Top of the Bench 2024 Practical Challenge

WATER

Imagine the scene. You are swimming in the sea on a hot summers day. You exit the sea and lie on the sand in the sun. As you relax the sun dries your skin. You lick your lips. They taste salty. Why? Because sea water contains dissolved salt.

Salt is the chemical compound sodium chloride. Salt was used to preserve food in the days before refridgerators and freezers had been invented. Salt is also essential for ensuring our bodies can function.

The importance of salt has been recognised for thousands of years. The word '*salary*' means literally a payment in salt as was the custom in the Roman legions.

In this activity your team will:

- investigate how the solubility of a substance in water changes with temperature and see how this can be used to purify salt obtained from sea water.
- analyse a sample of salt that has had an additive added to help support public health.

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Investigation 1 – Investigating solubility

Introduction

Sodium chloride is obtained from sea water by evaporation and crystallisation.

Sea water is placed into shallow lakes. As the water evaporates the sodium chloride comes out of solution and forms crystals. The crystals rise to the surface and are collected.

The point at which the crystals form is determined by the solubility of the sodium chloride.

The solubility of a substance is the maximum mass of a substance that dissolves in a known volume of water.

The solubility of a substance changes as the temperature of the water increases.

In this part of the practical challenge, you will investigate how the solubility of an unknown substance, **substance A** changes with temperature.

You will then apply your results and compare the solubility of **substance A** with the solubility of **sodium chloride**.

Instructions

All results and answers should be written in the Answer booklet for Investigation 1.

A basic method for the investigation is given on the next page.

You should;

1. Read the method.
2. Carry out the practical.
3. Record the results in **Table 1**.
4. Follow the instructions to plot a solubility curve for **Substance A**.
5. Apply your results to obtaining sodium chloride from sea water.

Method

1. Fill a 250 cm^3 beaker to two thirds full with boiling water from the kettle. This is your **hot water bath**.

2. Place a mixture of ice and water in a second 250 cm^3 beaker. This is your **cold water bath**.

3. Carefully transfer exactly 5.0 g of **Substance A** into a boiling tube. Add exactly 10.0 cm^3 of distilled water.

4. Warm the boiling tube in the hot water bath until the solid dissolves.

5. Remove the boiling tube from the hot water bath and allow the solution to cool.

   To cool the solution below room temperature place the boiling tube in the cold water bath.

6. Note the temperature at which crystals first appear.

   Record this temperature to the nearest whole °C in **Table 1** in the **Answer booklet**.

7. Carefully add 1.0 cm^3 water to the solution in the boiling tube.

   Warm the solution again until all the solid dissolves.

8. Repeat the cooling and note the new temperature at which crystals appear.

9. Repeat steps 7 and 8 until the total volume of water is 15 cm^3.

10. To improve the accuracy of your results repeat steps 3-9.

11. Calculate a mean temperature at which crystals first form for each volume of water.

NOTE You may need to refresh the hot water in your water bath if the temperature drops.

Analysis

1. Complete **Table 2** in the results booklet.

   To calculate the solubility of **substance A** in g per cm^3 divide 5.0 g by the total volume of water it is dissolved in.

   Record the solubility to **2 decimal places**.

   The **crystallisation temperature** is the mean temperature at which crystals first appear.

2. A solubility curve is used to show how the solubility of a substance varies with temperature.

   Plot your results on the axes given in **Graph 1**.

   Draw a line of best fit.

   Label the line **Substance A**.

*Continue onto the next page to **apply** your results to the purification of sea salt.*

Application

A sample of sea water has been contaminated by **Substance A**.

Sea water contains sodium chloride.

The solubility of sodium chloride is given in **Table 3**.

Temperature in °C	**Solubility in g per cm^3**
0	0.36
20	0.36
40	0.36
60	0.37
80	0.38

Table 3

1. Plot the data in **Table 3** on **Graph 1**.

   Draw a line of best fit.

   Label the line **Sodium chloride**.

2. A solution of sea water containing equal quantities of **sodium chloride** and **Substance A** was evaporated at 25 °C.

   Predict whether **sodium chloride** or **substance A** would form crystals first.

   Use **Graph 1**.

   Give one reason to support your prediction.

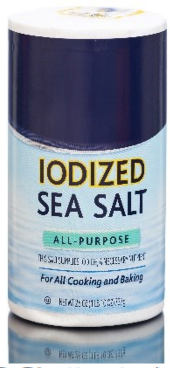
Investigation 2 – Analysing iodised salt

Introduction

Iodine is an important part of a healthy diet. It helps to make thyroid hormones, which keep cells and the metabolic rate (the speed at which chemical reactions take place in the body) healthy.

Most people can get all the iodine they need by eating a varied and balanced diet. However where this is not possible, one way to add iodine into your diet is by using iodised salt. This is salt which has iodate (IO_3^-) ions added.

In this activity you will analyse a sample of iodised salt to see if it meets Food standards for the amount of iodine added.



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Instructions

All results and answers should be written in the Answer booklet for Investigation 2.

An explanation of how the amount of iodine in a sample of salt can be determined is given on the next page followed by a basic method for the investigation.

You should;

1. Read the background and method carefully.
2. Carry out the practical.
3. Record the results in **Table 4**.
4. Follow the instructions to calculate the mass of iodine in the sample of iodised salt.
5. Conclude if the sample meets food standards.

Background

The amount of iodate, IO_3^- present in a sample can be determined by titration with sodium thiosulfate ($Na_2S_2O_3$) solution.

When iodate ions react with an excess of iodide in the presence of acid, the following reaction occurs:

$$IO_3^- + 5I^- + 6H^+ \rightarrow 3I_2 + 3H_2O$$

The iodine, I_2 produced in this reaction can then be titrated with sodium thiosulfate solution.

The iodine reacts with the thiosulfate ions according to the equation:

$$I_2 + 2S_2O_3^{2-} \rightarrow 2I^- + S_4O_6^{2-}$$

During the titration the thiosulfate ions react with the iodine. The brown colour of the iodine will fade to a straw/yellow colour as the iodine is used up. This colour change happens very near the end point of the titration.

To allow the end point to be observed accurately, 1 cm^3 of starch indicator are added to the conical flask. This turns the contents of the flask blue-black as the small amount of iodine still present reacts with the starch.

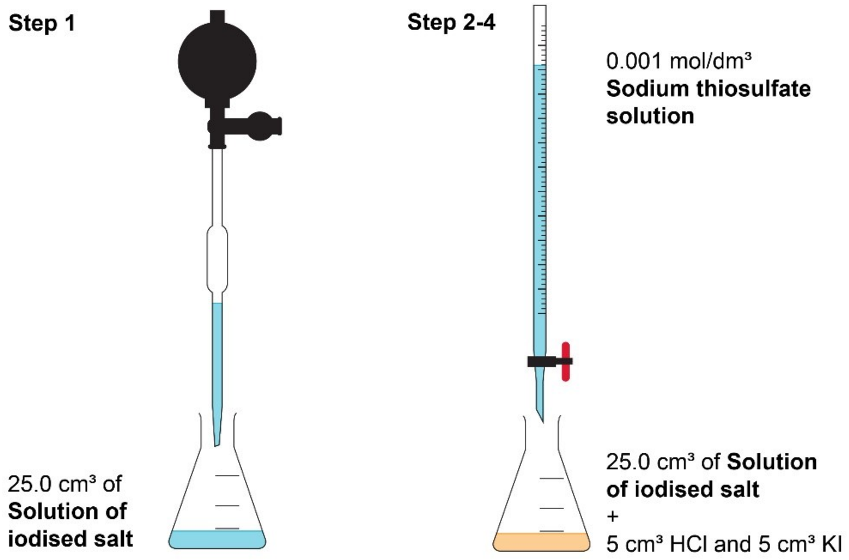
The titration is then continued until all the iodine just reacts with the sodium thiosulfate – this is the end point of the titration.

This is visible when the colour of the liquid in the conical flask changes from blue-black to colourless.

Method

You are provided with a solution containing 50.0 g of iodised salt dissolved in 250 cm^3 of water.

This is labelled **Solution of iodised salt**.



1. Rinse a 25.0 cm^3 pipette with the **Solution of iodised salt**.

   Use the pipette to transfer exactly 25.0 cm^3 of the **Solution of iodised salt** into a 250 cm^3 conical flask.

2. Add 5 cm^3 of hydrochloric acid and 5 cm^3 of potassium iodide solution to the conical flask using a measuring cylinder. Both are in excess so do not worry about accuracy here.

   The solution will turn a yellow/brown colour as iodine is produced.

   Place the conical flask on a white tile.

3. Rinse and fill a burette with **sodium thiosulfate** solution to the 0.0 cm^3 line.

   Record the initial burette reading as 0.0 cm^3 in **Table 4** in the answer booklet.

4. Add sodium thiosulfate solution from the burette to the solution in the conical flask until the yellow/brown colour becomes very pale.

5. Add approximately 1 cm^3 of starch indicator solution to the contents of the conical flask. This will produce a dark blue-black colour.

6. Continue to add the sodium thiosulfate solution until the blue-black colour completely disappears.

7. Record the final burette reading to the nearest 0.1 cm^3.

8. Calculate the volume of sodium thiosulfate solution added – the **titre**.

9. Repeat the titration until concordant titres (titres agreeing within 0.2 cm^3) are obtained.

NOTE Between runs you will not need to rinse the pipette or burette. Dispose of the contents of the conical flask as directed and rinse the conical flask with plenty of distilled water but do not worry about drying it.

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Answer Booklet – Investigation 1

School name: ____ **Score** ___________

Results

Volume of water in cm^3	Temperature at which crystals first form in °C			
	Run 1	Run 2	Run 3	Mean
10				
11				
12				
13				
14				
15				

Table 1

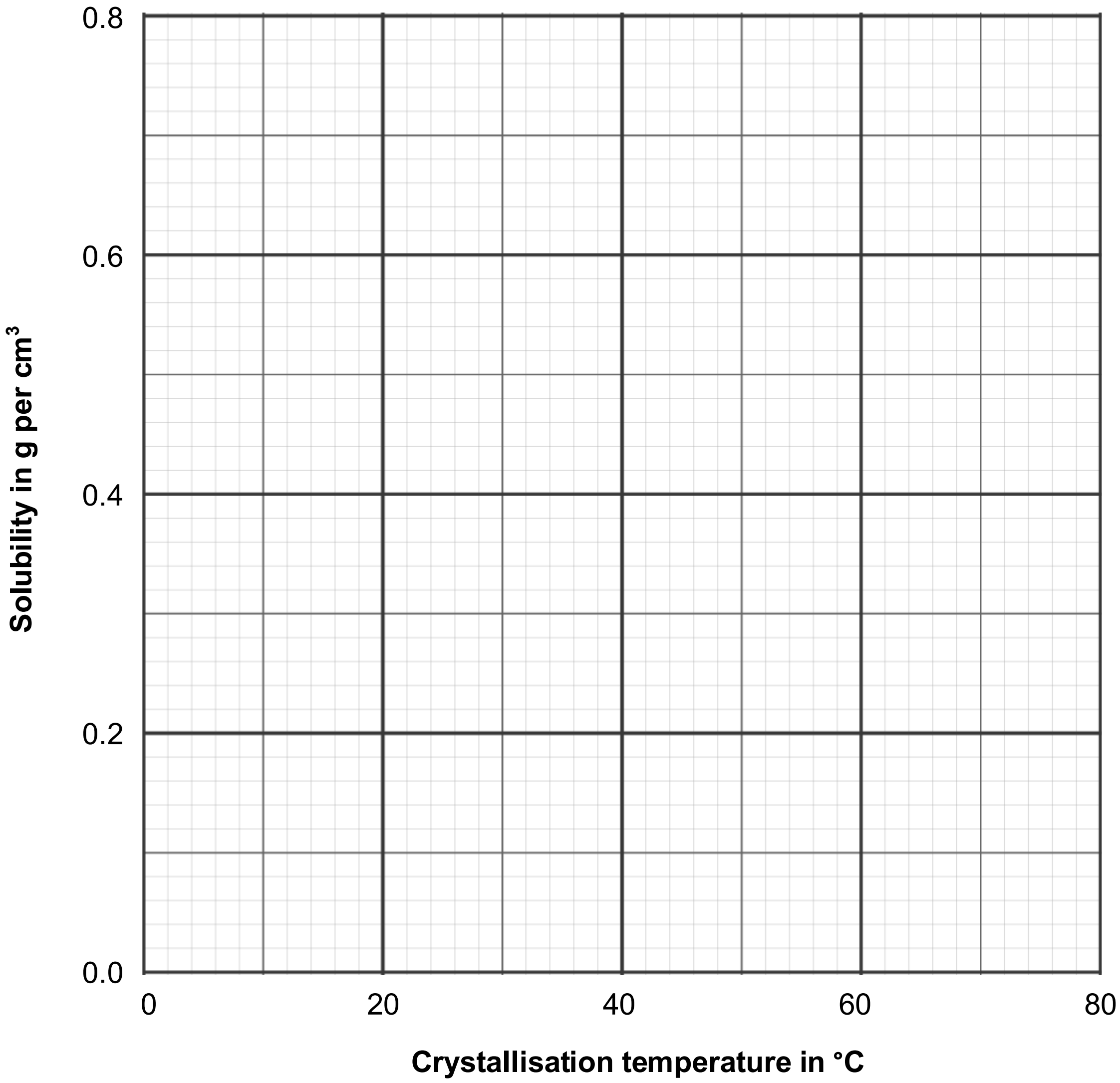
___ 3

Analysis

Volume of water in cm^3	Solubility in g per cm^3 *(5.0 g ÷ volume of water)*	Crystallisation temperature in °C
10		
11		
12		
13		
14		
15		

Table 2

___ 2



Graph 1

8

6

A solution of sea water containing equal quantities of **sodium chloride** and **Substance A** was evaporated at 25 °C

Predict whether **sodium chloride** or **substance A** would form crystals first.

Use **Graph 1**.

Give one reason to support your prediction.

Answer

The substance that would crystallise first is ______________________________

Reason ____

____

1

TOP OF THE BENCH 2024 PRACTICAL CHALLENGE

Answer Booklet – Investigation 2

School name: ____ **Score** ___________

Results

	Rough	Run 1	Run 2	Run 3	
Final burette reading in cm^3					
Initial burette reading in cm^3					
Titre in cm^3					

Table 4

___ / 10

Calculation

a. Circle the concordant titres on your results table (those within 0.2 cm^3 of each other)

___ / 1

b. Calculate the mean titre from your concordant titres.
If you did not get concordant titres calculate a mean titre ignoring any obvious anomalies.

Mean titre = __________ cm^3

___ / 1

c. Calculate the amount in moles of sodium thiosulfate in the mean titre.
Use amount in mol = concentration in mol/dm^3 × volume in dm^3

Amount of sodium thiosulfate in mean titre = ________________ mol

___ / 1

d. 2 mole of sodium thiosulfate ($S_2O_3^{2-}$) reacts with 1 mole of iodine (I_2).

$$I_2 + 2S_2O_3^{2-} \rightarrow 2I^- + S_4O_6^{2-}$$

Calculate the amount in mol of iodine in the conical flask during the titration.

Amount of iodine in the conical flask = ________________ mol

___ / 1

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e. The iodine (I_2) in the conical flask came from the reaction of the iodate (IO_3^-) in 25 cm^3 of the **Solution of iodised salt** with the hydrochloric acid and iodide ions added.

$$IO_3^- + 5I^- + 6H^+ \rightarrow 3I_2 + 3H_2O$$

1 mol of iodate (IO_3^-) produces 3 mol of iodine (I_2).

Calculate the amount in mol of iodate that reacted to produce the iodine in the conical flask.

1

Amount of iodate that reacted = __________ mol

f. The conical flask contained 25.0 cm^3 of the **Solution of iodised salt**.

Calculate the amount of iodate in 250 cm^3 of the **Solution of iodised salt**.

1

Amount of iodate in 250 cm^3 = __________ mol

g. One mole of iodate ions (IO_3^-) contains 1 mol of iodine atoms (I).

Therefore, the mass of iodine in the 50.0 g sample of iodised salt dissolved in the 250 cm^3 **Solution of iodised salt** can be determined by multiplying the amount in mol of iodate by the molar mass of iodine atoms (127 g/mol).

1

Mass of iodine in sample = __________ %

h. To meet food standards, iodised salt must contain '*equivalent to no less than 0.025 g and no more than 0.065 g of iodine per kilogram of iodised salt.*'

Use your results to determine if the sample of iodised salt analysed meets the Food standard.

Explain your answer.

Does the iodised salt meets food standards Yes / No

Explanation____

____

____

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