ROYAL SOCIETY OF CHEMISTRY

Global Experiment 2013

Chemistry Week 2013

A picture of health

16-23 November 2013

Royal Society of Chemistry Global Experiment 2013
Measuring vitamin C in food

Introduction

There are four simple parts to the Global Experiment. These instructions will guide you through them.

- Part A: Choose your experiment
- Part B: Calibrate your iodine solution
- Part C: Test and compare the vitamin C content in your food samples
- Part D: Share your data – post your results to our website

We have included some background information on vitamin C, a discussion of the chemical reaction taking place and teacher notes for additional information.

Background

We need vitamin C to stay healthy; it is a vital nutrient. Without enough vitamin C we can develop a disease known as scurvy.

Scurvy used to be deadly for sailors and soldiers, who often had to go for long periods without fresh fruit and vegetables. One symptom of scurvy is spongy and bleeding gums. This happens because vitamin C is required for the body to make collagen, which is an important component of connective tissue.

Humans, along with some other animals, have to eat foods containing vitamin C as our bodies can't synthesise it. The navy found that lime juice added to rum and water (grog) kept sailors healthy. This is why the English are sometimes referred to as Limeys.

Many fresh fruits and vegetables contain vitamin C. Citrus fruits, such as oranges and lemons, are especially good sources. Vitamin C may also be added to processed food as a supplement.

Vitamin C is L-ascorbic acid – (5R)-[(1S)-1,2-dihydroxyethyl]-3,4-dihydroxyfuran-2(5H)-one – or one of its oxidised forms (figure 1). Any of these have the biological effect of vitamin C.

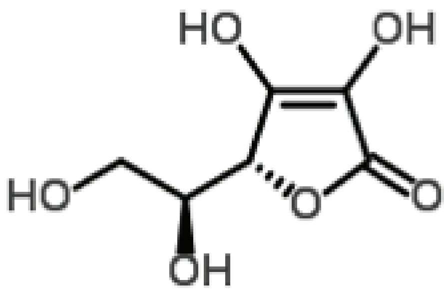
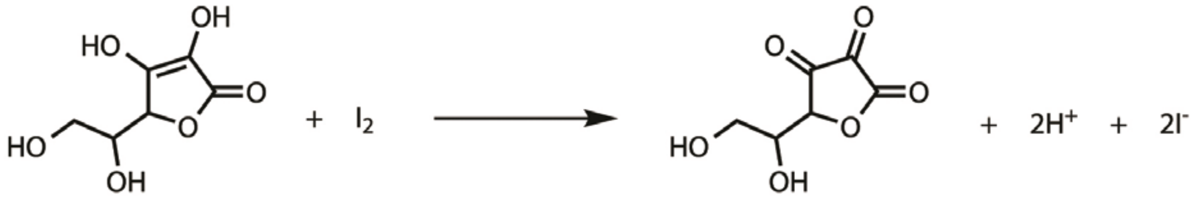


Figure 1 – L-ascorbic acid

Ascorbic acid does not just have activity as a vitamin, it is also an antioxidant. The term oxidation originally referred specifically to a reaction that combined something with oxygen. Now, however, it has a much wider meaning. If one reactant is being oxidised another must be being reduced to balance out the transfer of electrons. These types of reactions are known as redox (REDuction-OXidation) reactions. An antioxidant (or reducing agent) is used to reduce another reactant while being oxidised itself (a bit like a see-saw: if one end goes up the other must come down). We can use this property of ascorbic acid to measure how much we have in a solution. Figure 2 shows the redox equation for ascorbic acid and iodine.



Ascorbic acid

Dehydroascorbic acid

Figure 2 – The reaction of ascorbic acid with iodine

Ascorbic acid reduces iodine to iodide and in the process it is oxidised to dehydroascorbic acid. We can show that elemental iodine is present in solution by using starch – this produces a characteristic purple/black colour.

One molecule of ascorbic acid converts one molecule of iodine into two iodide ions. Once all of the ascorbic acid has been oxidised the addition of more iodine results in the purple/black colour forming (this is an iodine/starch complex).

It is possible to measure the amount of vitamin C in a liquid by counting the number of drops of tincture of iodine required to react with all the ascorbic acid present. It is also possible to calibrate your tincture of iodine using a known amount of ascorbic acid (a vitamin C tablet) dissolved in a known amount of water.

Tincture of iodine is widely used as an antiseptic, but care must be taken when using it for this experiment. It is for external use only and may stain skin, clothes and surfaces.

Part A: Choose your global experiment

Many fruits and vegetables contain vitamin C. Some of these we eat raw, others cooked and some are squeezed into juice as a drink. In these experiments we will extract vitamin C from food and test how much is present.

We can examine whether the method of preparing the food affects the amount of vitamin C present. Does boiling vegetables reduce the amount of vitamin C we eat? If we leave food overnight is the vitamin C affected by the oxygen in the atmosphere?

We have suggested four different experiments. You should perform one experiment, make conclusions on the data and upload the results to our website. By sharing your data we hope to gather information about all the different experiments and types of food.

The fruit and vegetables we want you to test are:

Vegetables	Fruits
Broccoli	Apple
Cabbage	Kiwi fruit
Cauliflower	Orange
Potato	Pink grapefruit
Red pepper	Red tomato

Pick one or more of the experiments – there's no need to do them all. You will be able to see the data from all the other participants on our website.

Experiment 1: Comparing foods

Split the class into small teams. Each team should test one fruit or vegetable. The class can then combine and compare their results.

Experiment 2: Where your food was grown

Choose one type of fruit or vegetable, but test two or more varieties grown in different locations – perhaps oranges from Spain versus oranges from the US, or apples grown locally versus apples from France.

Are there differences in the vitamin C content based on where your food was grown?

Experiment 3: Ageing

Compare old and freshly prepared food. Choose one food from the table and prepare six samples of known weight (follow steps 1–6 in part C). Test three samples immediately. Leave the other three samples overnight and test them after 24 hours. (A teacher or technician could prepare the three 'aged' samples in advance).

Does ageing affect the amount of vitamin C present? Why?

Experiment 4: Cooking

Choose one vegetable and record the weight of six samples. Boil three samples for 10 minutes in water (a teacher or technician may want to do this beforehand – but record the weight before cooking).

Test all six samples. Are there differences in the vitamin C levels between cooked and raw food? Why?

Part B: Calibrate your iodine solution

You need to know how much of your iodine solution is required to oxidise a given amount of vitamin C. This is known as calibration and can be done using a soluble vitamin C tablet, where the weight of vitamin C is shown on the label. Follow the calibration instructions to find out how many milligrams of vitamin C react with one drop of iodine solution.

Starch and iodine can combine to form a complex resulting in a deep purple/black colour. This gives a clear end point for the reaction. An easy way to make a solution of starch is to add some hot water to a little cornflour. Some starch dissolves and the liquid will become cloudy.

Materials

- Soluble vitamin C tablet (ideally effervescent with 1000 mg vitamin C per tablet)
- 1 litre measuring jug
- Small measure (a 5 cm^3 syringe or two measures from a teaspoon, approx. 5 cm^3)
- Clear plastic disposable cups (or similar, eg glass beakers)
- Cornflour
- Kettle (hot water required – not boiling)
- Tincture of iodine (1%, 2% and 2.5% w/v solutions are available from pharmacists and all work fine or Amazon). Careful: tincture of iodine may stain your skin.
- Pipette or eye dropper (widely available or from Amazon)

Procedure

1. Prepare your starch solution: put a teaspoon of cornflour into a cup and ¾ fill it with hot water. Stir the suspension for a minute, and each time this is used.
2. Use the table below to record how much vitamin C is in the tablet (**A**).
3. Make the calibration solution by dissolving a vitamin C tablet in 1 litre (1000 cm^3) of water. Note this volume in the table (**B**).
4. Place 10 cm^3 of your calibration solution in a clean plastic cup. Note this volume in the table (**D**). Add water until the cup is about half full.
5. Add 5 cm^3 of starch solution to your cup and stir (see figure 3).
6. Carefully add tincture of iodine drop by drop to the cup and count the number of drops. Stir the solution gently after each drop. Stop adding drops when the solution turns a deep purple/black colour. Stir the solution for a further 30 seconds to ensure the colour change remains (see figure 4). Note down the total number of drops required (**F1**).
7. Calculate the mass of vitamin C that reacts with one drop of iodine. (**G1**)
8. To improve the accuracy of your calibration, repeat steps 4–7 twice more and record your data (**G2** and **G3**).
9. Using the Average Data table, calculate the average mass of vitamin C that reacts with one drop of iodine. (**I**)

Calibration results

1st calibration

	Result	Units	Help column
Mass of vitamin C in tablet		mg	A
Volume of water added in step 3		cm^3	B
Mass of vitamin C per cm^3 of calibration solution		mg cm^{-3}	A ÷ B = C
Volume of small measure (used in step 4)		cm^3	D
Mass of vitamin C in small measure		mg	C x D = E
Number of drops of iodine added		drops	F1
Mass of vitamin C per drop of iodine added		mg per drop	E ÷ F1 = G1

2nd calibration

	Result	Units	Help column
Mass of vitamin C in tablet		mg	A
Volume of water added in step 3		cm^3	B
Mass of vitamin C per cm^3 of calibration solution		mg cm^{-3}	A ÷ B = C
Volume of small measure (used in step 4)		cm^3	D
Mass of vitamin C in small measure		mg	C x D = E
Number of drops of iodine added		drops	F2
Mass of vitamin C per drop of iodine added		mg per drop	E ÷ F2 = G2

3rd calibration

	Result	Units	Help column
Mass of vitamin C in tablet		mg	A
Volume of water added in step 3		cm^3	B
Mass of vitamin C per cm^3 of calibration solution		mg cm^{-3}	A ÷ B = C
Volume of small measure (used in step 4)		cm^3	D
Mass of vitamin C in small measure		mg	C x D = E
Number of drops of iodine added		drops	F3
Mass of vitamin C per drop of iodine added		mg per drop	E ÷ F3 = G3

Average data

	Result	Units	Help column
Add all the 'mass of vitamin C per drop of iodine' data together		mg per drop	G1 + G2 + G3 = H
Average mass of vitamin C per drop of iodine		mg per drop	H ÷ 3 = I

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Conclusion

One drop of iodine reacts with ________ mg of vitamin C (I)

You will need this to measure how much vitamin C is in each of the foods you test in Part C.

Observations

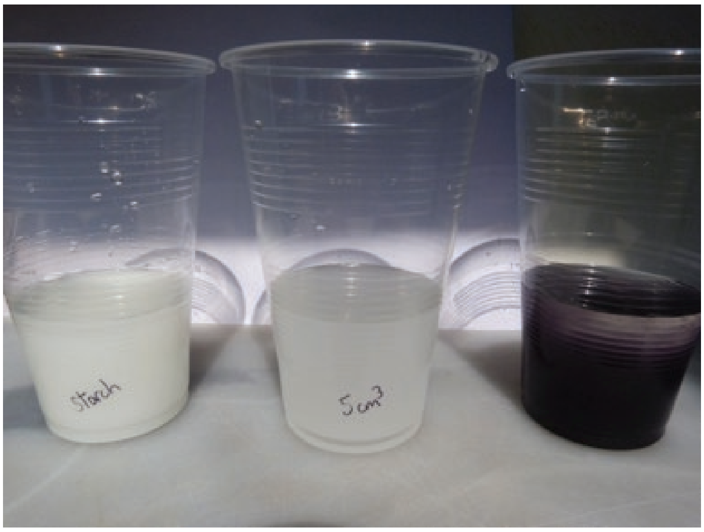

Figure 3 Left = starch solution. Right = iodine solution. Middle = solution ready for testing.

Figure 4 Left = starch solution. Right = iodine solution. Middle = solution for testing when the end point has been reached.

Part C: Testing your foods for vitamin C

We need to extract the vitamin C from solid food before we can measure how much there is. Vitamin C is soluble in water so we can use this to extract it from our food.

To prepare the food we have found that grating is the best method, but a kiwi, orange, grapefruit or tomato can be squeezed for the juice and the skin finely chopped or grated.

Materials

- Fruit or vegetable to be tested
- Balance or kitchen scales
- Grater, chopping board and knife
- 100 cm^3 measure (a measuring jug, or for consistency mark a cup at ½ level and re-use)
- Small measure (a 5 cm^3 syringe or two measures from a teaspoon, approx. 5 cm^3)
- Clear plastic disposable cups (or similar, eg glass beakers)
- Cornflour
- Kettle (hot water required – not boiling)
- Tincture of iodine (1%, 2% and 2.5% w/v solutions are available from pharmacists and all work fine or Amazon). Careful: tincture of iodine may stain your skin.
- Pipette or eye dropper (widely available or from Amazon)

Procedure

1. Decide how your fruit or vegetable is to be prepared.
    - Experiment 3 requires three 10g samples to be prepared and left for 24 hours
    - Experiment 4 requires three 10g samples to be boiled for ten minutes
2. Prepare your starch solution: put a teaspoon of cornflour into a cup and ¾ fill the cup with hot water. Stir the suspension each time it is used.
3. Cut approximately 10g of your food and record the mass (**J**).
4. Chop or grate the fruit or vegetable into small pieces.
5. Add 100 cm^3 of water to your prepared sample.
6. Gently stir the pulp and water mixture for about a minute.
7. Allow the pulp to settle. Decant off the liquid into a clean cup.
8. Add 5 cm^3 of starch solution to the liquid and stir (see figure 5).
9. Carefully add tincture of iodine to the mixture drop by drop. Count the number of drops as you add them and stir the solution gently after each drop. Stop when the solution turns a deep purple/black colour (see figure 6). Stir the solution for a further 30 seconds to ensure the colour change is permanent (add more iodine if needed). Note down the total number of drops added (**K**). Depending on the strength of your tincture of iodine solution it should take around 3–80 drops to reach the end point.
10. Repeat steps 3–9 twice more and record the data in the table (**J, K, L**).
11. Average your data as you did for the calibration (add all the attempts up and divide by the number of attempts). Note down this number of average drops you added in the table below (**M, N**).
12. Calculate the mass of vitamin C in milligrams per gram of food using your calibration standard. (**N × I = O**).
13. Based on your chosen experiment, repeat steps 3–12 above to compare with another fruit/veg, location grown, ageing (fresh versus old) or cooking (cooked versus raw). Draw conclusions from your results.
14. Post your data to the Global Experiment website: **http://rsc.li/global-experiment**

Results

Type of food: ______________________________

Food type:	Result	Units	Help column
(Sample 1) Mass of food used		g	J1
Number of drops of iodine added			K1
Number of drops of iodine added per gram of food		drops per gram	K1 ÷ J1 = L1
(Sample 2) Mass of food used		g	J2
Number of drops of iodine added			K2
Number of drops of iodine added per gram of food		drops per gram	K2 ÷ J2 = L2
(Sample 3) Mass of food used		g	J3
Number of drops of iodine added			K3
Number of drops of iodine added per gram of food		drops per gram	K3 ÷ J3 = L3
Add the number of drops of iodine added per gram of food		drops per gram	L1 + L2 + L3 = M
Average number of drops of iodine added per gram of food		drops per gram	M ÷ 3 = N
Mass of vitamin C in milligrams per gram of food		$mg\ g^{-1}$	N x I = O

Results for a different type of food, after ageing or after cooking

Record what you changed: ______________________________

Food type:	Result	Units	Help column
(Sample 1) Mass of food used		g	J4
Number of drops of iodine added			K4
Number of drops of iodine added per gram of food		drops per gram	K4 ÷ J4 = L4
(Sample 2) Mass of food used		g	J5
Number of drops of iodine added			K5
Number of drops of iodine added per gram of food		drops per gram	K5 ÷ J5 = L5
(Sample 3) Mass of food used		g	J6
Number of drops of iodine added			K6
Number of drops of iodine added per gram of food		drops per gram	K6 ÷ J6 = L6
Add the number of drops of iodine added per gram of food		drops per gram	L4 + L5 + L6 = M
Average number of drops of iodine added per gram of food		drops per gram	M ÷ 3 = N
Mass of vitamin C in milligrams per gram of food		$mg\ g^{-1}$	N x I = O

Conclusions

The food that contains the most vitamin C per gram is ______________________

My experiment shows that ______________________

____

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Observations

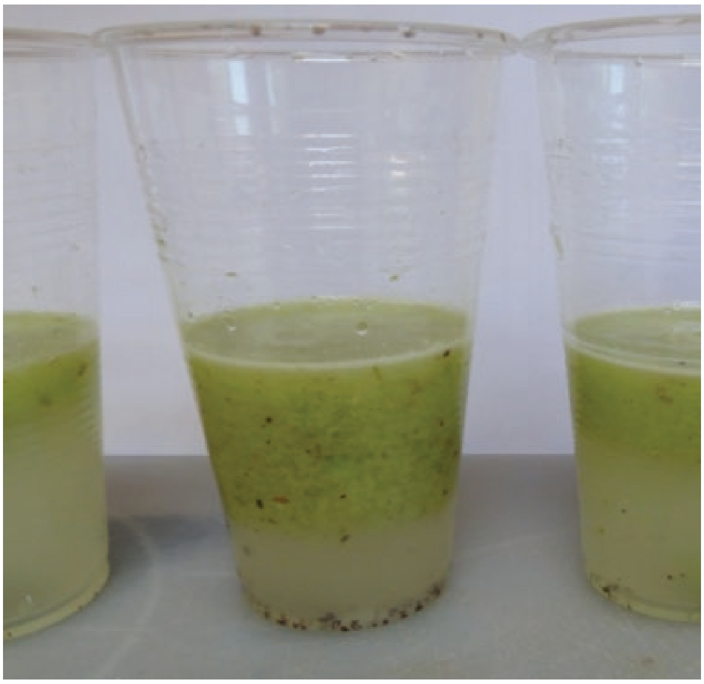

Figure 5 Starch/fruit/water mixture

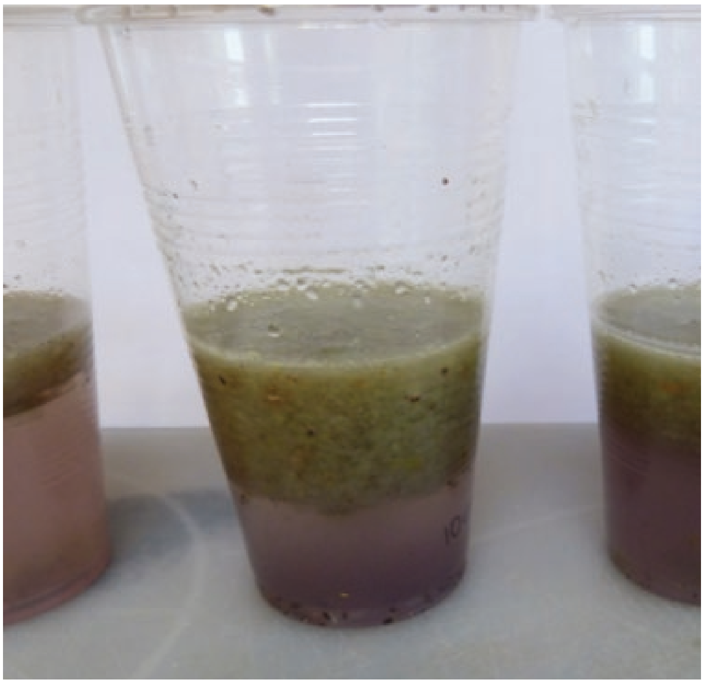

Figure 6 The end point is a sustained purple/black colour

Part D: Share your data

Post your data (**O**) to our Global Experiment website: **http://rsc.li/global-experiment**

You can compare your results and see the data from all the other participants.

Teacher's notes

It is possible to complete one full experiment in 1 hour if your students work in small teams. You can use the data on the Global Experiment website to compare other results and experiments (errors should be discussed – at the time of writing there are no guarantees how good the global data will be for spotting trends).

Materials

- You only need 10g of food per test so one apple can do quite a few experiments.
- The 100 cm^3 measure does not need to be accurate but does need to be reproducible. A marked level on the side of a cup will work.
- Any available container will do for the experiment itself: clear plastic cups, glasses or beakers are ideal as the colour of the solution is easier to identify.
- One bottle of tincture of iodine (25 cm^3, 1–2.5% w/v) solution is enough to complete one experiment as described on this site (you may want to have more bottles it you have multiple teams).

Procedure

To obtain the vitamin C, you can simply squeeze a fruit like an orange. However the instructions ask you to record the mass of the orange you started with, so it is a good idea to include the chopped orange skin in the extraction. Typically the skin is not eaten, so this should be discussed with the class to provide context for the experiment.

Calibration: we assume that the amount of vitamin C given on the packaging is accurate. The tablets used in testing this experiment contained 1000mg (1g) of vitamin C per tablet: one tablet was dissolved in 1 litre of water, measured using a kitchen measuring jug.

Each drop will make a purple/black colour on the surface of the liquid, a gentle stir will disperse this and the colour will disappear. As the reaction nears completion the solution will start to appear a little grey, even after stirring. The reaction is complete when the next drop turns the solution deep purple/black.

Following this procedure gives an end point that is easy to see, which maximises accuracy. The disadvantage is that the participants will be handling pure tincture of iodine, a 1–2.5 % w/v solution of iodine in ethanol. It is sold as an antiseptic and is routinely applied to skin (this is the brown solution used to disinfect skin before many surgical procedures). It will stain skin and other materials, but is not harmful unless taken internally (gloves would help to minimise staining).

If the solutions you are using are highly coloured (such as orange juice) it might be useful to have a comparison solution available, where the reaction is definitely complete, so that the end point is easy to identify.

Results

Do not be afraid to discuss errors in the data: this is not an 'exact' experiment. We have tried to minimise errors by the use of averaged data, however scientific balances, accurate volume measurements and titration burettes are needed for greater accuracy. Search for "vitamin C" on Learn Chemistry (**http://rsc.li/learn-chemistry**) for more examples and other resources.