16–18 years

Analysis of vitamin C content in cooked cabbage

ROYAL SOCIETY OF CHEMISTRY

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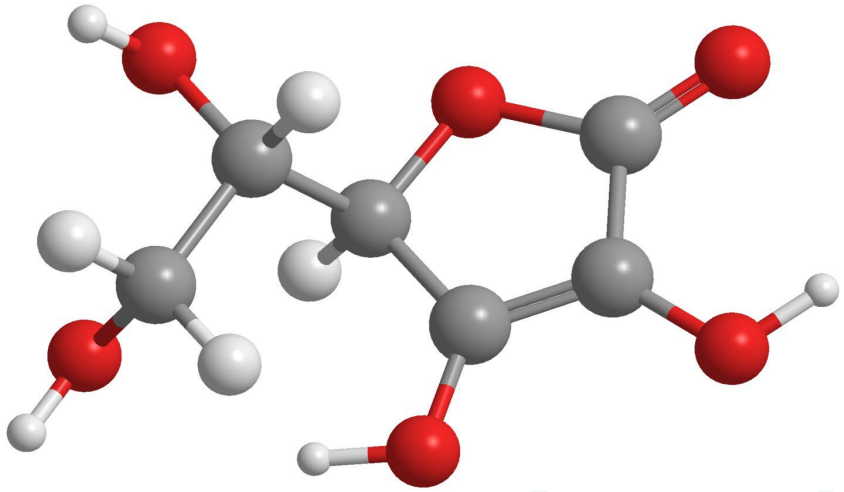
The problem

Cooking can reduce the content of vitamin C in food and the choice of cooking method is important to preserve the maximum amount of this critical vitamin.

The amount of vitamin C in food can be determined by a redox titration with a standard solution of dichlorophenolindophenol (**DCPIP**).

Your challenge is to plan and carry out the analysis of the vitamin C content of cabbage cooked by two different methods.



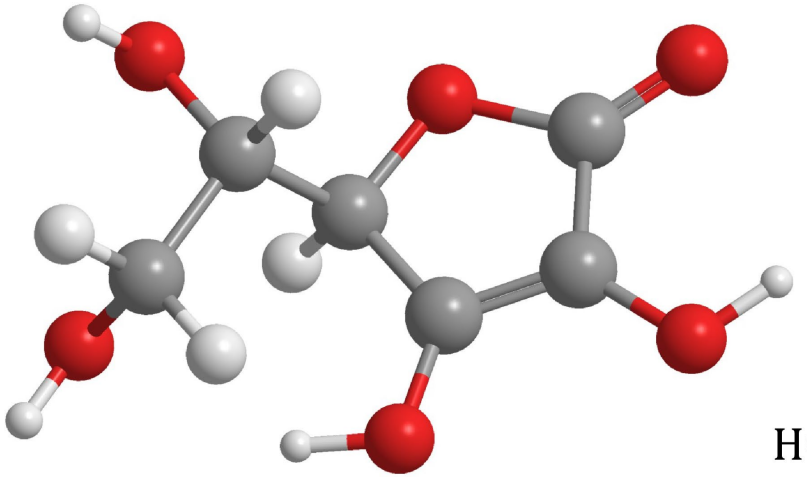
Learning objectives

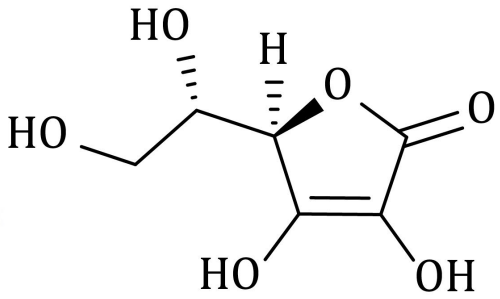
1. Apply the practical techniques of preparing a solution and carrying out a titration to analyse the mass of vitamin C in cooked cabbage.
2. Plan a practical method for your analysis from partial instructions, taking into account health and safety considerations and the required accuracy and precision.
3. Record, analyse and present data to reach a conclusion from your results.
4. Apply concepts of redox, solubility, enzyme and numerical chemistry to the analysis of vitamin C in cabbage.

Task 1 – Structure and bonding in vitamin C

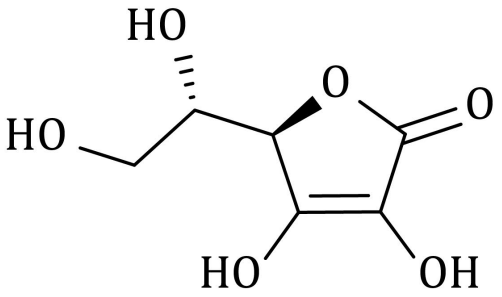
The ascorbic acid (vitamin C) molecule contains alkene, secondary alcohol, primary alcohol and ester functional groups.

It does **not** contain the carboxylic acid functional group.





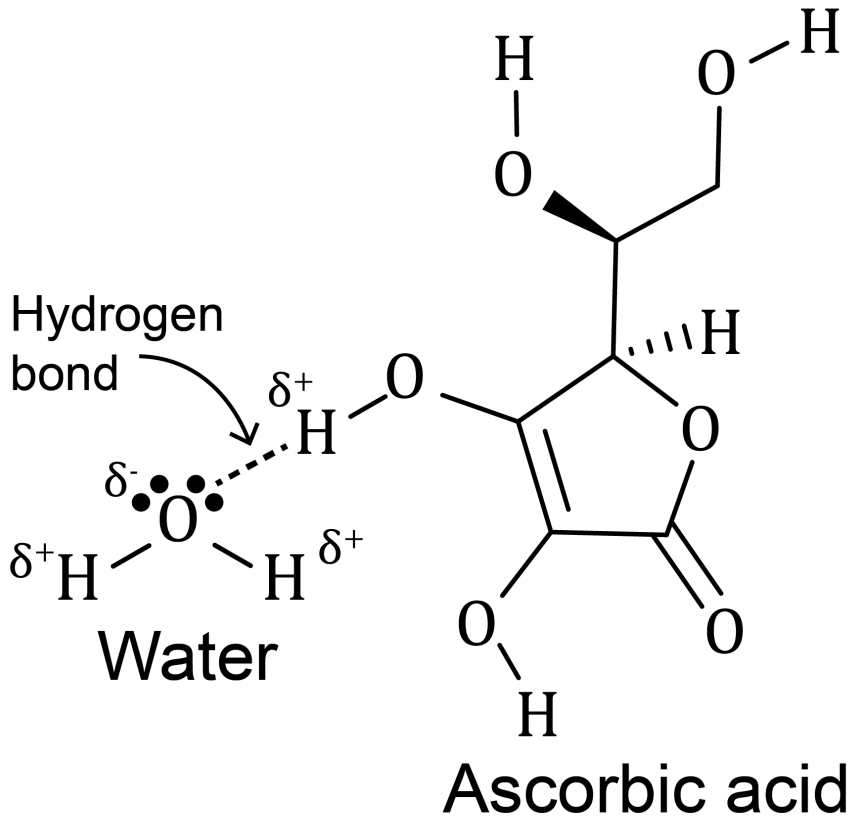
Vitamin C
(ascorbic acid)



Task 1 notes

Task 1 – Structure and bonding in vitamin C

Ascorbic acid (vitamin C) will dissolve in water because the four polar O–H groups and the carbonyl group (C=O) will hydrogen bond with water.

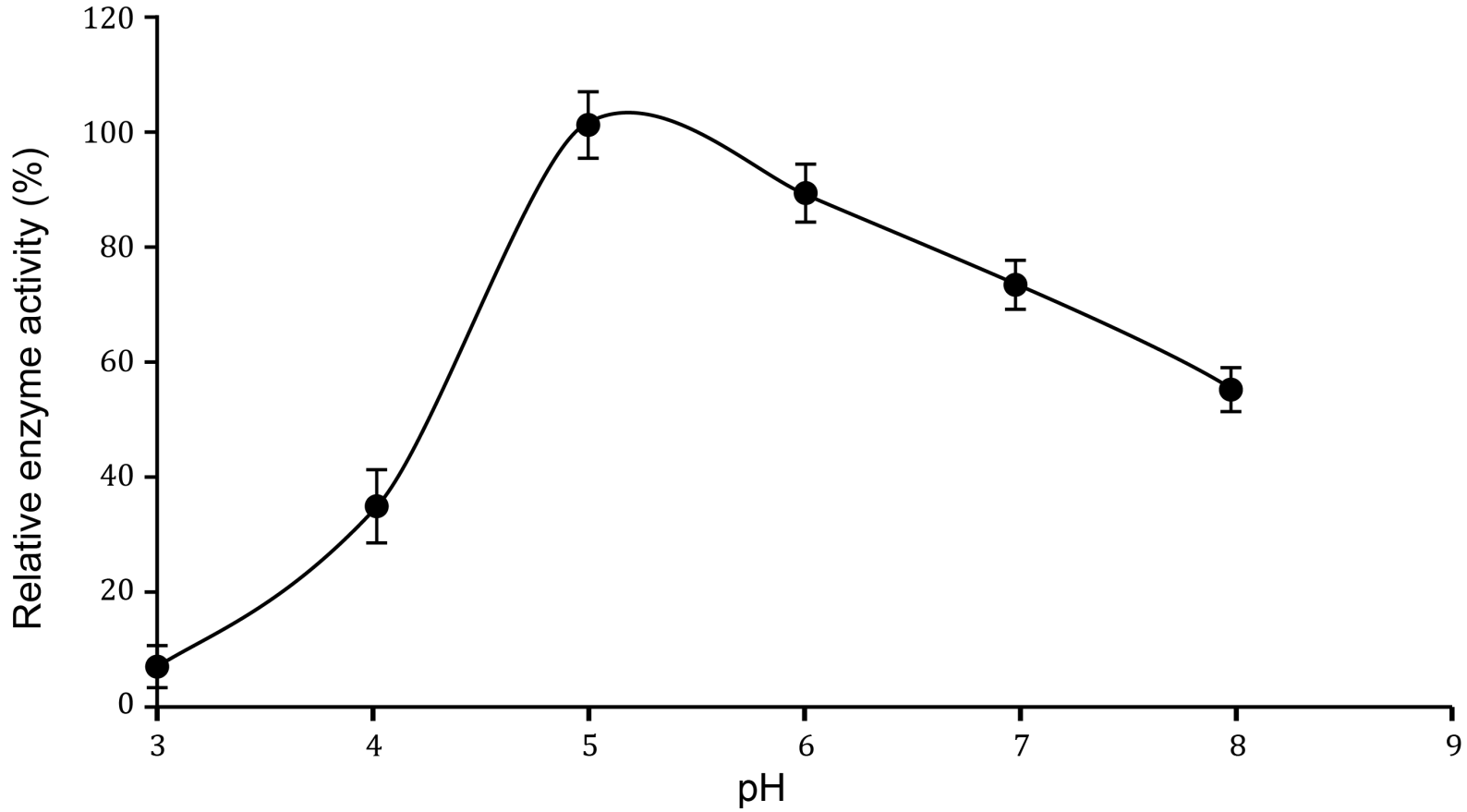


Task 1 notes

Task 1 – Structure and bonding in vitamin C

Enzymes have their optimum activity within a narrow pH range.

For ascorbic oxidase, which oxidises vitamin C, this is at pH 5.

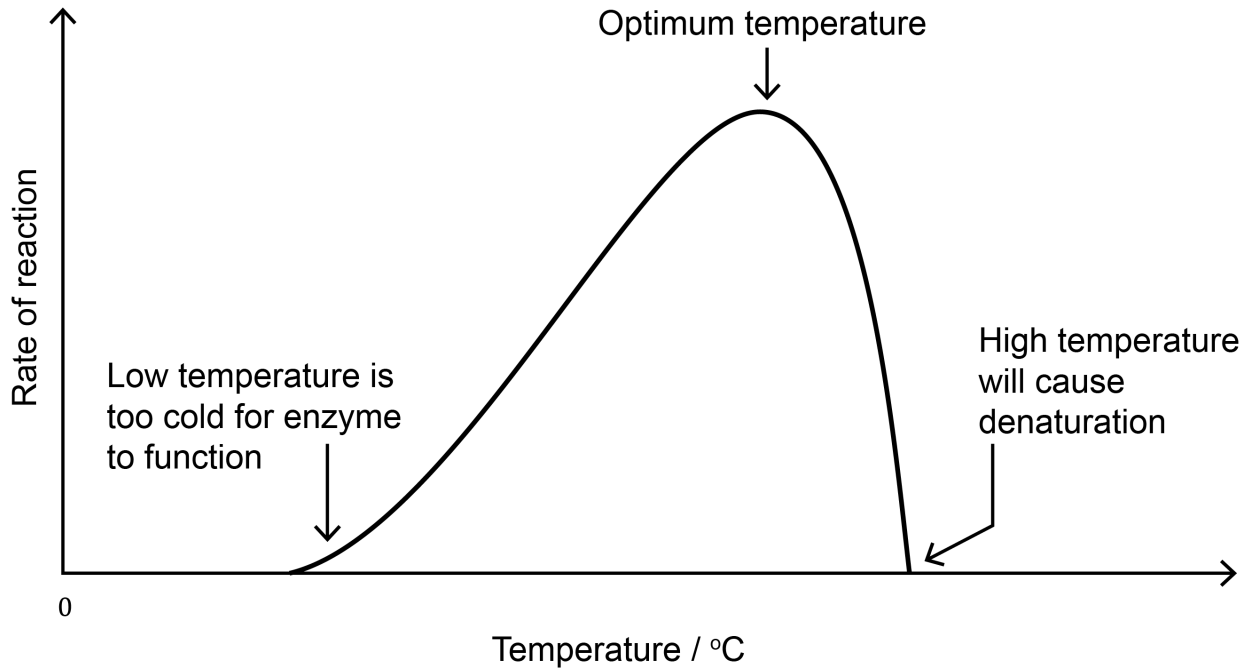


Task 1 notes

Task 1 – Structure and bonding in vitamin C

At low temperatures enzymes have low activity. As the temperature increases, the reaction rate increases.

The activity peaks at an optimum temperature which is specific to each enzyme. Enzymes are denatured and therefore inactive at extreme temperatures.

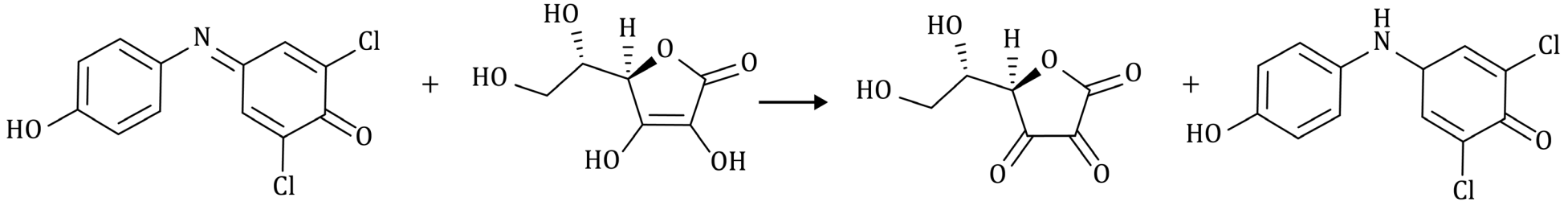


Task 1 notes

Task 2 – The redox reaction between ascorbic acid (vitamin C) and DCPIP (dichlorophenolindophenol)

(a) Ascorbic acid = reducing agent, DCPIP = oxidising agent

(b) Equation:



Dichlorophenolindophenol | Ascorbic acid | Dehydroascorbic acid

(c) 1:1

Task 2 notes

Task 3 – Plan the analysis of the vitamin C content of cooked cabbage

Stage 1: standardisation of the DCPIP dye

(a) Pipette and safety filler for vitamin C, safety glasses. Burette to titrate DCPIP.

(b) $F = \frac{25 \times 200}{27.50 - 0.50} \times 1000 = 0.185\ mg\ cm^{-3}$

Specific health and safety measures for Stages 2 and 3

- Supervision needed using sharp knives for cutting; cuts to be reported.
- Bring boiling water to the beakers and use a 250 cm^3 beaker.
- Use cloth / gloves to protect hands when handling hot equipment.
- Wear gloves and safety glasses when handling 5% phosphoric acid (H_3PO_4).

Task 3 – Plan the analysis of the vitamin C content of cooked cabbage

Stage 2: determination of the vitamin C content of cabbage cooked in boiling water

NB: use of a fume cupboard will reduce the smell of cabbage in the laboratory.

i. Weigh out 50 g of cabbage on an analytical balance and shred finely.
ii. Place the cabbage in 100 cm^3 of boiling water, allow to simmer for 10 minutes.
iii. Carefully pour off the hot water after this time and liquidise the cooked cabbage.
iv. Add 250 cm^3 of 5% phosphoric acid (H_3PO_4) to the liquidised cabbage, stir and weigh the mixture.
v. Remove about 20 cm^3 of the mixture and weigh. Filter the mixture through muslin or glass wool. Retain the filtrate and make it up with the washings to 25 cm^3. (The exact volume is not needed in the calculation so this volume can be measured with a measuring cylinder.)
vi. Transfer 25 cm^3 portions to a conical flask. Titrate against standardised DCPIP until the you reach end point, where a pink colour is seen and persists for 10 seconds.
vii. Repeat the titration until your record two concordant titres.

Task 3 notes

Task 3 – Plan the analysis of the vitamin C content of cooked cabbage

Stage 3: determination of the vitamin C content of cabbage cooked in cold water which is brough to the boil

i. Weigh out 50 g of cabbage on an analytical balance and shred finely.
ii. Place the cabbage in 100 cm^3 of cold deionised water and slowly bring it to the boil. Allow to simmer when boiling temperature is reached until the total time in the water is 10 minutes.
iii. Carefully pour off the hot water after this time and liquidise the cooked cabbage.
iv. Add 250 cm^3 of 5% phosphoric acid (H_3PO_4) to the liquidised cabbage, stir and weigh the mixture.
v. Remove about 20 cm^3 of the mixture and weigh. Filter the mixture through muslin or glass wool. Retain the filtrate and make it up with the washings to 25 cm^3. (The exact volume is not needed in the calculation so this volume can be measured with a measuring cylinder.)
vi. Transfer 25 cm^3 portions to a conical flask. Titrate against standardised DCPIP until you reach the end point, where a pink colour is seen and persists for 10 seconds.
vii. Repeat the titration until you record two concordant titres.

Task 3 notes

Task 4 – Carry out the analysis of vitamin C in cabbage

Recording your data

Titration data:

- Titration data table drawn showing initial and final volumes and titre used with units for each quantity.
- All titration readings should be to 0.05 cm^3.
- Concordant titres should be selected.
- Mean titre is calculated from concordant titres.

Mass readings:

Table(s) recording:

- $\boldsymbol{M_c}$,the mass of the liquidised sample of cabbage mixed with 250 cm^3 of 5% phosphoric acid with units.
- $\boldsymbol{m_c}$, the mass of the 20 cm^3 portion of this mixture with units.

All mass readings should be to 0.5 g (or accuracy of the balance used).

Task 4 – Carry out the analysis of vitamin C in cabbage

100 g of sample contains $= V \times F \times \frac{M_c}{m_c} \times 2\ mg$ of vitamin C

Example data using the formula to calculate the vitamin C content for cabbage cooked in boiling water:

M_c = 242.2 g

m_c = 23.8 g

F = 0.12 mg cm^{-3}

V = 10.00 cm^3

Example data using the formula to calculate the vitamin C content for cabbage cooked in water brought to the boil:

M_c = 248.6 g

m_c = 25.2 g

F = 0.12 mg cm^{-3}

V = 6.50 cm^3

Task 4 – Carry out the analysis of vitamin C in cabbage

100 g of sample contains $= V \times F \times \frac{M_c}{m_c} \times 2\ mg$ of vitamin C

Example data and solution using the formula to calculate the vitamin C content for cabbage cooked in boiling water:

M_C = 242.2 g

m_C = 23.8 g

F = 0.12 mg cm^{-3}

V = 10.00 cm^3

100 g of sample contains $10.00 \times 0.12 \times \frac{242.2}{23.8} \times 2 = 24.42\ mg$ of vitamin C

Task 4 – Carry out the analysis of vitamin C in cabbage

100 g of sample contains $= V \times F \times \frac{M_c}{m_c} \times 2\ mg$ of vitamin C

Example data and solution using the formula to calculate the vitamin C content for cabbage cooked in water brought to the boil:

M_C = 248.6 g

m_C = 25.2 g

F = 0.12 mg cm^{-3}

V = 6.50 cm^3

100 g of sample contains $6.50 \times 0.12 \times \frac{248.6}{25.2} \times 2 = 15.39\ mg$ of vitamin C

Task 4 – Carry out the analysis of vitamin C in cabbage

Conclusion to hypothesis on vitamin C content of cabbage cooked by both methods:

Based on example values and the fact that raw cabbage contains 36.60 mg of vitamin C per 100 g:

- 100 g of cabbage cooked in boiling water has lost $\frac{\mathbf{36.60 - 24.42}}{\mathbf{36.60}} \times \mathbf{100} = \mathbf{33.28}\%$ of vitamin C.
- This is less than 50% of vitamin C mentioned in the hypothesis so the hypothesis is incorrect for this sample.

- 100 g of cabbage cooked in water brought to the boil has lost $\frac{\mathbf{36.60 - 15.39}}{\mathbf{36.60}} \times \mathbf{100} = \mathbf{57.95}\%$ of vitamin C.
- This is more than 50% of vitamin C mentioned in the hypothesis so the hypothesis is correct for this sample.

- The hypothesis also correctly states that more vitamin C is lost when cabbage is cooked in water which is brought to the boil than when plunged into boiling water.