for the colour change from red to yellow to occur using Superdrug paracetamol:

Table 17

Titration

Initial Titre

(cm3)

Final Titre

(cm3)

Volume of ammonium cerium (IV) sulphate needed for the colour change

(cm3)

Rough

0. 0

8. 3

8. 3

First

8. 3

16. 2

7. 9

Second

16. 2

24. 2

8. 0

Average volume = (7. 9+8. 0)/2 = 7. 95cm3

Amended titre = 7. 95-0. 55 = 7. 4cm3

As 1 cm3 of ammonium cerium (IV) sulphate = 0. 007560g of Paracetamol

7. 4 x 0. 007560 = 0. 055944g

So, if 0. 3g of tablet 0. 055944g of pure Paracetamol

Then, 0. 55g of tablet 0. 102564g of pure Paracetamol

Percentage by mass (0. 102564/0. 55) x 100 = 18. 6%

Table 18 shows the melting points of the paracetamol:

Table 18

Brand

Melting Point (0C)

Tablet Sample

Crude Sample

Recrystallised Sample

Tesco

143

156

165

Morrisons

144

155

168

Superdrug

141

153

166

Averages of Initial and replicate

Table 19 shows percentage by mass of recrystallised paracetamol:

Table 19

Percentage by mass%

Brand

Initial

Replicate

Average

Tesco

49. 1

44. 5

46. 8

Morrrisons

42. 7

46. 4

44. 6

Superdrug

38. 2

37. 3

37. 8

Table 20 shows percentage by mass of pure paracetamol determined from reflux and titrations:

Table 20

Percentage by mass %

Brand

Initial

Replicate

Average

Tesco

17. 0

22. 2

19. 6

Morrisons

16. 5

20. 4

18. 5

Superdrug

21. 3

18. 6

20. 0

Table 21 shows the melting point of paracetamol of crude and recrystallised paracetamol:

Table 21

Melting point (oC)

Crude

Recrystallised

Brand

Initial

Replicate

Average

Initial

Replicate

Average

Tesco

155

156

156

163

165

164

Morrisons

157

155

156

167

168

168

Superdrug

159

153

156

164

166

165

Table 22 shows the results using a sintered glass crucible rather than filter paper during the filtration of Tesco recrystallised paracetamol:

Table 22

Sample 1

Sample 2

Mass of crystals (g)

0. 31

0. 12

Conclusions

The aim of this investigation was to determine the percentage by mass of pure paracetamol in formulations of branded paracetamol in 500mg tablets. Two techniques were employed so as to determine this:

-Extraction and purification of tablets by filtration and recrystallisation. -Hydrolysis of the drug under reflux followed by titration against ammonium cerium sulphate.

In addition to this, the purity of the paracetamol was investigated by determination of melting point of the respective brands of paracetamol.

The results of these procedures are discussed below.

Extraction and purification

Using this procedure it was found that Tesco had the greatest percentage by mass of the active ingredient, paracetamol, at 46. 8%. Morrisons tablet percentage by mass was 44. 6% while Superdrug had a percentage by mass of 37. 8%.

Reflux and Titrations

Using this procedure it was found that Superdrug had the greatest percentage by mass of the active ingredient, paracetamol at 20. 0%. The Tesco percentage by mass was 19. 6% while Morissons was 18. 5%.

Results were different for each respective brand of paracetamol and different between the two procedures.

Melting Point

The melting points of the crude paracetamol were all 156oC thus showing that all formulations of crude paracetamol had similar purity, and hence the first crystallization of the paracetamol was carried out very accurately.

The melting point of the Morrisons recrystallised paracetamol was 168oC which compared well with the given melting point of 169-171oC. Superdrug had a melting point of 165oC while Tesco had a melting point of 164oc. This shows that Morrisons had the highest purity of pure paracetamol followed by Superdrug and then Tesco.

Evaluation

Evaluation of procedures

Control of variables

During the filtration and recrystallising process two tablets were used in each sample and two samples were taken. This, alongside the duplication of results, gives 8 tablets which were used in the determination using this method and an average taken. This increased the reliability of the results.

During the procedures the same balances, burettes, flasks and pipettes were used so as to reduce the effects of error in these measurements.

When titrations were carried out, a rough titration was initially done so as to determine the equivalence point. This was followed by accurate titrations. When two concurrent values were within 0. 1cm3, an average was taken between these two values. The average was used to determine the mass of pure paracetamol greatly increasing the reliability of the results.

Since the end point of the titration was not very obvious, previous titrations were kept aside so as to standardise the intensity of yellow in the solution, so that all titrations had the same end point colour. This increased the reliability of the titrations.

All equipment used was cleaned using propanone to prevent chemicals from previous experiments contaminating this investigation. In addition to this the burettes and pipettes were rinsed with the solutions, before being filled with the same solution to prevent contamination.

When using the balance, as far as possible, it was placed away from draughts and windows so as to prevent the wind causing error in the weighing of substances.

Where possible, all reaction vessels and weighing receptacles were rinsed using a little of the liquid which would be used. This increased the yield of results, preventing the reactants being lost in the process.

Modifications

Initially, when dissolving the paracetamol in propanone, the tablet was not crushed however it took an inordinate time for the tablet to dissolve; by the time it had dissolved most of the propanone had evaporated

The volume of propanone was increased from 20cm3 to 50cm3 because more paracetamol dissolved. This allowed a greater percentage of the paracetamol to be extracted from the tablets. Consequentially it took longer for the crude paracetamol crystals to form.

Initially a sintered glass crucible was used to filter the recrystallised paracetamol. This resulted in the paracetamol being lost, so filter paper was fluted and used instead. This resulted in a greater mass of recrystallised paracetamol being collected.

When the paracetamol was being added to sulphuric acid, initially it was unheated and just swirled, however not all the paracetamol dissolved and hence, the sulphuric acid was warmed with the paracetamol to dissolve the crushed tablet before being boiled under reflux.

When using the ammonium cerium (IV) sulphate, it was found that if left for any length of time greater than one hour the solute came out of solution, therefore, before pouring the solution into the burette, it was stirred vigorously using a magnetic stirrer to ensure the same concentration of

solution was used in every titration. Because of this, the burette was only set up immediately before use.

Evaluation of results

Both procedures resulted in significantly lower percentages than the mass of paracetamol in each tablet as stated on the box. The expected percentage by mass was expected to be 90. 9%. This is calculated as shown:

Mass of tablet – 0. 55g Mass of paracetamol (on box) – 0. 50g

(0. 5/0. 55) x 100 = 90. 9%

Generally the replicate compared well with the initial experiment, with a maximum difference of 4. 6% by mass for the first procedure. For the second procedure there was a maximum difference of 5. 2% by mass. This can be put down to errors in the equipment and human errors when carrying out procedures.

The fact that both procedures indicated different formulations contained the most paracetamol, may be due to the fact that often paracetamol was taken from different blister packs, and hence from different batches, which may contain different masses of paracetamol. However human errors and errors in equipment are more likely to be to blame.

It can also be broadly sai