

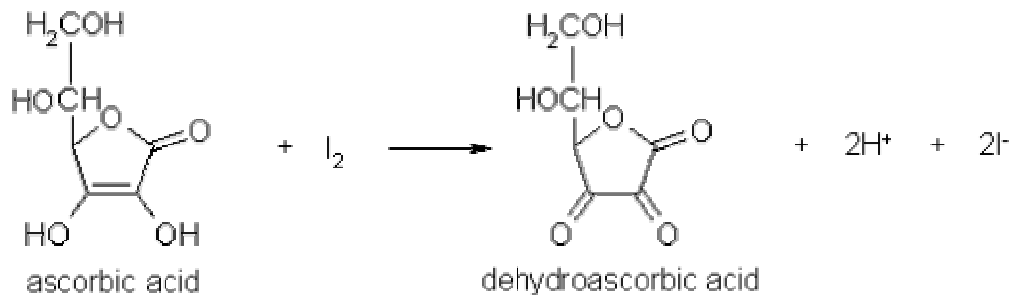
Analysis of commercial vitamin C tablets

Objective

To determine the vitamin C content in commercial vitamin C tablets by titration between vitamin C (ascorbic acid) & iodine solution. Hence, compare this data with the manufacturer's specification.

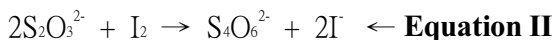
Principle

In this analysis, certain amount of iodine solution, which is known in excess, is added to acidified ascorbic acid solution. Brown iodine can be easily reduced by acidified ascorbic acid to form colourless iodide ion:



← Equation I

The excess iodine is then back titrated by standard sodium thiosulphate solution, by using a burette and starch solution (used as end point indicator) Similarly, iodine can also be decolourized by thiosulphate ion:



Any iodine present will react with starch to form a blue-black complex. However, when all available iodine has been reacted, the blue-black complex becomes colourless which signals the end-point. Hence, the mass of ascorbic acid reacted by iodine can be calculated.

Chemicals

vitamin C tablet(s), $NaIO_3$, 1M NaI solution, 0.5M H_2SO_4 , approximately 0.06M $Na_2S_2O_3$, freshly prepared starch solution

Apparatus

electronic balance, beaker, volumetric apparatus, pipette, glass rod, white tile, dropper, measuring cylinder

Procedure

- 1.> Accurately weigh 0.6 to 0.7g sodium iodate, NaIO_3 and record its mass.
- 2.> NaIO_3 is then dissolved in deionized water and is made up to 250cm^3 in a volumetric flask.
- 3.> Sodium thiosulphate, $\text{Na}_2\text{S}_2\text{O}_3$, is standardized by part of standard NaIO_3 solution is shown below:
 - (a) Pipette 25cm^3 of NaIO_3 solution into a conical flask and about 5cm^3 of 1M sodium iodide, NaI , together with 5-10 cm^3 of 0.5M sulphuric acid, H_2SO_4 , are also added. Then, the mixture is immediately titrated with approximately 0.06M $\text{Na}_2\text{S}_2\text{O}_3$ solution. Repeat this step for 3-4 times to obtain a more accurate titration data.
 - (b) When the reaction mixture becomes pale yellow, a few drops of freshly prepared starch solution is added and continue to titrate until the end-point is reached.
 - (c) Calculate the molarity of $\text{Na}_2\text{S}_2\text{O}_3$ solution.
- 4.> A vitamin C tablet is dissolved in 150cm^3 of 0.5M H_2SO_4
- 5.> The mixture is then transferred into a clean 250cm^3 volumetric flask and deionized water is added to reach the graduated mark.
- 6.> Pipette 25cm^3 of vitamin C solution (with dil. H_2SO_4) into a conical flask and about 5cm^3 of 1M NaI solution is added.
- 7.> Pipette 25cm^3 of standard NaIO_3 solution into the conical flask which contains a mixture of vitamin C, H_2SO_4 and NaI solution.

●Note: I_2 is generated by IO_3^- , I^- & H^+ :

$$\text{IO}_3^- + 5\text{I}^- + 6\text{H}^+ \rightarrow 3\text{I}_2 + 3\text{H}_2\text{O} \leftarrow \text{Equation III}$$
- 8.> The mixture is then titrated immediately with standard $\text{Na}_2\text{S}_2\text{O}_3$ solution to find out the number of moles of excess I_2 . Hence, the mass of ascorbic acid reacted can be calculated.

Results

$$\begin{aligned} \text{Mass of NaIO}_3 &: \underline{0.63} \text{ g} \\ \therefore \text{Molarity of } 250\text{cm}^3 \text{ standard NaIO}_3 \text{ solution} &: (0.63 \div 197.89 \div 0.25)\text{M} \\ &= \underline{0.012734} \text{ M} \\ \text{By equation III, no. of moles of } \text{I}_2 \text{ formed} &= \text{no. of moles of NaIO}_3 \times 3 \div 10 \\ &= (0.63 \div 197.89 \times 0.3)\text{mol} \\ &= \underline{9.550761 \times 10^{-4}} \text{ mol} \\ \text{By equation II, no. of moles of } \text{S}_2\text{O}_3^{2-} \text{ needed to react all } \text{I}_2 &= \text{no. of moles of } \text{I}_2 \text{ formed} \times 2 \\ &= (9.550761 \times 10^{-4} \times 2)\text{mol} \\ &= \underline{1.910152 \times 10^{-3}} \end{aligned}$$

_ mol

The table below shows the standardization of $\text{Na}_2\text{S}_2\text{O}_3$ solution by titration:-

	Trial	1st	2nd
Final reading /cm ³	32.75	31.00	30.80
Initial reading /cm ³	3.20	1.15	1.05
Volume of $\text{Na}_2\text{S}_2\text{O}_3$ /cm ³	29.55	29.85	29.75
Average volume of $\text{Na}_2\text{S}_2\text{O}_3$ added /cm ³	29.80		

\therefore Concentration of standard $\text{Na}_2\text{S}_2\text{O}_3$ solution = $1.910152 \times 10^{-3} \div (29.8 \times 10^{-3}) \text{ M} = \underline{0.064099} \text{ M}$

The table below shows the determination of I_2 which is not reduced by ascorbic acid by titration with standard $\text{Na}_2\text{S}_2\text{O}_3$ solution:-

	Trial	1st	2nd
Final reading /cm ³	12.70	26.90	14.80
Initial reading /cm ³	0.60	14.60	2.55
Volume of $\text{Na}_2\text{S}_2\text{O}_3$ /cm ³	12.10	12.10	12.25
Average volume of $\text{Na}_2\text{S}_2\text{O}_3$ added /cm ³	12.175		

Mass of vitamin C in a tablet (manufacturer's specification): 1 g

Mass of a vitamin C tablet: 4.54 g

No. of moles of I_2 added to react with vitamin C = 9.550761×10^{-4} mol

No. of moles of $\text{S}_2\text{O}_3^{2-}$ reacted by excess $\text{I}_2 = 0.064099 \text{ M} \times 0.012175 \text{ dm}^3$
= 7.804061×10^{-4} mol

From equation II, no. of moles of excess $\text{I}_2 = 7.804061 \times 10^{-4} \div 2 \text{ mol} = \underline{3.902030} \times 10^{-4} \text{ mol}$

$$\begin{aligned}
 \therefore \text{No. of moles of } I_2 \text{ is reacted by vitamin C} \\
 &= \text{no. of moles of } I_2 \text{ added to react with vitamin C} - \text{no. of moles of excess } I_2 \\
 &= \text{no. of moles of vitamin C reacted} \quad \quad \quad [\text{by equation I}] \\
 \therefore \text{No. of moles of vitamin C present in a tablet} \quad [\text{by equation I}] \\
 &= (9.550761 \times 10^{-4} - 3.902030 \times 10^{-4}) \text{ mol} \times 10 = \underline{5.648730 \times 10^{-3}} \text{ mol}
 \end{aligned}$$

$$\begin{aligned}
 \therefore \text{Mass of vitamin C present in a tablet (obtained by experiment)} = \\
 5.648730 \times 10^{-3} \times 176 = \underline{0.9942} \text{ g}
 \end{aligned}$$

● When compare this value with the manufacturer's specification, it's a little bit less than expected.

Precaution

- 1.> Ascorbic acid (vitamin C) is unstable and can be easily oxidized. Oxidation can be highly speeded up when it's heated or dissolved in water. To obtain the best results of the experiment, the tablet is dissolved in water only when titration is about to begin. Besides, the tablet (or the vitamin C solution) should avoid storage in direct sunlight, keep in a cool place and in an airtight bottle. Moreover, only pour out enough amount of vitamin C from the volumetric flask just about to use and then stopper it immediately.
- 2.> Starch solution should be added only when the solution becomes pale yellow.
- 3.> The mixture of reacted vitamin C and excess I_2 should be titrated with $Na_2S_2O_3$ immediately to reduce I_2 lost due to vapourization.
- 4.> Handle chemicals with care, $NaIO_3$ is an oxidant, H_2SO_4 is an irritant which may irritate the skin especially if there is a wound.
- 5.> Avoid exposure to I_2 solution since the I_2 vestige on skin is quite hard to remove, it will remain for a long time.

Discussion

~The function of vitamin C~

Vitamin C (ascorbic acid) is a white, odourless powder, and a water-soluble vitamin. When dry, it's reasonably stable in air but in solution, it oxidizes rapidly in the presence of air. In fact, it's known that vitamin C is the most unstable vitamin. The oxidation can be speeded up by heating or presence of moisture.

Vitamin C is one of the essential nutrients in our diet. It can be found in citrus fruits, leafy vegetables, tomatoes, potatoes and cabbage. It is necessary for the enzymatic activity of prolyl hydroxylase, which is responsible for the formation of collagen fibre - a 'cement' which holds tissues together. Collagen fibre plays an important role in teeth, cartilage, skin, blood vessels, etc. A deficiency in vitamin C results in defective collagen, causing

symptoms of scurvy, bleeding gum, loosen teeth, etc. Vitamin C also acts as a reducing agent in many metabolic processes, including synthesis of enzymes and hormones.

Linus Pauling, the winner of 2 Nobel Prizes, claims that we should intake large doses of vitamin C a day which he think that it may help to prevent common cold. He also argue that this can lesson the likelihood of having colon cancer. Pauling and his supporters argue that humans are one of five species that do not synthesize vitamin C. These five species live in tropical regions where vitamin C is readily available, so their bodies can concentrate on synthesizing other useful substances ensuring for survival. Pauling concludes that if humans were able to produce their own vitamin C equivalent to that produced by other species, it would be several thousand milligrams per day!!!

On the other hand, repeated studies have shown that excessive intake of vitamin C cannot decrease the number of colds, although it can reduce their severity. These studies show that human body could use only a limited amount of vitamin C, the rest of vitamin C is excreted. Pauling responded by pointing out that the amount of vitamin C needed in different people varies. For example, smokers need twice as much as non-smokers.

~Remarks of the experiment~

1.> Vitamin C is a reducing agent which can reduce I_2 into colourless I^- . However, the back titration is used instead of direct titration with I_2 because

I_2 can be easily vapourize thus the molarity of I_2 solution is difficult to control, thus using 'standard' I_2 solution for titration is impossible. In the

experiment, the known amount of I_2 is generated by fixed amount of $NaIO_3$, the excess amount of I_2 is reduced by $Na_2S_2O_3$ immediately, to

reduce I_2 lost by vapourization. This also explains why I_2 is placed in conical flask but not burette when standardizing $Na_2S_2O_3$.

2.> $NaIO_3$ should be weighed accurately (must not be excess) because this will affect the amount of I_2 generated.

3.> Starch solution can form a blue-black complex with I_2 , since it can detect a very little amount of I_2 present, it's used to determine the end-point,

with the colour changes from pale blue to colourless (no I_2 present). However, it should be added only at the time when the solution becomes very

pale yellow (nearly colourless) because the complex form between starch and I_2 at a high concentration is irreversible. Even if the end point is

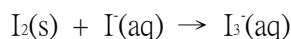
reached. the blue-black suspension will still remain.

4.> In the procedure 6-7, NaI is added to vitamin C solution before $NaIO_3$ is added because $NaIO_3$ is an oxidizing agent, it will oxidize vitamin C instead of I_2 .

5.> $Na_2S_2O_3$ is unstable which can be easily oxidized by air, so it's needed to standardize before use if it's not freshly prepared.

6.> Since starch dissolves in water to form colloid, the starch solution needs to boil for a few minutes to precipitate the starch suspension for practical use.

7.> Iodine is only slightly dissolved in water; however, the excess NaI can highly increase its solubility (so that it needn't to be measured accurately):



This can also explain that why iodine solution appears reddish (colour of I_2) but not brown.

8.> To obtain the results more accurately, it's recommended that we shall use the vitamin C tablets which are tasteless and contain no colourings.

However, orange-flavoured tablets is also accepted but not grape-flavoured, since it's colour may affect determination of the end point (blue to colourless !).

9.> Theoretically, vitamin C tablets which has orange-flavoured always has a higher vitamin C content than that of grape-flavoured, since people think that the former is more sour than latter and manufacturers will add more vitamin C to the former one as flavourings. Enriching the tablets with vitamin C can attract more people to buy.

10.> In the experiment, each tablet used weighs about 4.5g, but has only 1g of vitamin C, the remains may be bicarbonates/carbonates (to have a cooling effect), colourings, flavourings, binder (stick the powder together), etc.

11.> From the result obtained, it is about 0.58% less than manufacturer's specification, the difference may due to the poor technique of titration, self-oxidation of vitamin C, etc.

Conclusion

Vitamin C is an essential vitamin to prevent scurvy, and it can be found in citrus fruit and green vegetables. Although it's so useful, now it is still too soon to say that whether Pauling is right or not. It may need several years until there is enough evidence.

The mass of vitamin C tablet obtained by the experiment is quite close to manufacturer's specification which is acceptable.