Food prevents us from some serious illnesses and disorders health essay

Health & Medicine

Extended essay-Chemistry-Is it true that the salt we are using in food prevents us from some serious illnesses and disorders? Name: Rinkovec TamaraSchool: Prva gimnazija VaraždinSession: May 2013Session number: 003045-007IntroductionTable salt (sodium chloride) is product that is most common substance in food production. It is not only made for direct human consumption but also is a carrier for additives and nutrients. A substance of salt that has a key role in maintaining normal life in human is iodine. [1]Scientists discovered that the lack of iodine can cause severe problem such as goitre and the irreversible processes of brain damage. Iodine’s often present in iodate form but can also be found in form of iodide.[2]The topic that will be explored throughout this extended essay is determination of amount of iodine present in most common salts present at Croatian market. Two species of different sort will be instigated to determine the amounts of iodine present.[3]Most common products on the market are salts named " Paška sol" that is produced on the island of Pag in Croatia, by evaporation of sea water and the other one " Tuzlanska sol" made in Bosnia and Herzegovina which is a rock salt exploited from mines. Each of those is iodized with potassium iodate. The investigation is based on the titrimetric procedure with thiosulfate as reducing agent and starch indicator solution. The determination of iodine will be done in five trials for each salt which is the way the legislation requires. Research questionAre the amounts of iodate in samples of rock and sea table salt determined by titration with sodium thiosulfate satisfying and within limits of both World Health organization and Croatian government regulations? HypothesisThe amount of iodine present in salt should be within levels of 20 – 40 mg of iodine (or 34 – 66 mg

potassium iodate) per kg of salt according to World Health Organization (WHO) recommendation or according to the Croatian legislation at a level of 25 mg per kg so that the salt together with natural existing iodine contains no less than 20 mg nor more than 30 mg of potassium iodide. [4]5Background informationTable salt and iodineIodine is a chemical element that appears as solid brown crystals[6]but easily sublimates and produces dense purple vapour. Iodine never occurs free in the nature but it is present in rock, soils, water bodies, plants, animal tissues and foodstuffs. Around the world in many cuisines the salt is used in cooking. Refined salt usually contains about 97 to 99 per cent of solid sodium chloride. The other 1 to 3 per cents are water and other substances like magnesium or sodium salts together with iodine compounds. The most common forms of iodine in table salt are as a potassium/sodium iodide or sodium/potassium iodate. It is used to help reduce the iodine deficiency in humans which affects about two billion people. Iodine deficiency can cause the illness called goitre which is characterized by a swelling of the thyroid gland and in new-borns mental illness, cretinism.[7]History of iodizing salt and its importanceThe relationship between good sources of iodine and the prevention of goitre dates back to antique period. This concept of iodizing began with the French chemist Boussingault at the beginning of the 19th century.[8]Since then, salt iodization has become progressively the main approach to control iodine deficiency throughout the world. It is feasible, safe and rapidly effective. Before the process of iodizing salt has been implemented there was problem with people who lived in parts of the world where the soil was naturally low in iodine, meaning that the local vegetables had small iodine content so the

people were suffering of goitre. To prevent the illness to spread a chewing gum ‘ Iodigum’[9]that contained iodine was invented. Later on, when the salt iodization started, the usage of such gum has stopped because it became unnecessary. The titrimetric methodThe method that will be used to determine the unknown concentration of the iodine content in sample of salt is iodometry, redox titration with sodium thiosulfate and starch indicator solution.[10]First of all, iodide is added as a reducing agent. In reaction with potassium iodate that originates from table salt it will produce pure iodine molecules. The reaction happens according to the equation below and it is visually seen as a change in solution colour that turns from colourless to yellow. The reason why will excess of potassium iodide be added is to help solubilize the free iodine which is quite insoluble in distilled water and to ensure that all iodate ions transform into iodine. The addition of hydrochloric acid is necessary because acid as a proton donor generates hydrogen ions that are needed in first redox reaction.[11]$IO_3^-(aq) + 5\ I^-(aq) + 6\ H^+ \rightarrow 3\ I_2(aq) + 3\ H_2O(l)$Next step in procedure is titration with thiosulfate. It consumes the iodine produced in the previous step. The yellow colour of solution in the Erlenmeyer flask will by adding of thiosulfate fade because I_2 molecules will become ions, I^-, that are soluble in water and hence colour will disappear. To determine an end-point of titration, starch indicator solution is added. After addition of indicator solution turns purple and by further titration the colour again fades. Disappearance of purple colour suggests end-point of titration - all iodine was used up and transformed in iodide in the redox reaction.[12]$I_2(aq) + 2\ S_2O_3^{2-}(aq) \rightarrow 2\ I^-(aq) + S_4O_6^{2-}(aq)$$I_2(aq) + I^-(aq) \rightleftharpoons I_3^-(aq)$The thiosulfate ion is strong reducing agent and will

reduce iodate ions that are coming from salt into iodine molecules. With iodine, thiosulfate ion oxidizes into tetrathionate ion. Unlike other agents, iodine won’t oxidize tetrathionate ion furthermore into sulphate ion which will make the reaction quantitative. During the reaction thiosulfate will oxidize by formation of dimer molecules (the scheme below[13]).

Titrations will be done with a starch solution as an indicator. The blue colour of the solution that appears is because absorption of iodine in spiral chain of-amylose. Since B-amylose contains thousands of glucose molecules bonded by α-1, 4 bonds, it is keen on producing helix structure that can surround iodine molecules. When iodine, I2 is trapped in this helix, a purple colour appears. During the titration, addition of thiosulfate will reduce iodine into iodide and this will no longer be trapped inside, hence colour will disappear. Furthermore, quantitative redox reaction where thiosulfate ion goes into tetrathionate ion requires pH lower than 7 which is why hydrochloric acid is added.[14]Method[See Appendix I for the list of apparatus and chemicals and Appendix II for the details of preparation of solutions]Standardized solutionThe standardized solution is a reagent of a known concentration used in volumetric analysis.[15]In this experiment it is a solution of sodium thiosulfate made by diluting the 1L of 0. 1 mol dm-3 sodium thiosulfate to a 250mL solution with the concentration 0. 002 mol dm-3 by taking 5 mL of concentrated thiosulfate and adding the water to the point of 250 mL in volumetric flask.[16]Making the salt solutionI bought in a local store two most frequent types of salt.[17]Using the balance I measured 50. 000 g ± 0. 005 g of each salt and dissolved into 250 ml of distilled water. Hence the

solution was finely divided by using the pipette into five equal Erlenmeyer flasks and each was covered with a small watch glass, so at the end of the process each flask contained 50 mL of solution which is equivalent to 10 g of salt. Adding the potassium iodide and hydrochloric acidOnce the salt solution was made in each flask at a time, a 5 mL of 1 mol dm-3 of hydrochloric acid and 1 mL of 0. 6 mol dm-3 potassium iodide solutions were added. Titration of iodine with thiosulfateThe titration with thiosulfate consumes the iodine produced in the previous step. By adding of thiosulfate yellow colour is fading. To be able to accurately determine when all iodine molecules are used up and see a colour change, a 1 mL of 5% starch indicator solution was added. After addition of indicator solution turns purple by further titration the colour again fades. When the purple colour disappears reaction has reached the end point. resultsTables with volumes of thiosulfate solution recorded throughout the experiment

Sea salt from Pag, Croatia

TrialV (cm3)KI ± 0. 02Starch ± 0. 01HCl ± 0. 02Salt solution ± 0. 05

S2O32- ± 0. 10

151550

3. 8

251550

3. 7

351550

3. 8

451550

3. 8

551550

3. 8

Table 6. 1: Volumes of reagent used throughout experiment and the volume of thiosulfate used to react with iodine present in the solution for five samples of Sea salt solution from Pag, Croatia

Rock salt from Tuzla, Bosnia and Herzegovina

TrialV (cm3)KI ± 0. 02Starch ± 0. 01HCl ± 0. 02Salt solution ± 0. 05

S2O32- ± 0. 10

151550

4. 4

251550

4. 3

351550

4. 3

451550

4. 4

551550

4. 3

Table 6. 2: Volumes of reagent used throughout experiment and the volume of thiosulfate used to react with iodine present in the solution for five samples of Rock salt solution from Tuzla, Bosnia and HerzegovinaThe pictures of solutions made during experimentPicture 1: The yellow solution, mixture of salt solution, potassium iodide and hydrochloric acidPicture 2: The slightly yellow solution during the process of titration, before the point of adding the 5% starch indicator solutionPicture 3: The purple-blue solution produced after adding 5% starch indicator solution. The colour helps to determine the end point of titration because it is easier to see change from blue to colourless than from yellow to colourless. Picture 4: The end point of titration; the change of colour from purple/blue to colourless indicates that the titration has reached the end pointAnalysis and calculationsThe reactions and ratiosIn the following section I will show the calculation for one trial of one salt. Calculations for all the other trials are presented in Appendix III. The reactions occurring throughout this titration are following: Step 1: reaction of iodate ions with iodide from potassium iodide solution to form iodine

$$IO3\text{-}(aq) + 5\ I\text{-}\ (aq) + 6\ H+ \rightarrow 3\ I2\ (aq) + 3\ H2O\ (l)$$

Step 2: reaction of produced iodine with thiosulfate to produce iodide ions

$$I2\ (aq) + 2\ S2O32\text{-}\ (aq) \rightarrow 2\ I\text{-}\ (aq) + S4O62\text{-}\ (aq)$$

Thus the ratios between ions are: n(I2) : n (IO3-) = 3 : 1

$$3\ n\ (IO3\text{-}) = n\ (I2)$$

n (I2) : n (S2O32-) = 1 : 2

n (S2O32-) = 2 n (I2)

Since the amount of iodine produced in first reaction is the same as the amount of iodine that undergoes second reaction it holds thatn (I2; a) = n (I2; b)3 n (IO3-) = n (S2O32-)

n (IO3-) = n (S2O32-)

Sample calculationsSince the concentration of sodium thiosulfate is c (S2O32-) = 0. 002 moldm-3 and the volume needed for the redox reaction is 3. 80 cm3 (see Table 7. 1) the amount in moles is calculated by the formulan (S2O32-) = c • V = 0. 002 moldm-3 • 3. 80 • 10-3 dm3 = 7. 60 • 10-6 moln (IO3-) = n (S2O32-) = • 7. 6 • 10-6 mol = 1. 27 • 10-6 molMoreover each trial was a 50 ml salt solution and since the 250 mL solution of 50 g of salt was spread in five equal Erlenmeyer flasks each contained 10 g of dissolved sodium chloride. The molar mass of potassium iodate which is the form in which iodine was present in both salts is M(KIO3) = 214 g mol-1. Hence the mass of potassium iodate is calculated by the formulam (KIO3; 10 g) = 1. 27 • 10-6 • 214 g mol-1 = 0. 272 mg

m (KIO3; 1000 g) = 27. 2 mg

If the amount in moles for potassium iodate and potassium iodide is the same than it follows that: n (KIO3) = n (KI)

=

m (KI) = Since molar mass of potassium iodide is M(KI)= 166 g mol-1 and molar mass of potassium iodate is M(KIO3) = 214 g mol-1: m (KI) = 0. 776 • m (KIO3)

m (KI) = 0. 776 · 27. 2 = 21. 1 mg per kilogram of salt

Error calculationErrors that have occurred during measurements are concerning salt solution preparation and sodium thiosulfate measurements. In first are involved balance (±0. 005 g) and uncertainty of flask (±0. 12 mL), while in former pipette (± 0. 05 mL) and burette (± 0. 1 mL). I will calculate both absolute and relative uncertainty with formula: Calculating average masses[18][See Appendix III for all other calculations]Result tables

Sea salt from Pag, Croatia

TriaIn (S2O32-)(10-6 mol)n (IO3-)(10-6 mol)m (KIO3; 10g)(mg)m (KIO3; 1000g) (mg)m (KI; 1000g)(mg)17. 601. 270. 272

27. 2

21. 1

27. 401. 230. 264

26. 4

20. 5

37. 601. 270. 272

27. 2

21. 1

47. 601. 270. 272

27. 2

21. 1

57. 601. 270. 272

27. 2

21. 1

Average7. 561. 260. 270

27. 0

20. 9

Table 7. 1: The results of the calculations made for five trials of the sea salt sample iodine determination

Rock salt from Tuzla, Bosnia and Herzegovina

Trialn (S2O32-)(10-6 mol)n (IO3-)(10-6 mol)m (KIO3; 10 g)(mg)m (KIO3; 1000 g) (mg)m (KI; 1000 g)(mg)18. 801. 470. 314

31. 4

24. 4

28. 601. 430. 306

30. 6

23. 7

38. 601. 430. 306

30. 6

23. 7

48. 801. 470. 314

31. 4

24. 4

58. 601. 430. 306

30. 6

23. 7

Average8. 681. 450. 309

30. 9

23. 9

Table 7. 2: The results of the calculations made for five trials of rock salt samples from Tuzla for determination of iodine

Error analysis, Rock and Sea salt

TrialSea salt from PagRock salt from Tuzlam (KIO3; 1000 g)(mg)Relative uncertainty (%)Absolute uncertainty(± mg)m (KIO3; 1000 g)(mg)Relative uncertainty (%)Absolute uncertainty(± mg)127. 22. 79

0. 759

31. 42. 43

0. 763

226. 42. 86

0. 755

30. 62. 48

0. 779

327. 22. 79

0. 759

30. 62. 48

0. 779

427. 22. 79

0. 759

31. 42. 43

0. 763

527. 22. 79

0. 759

30. 62. 48

0. 779

Table 7. 3.: The results of the error calculations made for five trials for sea and rock salt presented on mass of potassium iodate per kilogram of saltInterpretation of resultsFirstly, I will comment and analyse the volumes and masses of iodine in salt separately for the salt from Pag and for the salt from Tuzla, hence I will compare those two data sets. Furthermore I will also compare the obtained result with expectations and limits given by Croatian government and WHO. Table 6. 1. shows the consumption of thiosulfate in the process of redox titration. In the first part of the experiment I was identifying the amount of iodine content present in sea salt; island of Pag,

Croatia. Volumes of the 0. 002 mol dm-3 of thiosulfate were 3. 7 cm3 in one trial and 3. 8 cm3 in four other trials. The titration was performed five times since the Croatian legislation suggests that each salt analysis should be performed in five trials for one salt sample. Since the volumes of thiosulfate used are all in 0. 1 cm3 range I accept them as valid. After the calculations, it was found that the mass of potassium iodate present in the sea salt sample is between 26. 4 ± 0. 755 mg and 27. 2 ± 0. 759 mg. Both of this mass values are within limits given by both WHO[19]and Croatian legislation[20]. Thus, the sea salt present on Croatian market, has 27. 0 mg of potassium iodate per kilogram of salt meaning that a salt we're consuming has right mass of micronutrient needed to keep us healthy. This mass of potassium iodate, according to my calculations, corresponds with the 20. 5 mg and 21. 1 mg of potassium iodide per kilogram of salt which is within set limits. The other part of the experiment determines the iodate content in the rock table salt from Tuzla, Bosnia and Herzegovina which is the other, most occurring type of salt on our market. The volumes of thiosulfate presented in section 6 show that to react with all the iodate in solution it was necessary 4. 3 cm3 or 4. 4 cm3 of 0. 002 moldm-3 thiosulfate solution. In three out of five trials the volume of thiosulfate needed was 4. 3 and in two other the volume needed was 4. 4 cm3. The mean volume of thiosulfate is 4. 34 cm3. Since the results are within the range of 0. 1 cm3 I accept them as valid. After the calculations were done, it was shown that the iodate content present was 31. 4 ± 0. 763 mg per kilogram of salt in one case or 30. 6 ± 0. 779 mg of iodate per kilogram of salt in other case. The mean value of iodate mass is 30. 9 mg. By further calculations this masses of

potassium iodate correspond to 24. 4 mg and 23. 8 mg of potassium iodide per kilogram of salt. Once again these values are in the limits of legislation and are just good to keep people healthy. In comparison it can be seen that while titration of sea salt shows the masses of 27. 2 mg or 26. 4 mg per kilogram (on average 27. 0 mg), titration of iodized rock salt shows the masses of iodate present are 31. 4 mg or 30. 6 (on average 30. 9 mg) per kilogram of salt. The general trend here is that sea salt contains less iodate than rock salt from Tuzla. The package of the salt from Pag states that the amount of potassium iodate should be within limits of 25. 5 and 35. 5 mg per kilogram of salt. The algae and other living organism that not only contain iodine but also produce it are the reason why I taught that the iodate content will be higher for sea salt. The content of the salt of Tuzla states that the amount of potassium iodate present in the salt is equivalent to 20 – 30 mg of iodine. The reason why the companies that make salt are putting the ranges within the iodate level should occur is because of the principle the potassium iodate is added. While the sea salt is produced by evaporation of water on the outside, rock salt is produced by grinding halide crystals that have no iodine content at all. The potassium iodate is added in different stages of recrystallization which explains why there is no strict iodate value. Most importantly, the level of potassium iodate in salt is good and keeps us healthy. ConclusionFrom my results and calculations it can be clearly seen that the salt that is in common usage all around the Croatian market is regularly iodized. The average of 30. 9 mg of potassium iodate for rock salt from Tuzla and 27. 0 mg of potassium per kilogram of sea salt from island of Pag are within the limits set by authorities. The limits given by the World

Health Organization[21]suggest mass of 34 to 66 mg of potassium iodate per kilogram of salt. My masses are below that level, but are within Croatian legislation[22]that is much stricter saying that the iodized salt must have iodine content in the range of 20 to 30 mg of potassium iodide. By the calculations made, the both salts are within certain range. As an answer to my research question, the amounts of iodate in samples collected from Croatian market are within limits of both World Health organization and Croatian government regulations. This experiment showed that people shouldn’t worry and be afraid of illnesses like goitre, which happens as a result of iodine deficiency, or acne that happen as a result of iodine sufficiency. Normal, healthy and regular nutrition should obtain just enough amounts of micronutrients so none of the drastic measures should be taken to give the organism more or less of it, particularly iodine. EvaluationRandom errorA subjects to possible random errors are all the quantities and volumes of reactants used. However not all reactants carry an error. Firstly, potassium iodide and acid solutions that are of known concentration could bring an error, however they are added in excess so it doesn’t really matter. Furthermore, the starch indicator solution is also not important. The biggest random error occurring is ± 0. 005 g by the balance used to make salt solutions, ± 0. 1 mL by the burette used for the titration and the errors of the volumetric flasks (±0. 12 mL) and pipette (± 0. 05 mL) for preparation of salt solution.[23]The relative error varies from 2. 43 to 2. 86% which is quite small. When turned into absolute uncertainty, it correspond range of 0. 755 mg to 0. 779 mg. All measurements are within range less than ± 1 mg which is very good and accurate. Systematic errorThe method used for

determination of iodate in salt is limited in some ways. Firstly, it was assumed that in every Erlenmeyer flask were 10 grams of salt since sodium chloride dissolves completely as does potassium iodate. Some of the salt may have been lost while moving it from the balance into the 250 mL flask. The salt solution then reacted with potassium iodide in acidic area to produce the elementary iodine. In this step excess both iodide and acid was added since these don’t have an influence in the titration part. The solution was then titrated with thiosulfate solution c = 0. 002 moldm-3. The titration is quite precise method used widely, however there are some errors that appear. While adding the thiosulfate, the solution in flask has to be stirred, so there is the possibility that some of the thiosulfate remained on the walls of the flask and didn’t react with iodine but was spent on the account of the volume of thiosulfate used. The end-point of titration is determined by the change in colour; with using the starch indicator, the possibility of misjudging the colour at the end point was avoided. The other error is misreading the volume which can happen at any moment and due to whatever reason. To prevent influence of some remaining chemicals in burette, I washed it with distilled water and thiosulfate solution. The reason why the concentration of thiosulfate solution was c= 0. 002 moldm-3 was because the amount of iodate present in the salt is very small; less than 0. 5 mg per 10 g of salt. By this small concentration I avoided the problem of too strong reactant. Evaluation of sourcesThe majority of the literature used is reliable since those were the books and the articles posted by scientists. I also used some of the papers published by Croatian government and World Health organization. Some of the data used were from the internet, I mostly tried to

use as reliable as possible, but some of the statements may be questionable. Unanswered questionsDoing this extended essay I found a few questions that could extend the investigation. Firstly, I would like to further investigate and determine the iodate amount not only in most common products on the market but also some of the salts from other parts of the world. It would also be interesting to determine the iodine amount in the same type of iodized salt but bought from different stores to see if the iodine amount varies or stays the same. Furthermore, it would be interesting to use iodometry, as a method, to determine copper content, in some alloy for example, or to determine content of vitamin C in sample.