Cambridge Assessment International Education

Teaching Pack

Investigating salinity and the Freezing Point of Water

Cambridge International AS & A Level

Marine Science 9693

Version 1

Cambridge Pathway

Contents

Icons used in this pack:

Briefing lesson

Planning lesson

Lab lesson

Debriefing lesson

Introduction

This pack will help you to develop your learners' experimental skills as defined by assessment objective 3 (AO3 Experimental skills and investigations) in the course syllabus.

Important note
Our *Teaching Packs* have been written by **classroom teachers** to help you deliver topics and skills that can be challenging. Use these materials to supplement your teaching and engage your learners. You can also use them to help you create lesson plans for other experiments.

This content is designed to give you and your learners the chance to explore practical skills. It is not intended as specific practice for Paper 2 (AS Level Data-handling and investigative skills) or Paper 4 (A Level Data-handling and investigative skills).

This is one of a number of *Teaching Packs* and each pack is based on one experiment. The packs can be used in any order to suit your teaching sequence.

The structure is as follows:

Briefing lesson (1 hour*)
This lesson reinforces the key concepts, relevant skills, knowledge and understanding linked to the experiment.

↓

Planning lesson (1 hour*)
This lesson focuses on planning an experiment.
It ends with a demonstration video of the experiment.

↓

Lab lesson (2 hours*)
This lesson focuses on carrying out the experiment including the collection and recording of observations, measurements and estimates.

↓

Debriefing lesson (1 hour*)
This lesson focuses on the analysis and interpretation of data.
This includes making conclusions, evaluating methods and the quality of data and how improvements could be made.

** the timings are a guide only; you may need to adapt the lessons to suit your circumstances.*

In this pack you will find lesson plans, worksheets and teacher resource sheets.

Experiment: Salinity and the Freezing Point of Water

This *Teaching Pack* focuses on an experiment to investigate the effect of salinity on the freezing point of water.

This experiment has links to the following syllabus content (see syllabus for detail):

- 1.2.4 define the term salinity as the concentration of dissolved salts in sea water (note that the unit for salinity used in this syllabus is parts per thousand (ppt))
- 1.2.5 (PA) investigate the effect of salinity on the freezing point of water

The experiment covers the following experimental skills, as listed in **AO3: Experimental skills and investigations:**

- describe how to ethically and safely use techniques, apparatus and materials in an investigative context
- plan experiments and investigations
- present and display data and observations in suitable formats
- evaluate given experimental methods and the quality of data, and suggest possible improvements.

Prior knowledge

Knowledge from the following syllabus topics is useful for this experiment.

- 1.1.1 explain the changes of state in water, between solid, liquid and gas, in terms of the kinetic particle theory
- 1.2.1 explain the terms solute, solvent, solution and solubility
- 1.2.2 describe how soluble salts, such as sodium chloride, dissolve in water by the dissolution of ions
- 1.2.3 explain the effect of water temperature on the solubility of salts

Briefing lesson: Salinity and Diluting Solutions

Resources	• Worksheet A: Preparing solutions for a range of concentrations • Video: *Salinity and the freezing point of water* For each group: • Sodium chloride (solid granules) – allow at least 12.5 g per group • Distilled water • 500 cm^3 volumetric flask / 500 cm^3 measuring cylinder • 100 cm^3 measuring cylinder For the class: • Electronic balance(s) – accurate to at least 1 decimal place
Learning objectives	By the end of the lesson: • ***all*** learners should understand the term *salinity*. • ***most*** learners should be able to produce solutions of different salinities. • ***some*** learners will be able to systematically produce a series of solutions of different salinities.

Timings	Activity
10 min	**Starter/Introduction** To reinforce key terms, encourage learners to ask '*What's the question?*' when given an answer. Use Teacher Instructions 1 to run this activity, in which a range of single-word terms are provided.
10 min	**Main lesson** Introduce concentrations of solutions and different terms used to described concentrations: • Percentage • Molar • Salinity (ppt) Explain the use of salinity due to sea water containing a varying mixture of different dissolved salts, and the relative precision of ppt compared to percentage composition when people tend to round values to whole numbers. Ask learners what equipment could be used to measure volumes of liquids and discuss the precision of different pieces of equipment. Even if volumetric flasks and burettes/pipettes are not available (they are not listed as basic required equipment in the syllabus) it is useful for learners to be aware of them as they can reference more precise equipment when evaluating methods.
10 min	Use Worksheet A to explain to learners how to create a solution of a particular concentration (in this case a solution of 25 ppt salinity) and then create a series of solutions of different salinities from the 25 ppt solution. The first part of the video: *Salinity and the freezing point of water* can be viewed to demonstrate appropriate techniques for making up and diluting solutions, or this could be demonstrated by the teacher with the equipment learners have available.
20 min	Learners then practice making up and diluting solutions themselves to become more familiar with the method.

Plenary

Review how to make a solution of a particular salinity and ask learners to suggest what equipment and masses of salt should be used to make the following solutions:

- 1 litre of 40 ppt salt water (40.0 g);
- 250 cm^3 of 50 ppt salt water (12.5 g);
- 100 cm^3 of 20 ppt salt water (2.0 g).

Planning lesson: Planning to investigate the effect of salinity on freezing point

Resources	• Worksheet B: Planning an investigation into salinity and freezing point • Resource Plus Video: *Salinity and the Freezing Point of Water* • Resource Plus Video: *Designing Tables*
Learning objectives	By the end of the lesson: • ***all*** learners should be able to describe a safe plan describing how to measure the freezing point of solutions of different salinity. • ***most*** learners should be able to describe an appropriate method to produce solutions of different salinities and plan to collect a suitable range of results. • ***some*** learners will be able to describe a detailed plan describing how to produce a suitable range of solutions of different salinities, obtain repeat measurements to produce means results and how to present their results as a graph.

Timings	Activity
10 min	**Starter/Introduction** Pose the question: 'Does the salinity of water affect it's freezing point?' and ask learners to consider **two** possible approaches to measure the freezing point of different samples of water. Use the 'Think, Pair, Share' strategy to encourage learners to think about the question on their own and come up with ideas, then pair with a partner to discuss their ideas and possibly develop their answers further before sharing their ideas with the class. Each pair feeds back one idea to the group (many pairs will come up with similar approaches which is ok – the aim is to get learners thinking and consider more than one possible approach).
40 min	**Main lesson** Learners design a plan to change the salinity of water and measure the freezing point of the solutions they produce. Worksheet B will help learners organise their plans to ensure that they include: • What they will measure • How they will measure/collect the data • How many sets of data they plan to collect • What equipment they will need to complete their investigation • Identification of potential risks and plans to minimise the risks or identify steps to take should any incidents/changes occur – it is important if students are to carry out their own plans that you are confident their plans are safe. • A results table to record the data they plan to collect – see Resource Plus video: *Designing tables* for more support • How they plan to analyse the data they collect
10 min	**Plenary** Students swap plans with another student or group and give feedback on areas to improve their plans. Discuss any issues raised by students.

Lab lesson: Carrying out the plans

Resources	• Equipment identified by students in their plans
Learning objectives	By the end of the lesson: • ***a***ll learners should collect some results following a method • ***most*** learners should be able to collect sufficient results to be able to draw conclusions • ***some*** learners will be able to collect sufficient repeat data to calculate mean results

Timings	Activity
5 min	**Starter/Introduction** **Safety** Brief all learners on key safety points that all must follow while collecting their data. Ask learners if they have any questions about the safety instructions to check everyone understands. Give learners an opportunity to review their plans before starting. Distribute equipment to learners as necessary to complete their plans.
5 min	
100 min	**Main lesson** Learners follow their plans and collect data. **Safety** Circulate the working area at all times during the lab work so that you can make sure that your learners are safe and that the data they are collecting is accurate.
10 min	**Plenary** Gather learners back together and check for problems and that all equipment is tidied away. Discuss any immediate issues or problems that learners have faced collecting their data.

Teacher notes

Watch the *Salinity and the freezing point of water* video (teacher version) and read these notes.

Each group will require:

- Distilled water
- Salt (sodium chloride)
- Measuring cylinders or burettes to measure different volumes
- Beakers or small volumetric flasks to make their diluted solutions in
- Plastic beakers or cups to freeze solutions in (if using disposable cups please re-use these as much as possible)
- Glass stirring rod
- Card (to hold the probes in place)
- Temperature probes

The class will require access to:

- Freezer
- Electronic balance (to at least 1 decimal place)

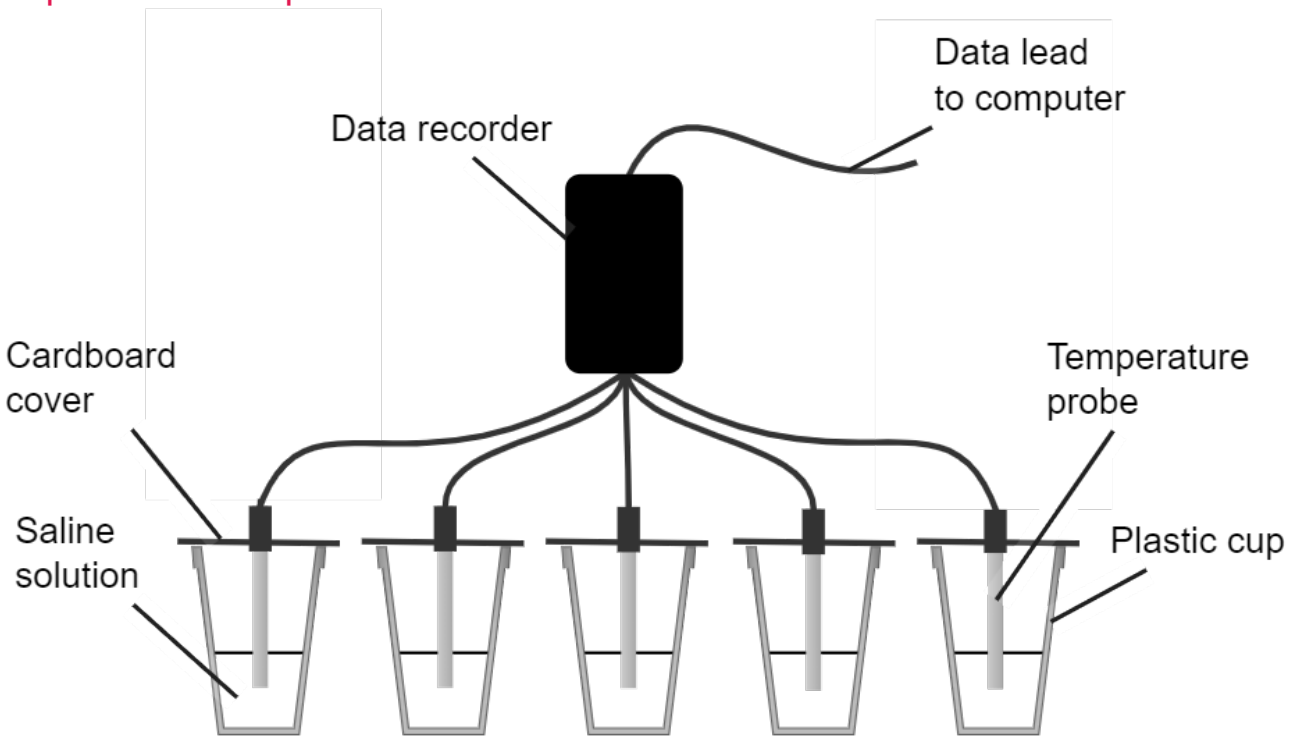
Safety

To avoid cross contamination, do not use a freezer which contains food for human consumption.

Note that glass will shatter in a freezer, so always use plastic containers.

It is your responsibility to carry out an appropriate risk assessment for this experiment.

Experiment set-up



Teacher method

This is your version of the method for this experiment that accompanies the *Teacher walkthrough* video.

Do not share this method with learners until after they have planned their own methods.

Before you begin

Plan how you will group your learners during the experiment session.

Think about:

- the number of groups you will need (group size 2–4 learners)
- the amount of equipment required

Method

1. Add approximately 800 cm^3 of distilled water to a 1000 cm^3 measuring cylinder.
2. Weigh 40.0g of salt using an electronic balance.
3. Add the 40.0 g of salt to the water in the measuring cylinder and mix until the salt fully dissolves.
4. Top up the volume of the solution to 1000 cm^3 with more distilled water and mix thoroughly. This can be poured into a large beaker or other container. Label this solution 'Saline Solution 40 ppt'.
5. From this stock solution four further solutions of different salinities will be produced: Measure 75 cm^3 of the stock 40 ppt solution using a 100 cm^3 measuring cylinder, then top up to exactly 100 cm^3 with distilled water. Mix well and pour this solution into a plastic beaker or cup and label 'Saline Solution 30 ppt'.
6. Repeat step 5 two more times by diluting the stock solution as shown in the table below to produce concentrations of 20 ppt and 10 ppt.

Concentration / ppt	Volume of 40 ppt solution / cm^3	Volume of pure water / cm^3
40	100	0
30	75	25
20	50	50
10	25	75
0	0	100

7. Measure 75 cm^3 of distilled water in a 100 cm^3 measuring cylinder, pour it into a plastic beaker or cup and label it 'Saline Solution 0 ppt'.
8. Place each cup on a tray ready to be placed into the freezer.
9. Cut some card to cover the top of each cup, pierce a hole through the middle large enough to push through a temperature probe.
10. Push the temperature probes through the card and position them so that they sit in the middle of the solution without touching the sides or the bottom of the cup. The hole should be a tight fit on the probe wire so that it can be positioned accurately within the cup.
11. Connect each temperature probe to the data logger.
12. Start the data logger and place the tray of cups into the freezer.
13. Check the temperatures on the data logger – when all solutions have reached at least -5 ^oC the data logger can be stopped.
14. Repeat each set of readings two more times if time allows.

Alternative Lab lesson: Virtual experiment

Resources	• Resource Plus Video: *Designing Tables* • Resource Plus Video: *Salinity and the freezing point of water* • Copy of teacher method handout • Worksheet C: Example results • Worksheet C Answers: Completed results table
Learning objectives	By the end of the lesson: • ***a***ll learners should measure freezing points related to the video • ***most*** learners should be able to measure sufficient data to be able to draw conclusions • ***some*** learners will be able to calculate mean temperatures for the freezing point of each salinity and identify if there are any anomalies

Timings	Activity
20 min	**Starter/Introduction** Go through the teacher method handout with the learners and discuss the method. Learners construct a results table to record the data, these should include columns to record repeats and mean values. See video: to remind students if necessary,
15 min 15 min	**Main lesson** Watch the video in full detailing the process. Hand out worksheet C (Example results) and discuss how learners can use the cooling curves to identify the freezing point for each solution tested. Discuss the curves on the worksheet – the temperature drops and then significantly increases and levels off for the remaining time, discuss with learners what this tells us about the freezing point (the water is supercooled before it freezes – the temperature rises rapidly as the water freezes, releasing latent heat and then maintains a constant temperature until the water has all frozen). Learners complete their results table by analysing the cooling curves on worksheet C and calculating means for each concentration.
10 min	**Plenary** Hand out worksheet C Answers (Completed results table) – ask learners to compare their data with the table provided and suggest reasons for any differences. Learners could also compare their results with those from others/other groups in the class. Differences may be due to cooling curves that don't produce distinct levelling off. If the curves do not produce flat sections indicating freezing this may be due to the presence of a fan circulating air in the freezer, or repeatedly opening the freezer door during the experiment.

Debriefing lesson: Interpreting results

Resources	• Results from lab lesson / alternative lab lesson • Graph paper • Resource Plus Video: *Drawing Graphs*
Learning objectives	By the end of the lesson: • ***all*** learners should produce a graph of their results • ***most*** learners should be able to produce a line graph of their results and evaluate the reliability of their data • ***some*** learners will be able to suggest improvements to their method and how they might confirm their findings

Timings	Activity
10 min	**Starter/Introduction** Recap from lab lesson and check learners have their data/results. Discuss how the data can be analysed – learners should have planned how they will process their data.
10 min	**Main lesson** Watch the video: *Drawing Graphs* and discuss the most appropriate type of graph for the data they have collected.
15 min	Learners process the data by line graphs using the data they have collected.
15 min	Learners make conclusions about their findings and evaluate their method to establish any potential improvements they could make to improve the quality of their results.
10 min	**Plenary** Discuss outcomes and compare conclusions – if any groups do not achieve an obvious trend in their results, ask them to share their suggestions with the class where they think they went wrong, and how they could improve their method.

Worksheets and answers

	Worksheet	Answers
For use in *Briefing lesson*:		
Teacher instructions 1: What's the question?	**15**	
A: Preparing solutions for a range of concentrations	**16**	
For use in *Planning lesson*:		
B: Planning an investigation into salinity and freezing point	**20**	
For use in *Virtual Lab lesson*:		
C: Example results from Salinity and Freezing Point video	**21**	**22**

Teacher instructions 1: What's the question?

Use this worksheet with the briefing lesson: Salinity and Diluting Solutions

In this activity, pose questions 'in reverse' to learners. Give them a series of answers and then challenge them to suggest a question for which the answers could be given. This engages learners in higher-order thinking skills.

Examples should focus on the topics relevant to the upcoming topic, including populations and communities. Three examples are provided below.

Answer to provide to learners	Suggested question
Solute	*'What is the term used to describe a solid that is being dissolved?'*
Solvent	*'What is the term used to describe the liquid in which a solid is dissolved?'*
Solution	*'What is the term used to describe a mixture of a solid dissolved in a liquid?'*

Worksheet A: Preparing solutions of a range of concentrations

Use this worksheet with the briefing lesson: Salinity and Diluting Solutions

It can be useful to prepare a series of solutions of different concentrations with regular differences between each concentration.

Key Terms

Key Word	Description
Solute	*The solid being dissolved*
Solvent	*The liquid being used to dissolve a solid*
Solution	*A mixture of the solute dissolved in a solvent*

Measuring concentration

There are several different ways of describing concentration.

Percentage Solutions

This is the mass of solute (in grams) dissolved in 100 g / 100 cm^3 of solution.

e.g. 3 g of starch is dissolved in 100 g of water to make a 3 % starch solution.

Molar Solutions

One mole of a compound is the relative formula mass (RFM) of the compound in grams.

e.g. Ammonium nitrate has a RFM of 80. One mole of ammonium nitrate therefore has a mass of 80 g.

The concentration of a solution in moles is the number of moles of solute dissolved in a litre of solvent.

e.g. 80 g of ammonium nitrate dissolved in 1 litre of water make a 1 mole per litre solution.
20 g of ammonium nitrate dissolved in 1 litre of water makes a 0.25 moles per litre solution.

Salinity

Salt water usually contains many different chemicals, so molar concentrations are not appropriate to use. We could use percentages to describe solutions of salt water, but many people tend to round percentages to whole numbers – the typical percentage of sea water is 3.5 %, rounding this to 4 % would suggest a significant change to the actual amount of salts dissolved in the solution.

We use parts per thousand (ppt) to describe salinity to allow us to see smaller changes in salinity between solutions. This is the mass in grams of solute(s) dissolved in 1 litre (1000 cm^3) of solution.

Sea water typically has a salinity of 35 ppt.

Preparing and diluting a series of solutions

In the following activity you will prepare a set of solutions of different concentrations.

The aim is to produce 100 cm^3 of five concentrations of salt water:

- 5 ppt
- 10 ppt
- 15 ppt
- 20 ppt
- 25 ppt

Possible methods:

1. Dissolve the appropriate amount of salt directly into 100 cm^3 water.

   This would require 0.5 g for the lowest concentration (5 ppt) – this is a small mass to measure and will produce less accurate results.

2. Dissolve the appropriate amount of salt into 1000 cm^3 water.

   This will require 5.0 g for the lowest concentration (5 ppt) – this will be more accurate but 90 % of each solution is not required so this is very wasteful.

3. Prepare a stock solution of the highest concentration and dilute this to produce the other concentrations.

   This requires 25.0 g of salt to produce 1000 cm^3 for the highest concentration (25 ppt) – this can then be diluted to different concentrations. 1000 cm^3 will still be much more than we need.

The following table shows how much of the stock solution and pure water will be needed to produce 100 cm^3 of each concentration:

Concentration / ppt	Volume of 25 ppt solution / cm^3	Volume of pure water / cm^3
25	100	0
20	80	20
15	60	40
10	40	60
5	20	80

From the table we can add the total volume of 25 ppt solution we need to make: 100 + 80 + 60 + 40 + 20 = 300 cm^3. We should make slightly more than this to ensure we have enough in case of any mistakes when diluting our solutions so 500 cm^3 would be a suitable volume of 25 ppt salt water solution to produce.

500 cm^3 is half of one litre, so we need half the mass of salt (25.0 g divided by two) = 12.5 g.

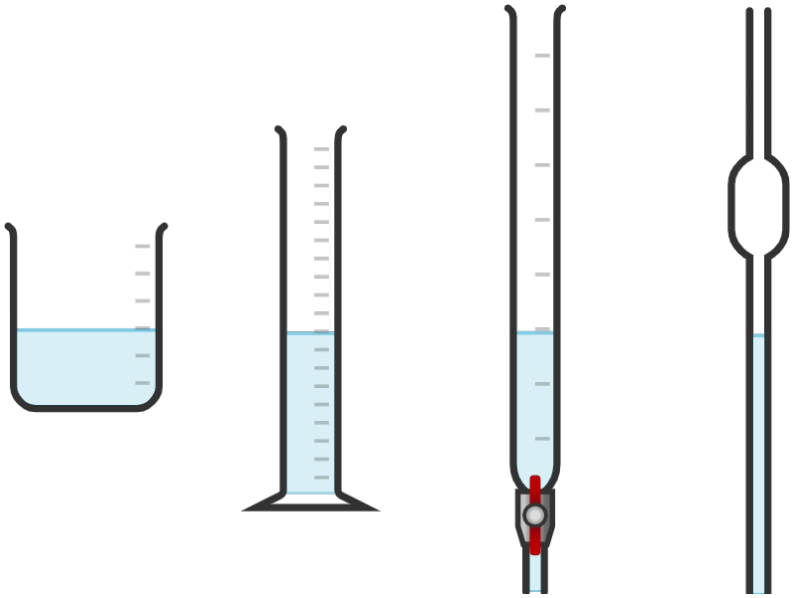
This approach is precise enough to produce accurate solutions and results.

The next important factor is the choice of equipment used to measure the mass of salt used, and the volumes of water and solutions.

Mass is measured using an electronic balance – the precision of the balance is important to measuring the mass of salt precisely. To measure 12.5 g we need a balance that measures to at least 1 decimal place.

Volume can be measured in a range of equipment such as:

- Beakers
- Measuring cylinders
- Burettes / pipettes



Burettes and pipettes are the most precise, but these are usually limited to 50 cm^3.

A 100 cm^3 measuring cylinder would be appropriate for the measurements we are making.

A 500 cm^3 volumetric flask would be the best apparatus to make the stock solution, but a 500 cm^3 or 1000 cm^3 measuring cylinder would be acceptable.

Equipment

- 500 cm^3 volumetric flask and stopper (or measuring cylinder)
- Electronic balance (accurate to at least 1 decimal place)
- 100 cm^3 measuring cylinder
- Sodium chloride (solid)
- Distilled water

Method

1. Pour approximately 400 cm^3 distilled water into the volumetric flask or measuring cylinder.
2. Use an electronic balance to weigh 12.5 g sodium chloride
3. Add the 12.5 g sodium chloride to the water in the flask/measuring cylinder and gently swirl or stir until fully dissolved.
4. Top up the solution to exactly 500 cm^3.
5. Swirl the solution to mix thoroughly. **This is the stock 25 ppm solution**.

Use a 100 cm^3 measuring cylinder and the stock 25 ppm solution to make up the other solutions as follows:

6. Pour 80 cm^3 of the stock 25 ppm solution into the measuring cylinder.
7. Top up with 20 cm^3 distilled water to produce 100 cm^3 of concentration 20 ppm.
8. Repeat steps 6 and 7 for the other concentrations, using the measurements in the table below.

Concentration / ppt	Volume of 25 ppt solution / cm^3	Volume of pure water / cm^3
25	100	0
20	80	20
15	60	40
10	40	60
5	20	80

Worksheet B: Planning an investigation into salinity and freezing point

Use this worksheet with the planning lesson: Planning to investigate the effect of salinity on freezing point

When planning an investigation, you should consider what you are trying to find out and how you can achieve that.

The first question is what is the hypothesis or question being investigated? This should clearly identify variables. For an investigation into the effect of salinity on freezing point the hypothesis should relate a change in salinity of the water to the temperature the water freezes at, such as: 'The salinity of a sample of water affects the freezing point of the water'.

Once your hypothesis has been established you can begin to plan how to carry out the investigation and collect data.

Some key questions to consider include:

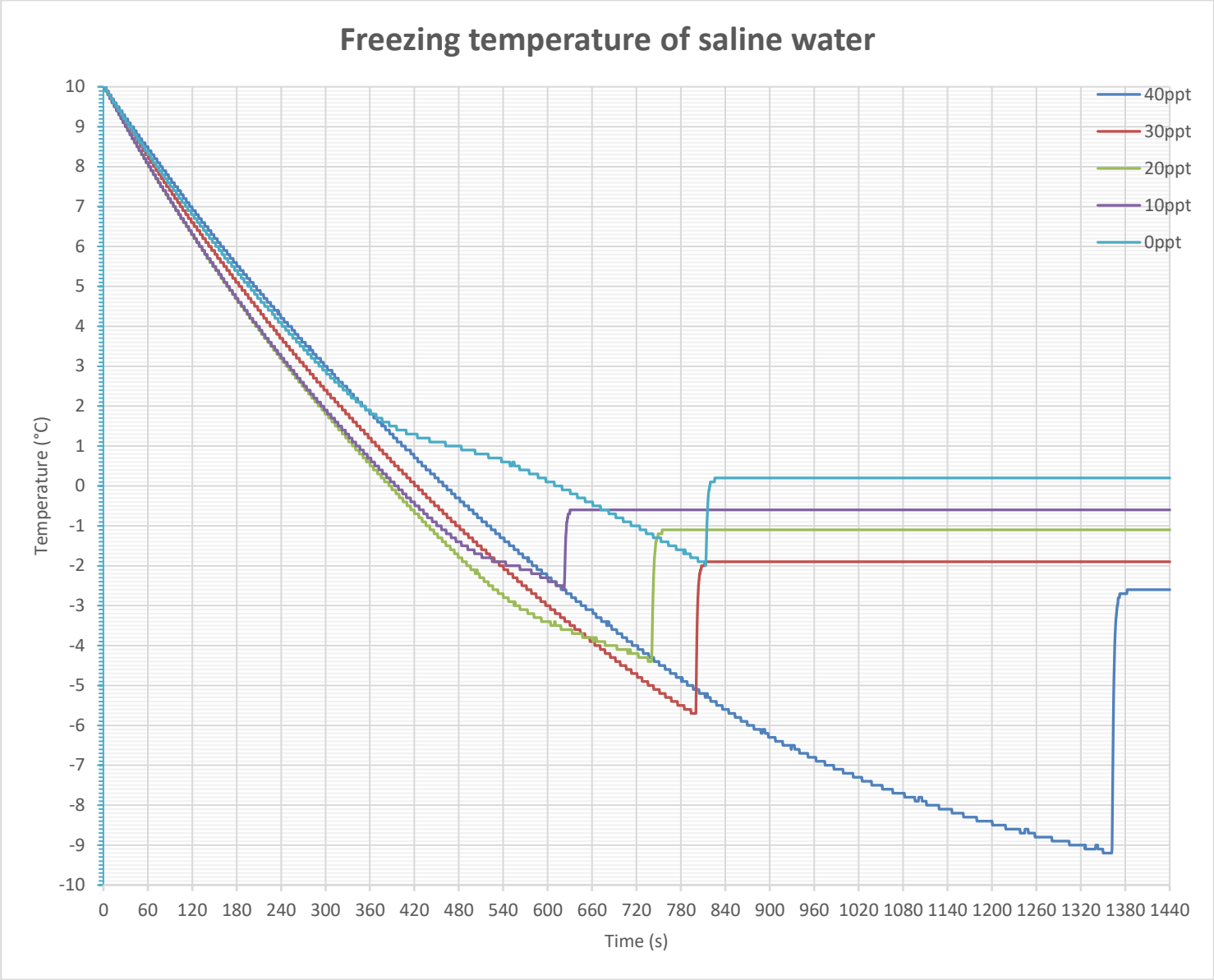
- What will you measure?
    - This should be linked to the hypothesis, i.e. the freezing point of each water sample.
    - How will you change the salinity of the samples of water?
- How will you measure/collect the data?
    - What equipment will you need to make the measurements?
    - Is the chosen equipment precise enough?
- How many sets of data do you plan to collect?
    - What range of salinities will you use (maximum and minimum salinities)?
    - How many different salinities will you test?
    - What will the intervals be between salinities?
    - Will you repeat the experiment for each salinity?
- Identification of potential risks and plans to minimise the risks or identify steps to take should any incidents/changes occur.
    - What could go wrong?
    - What risks are there?
    - How can you reduce the risk of these occurring?
    - What will you do if it did occur?
- What equipment do you need to complete your investigation?
    - Equipment for diluting and measuring
    - Equipment for recording freezing points
    - Safety equipment
- Design a results table to record the data you plan to collect
    - see the video on ***Designing tables***
- How do you plan to analyse the data you collect?

Worksheet C: Example Results

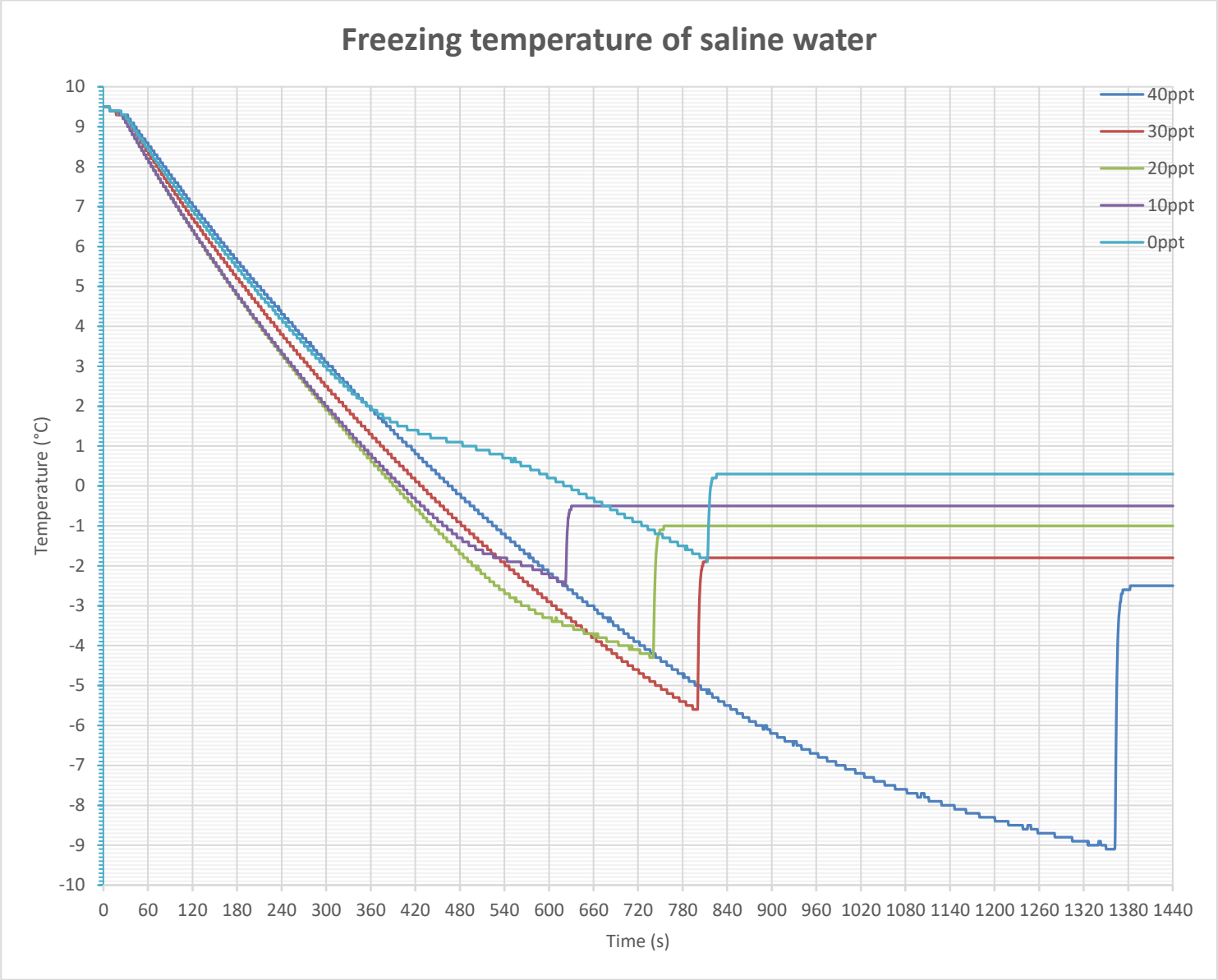
Use this worksheet with the Virtual Lab lesson

A sample set of cooling curves are provided below for the experiment shown in the video.

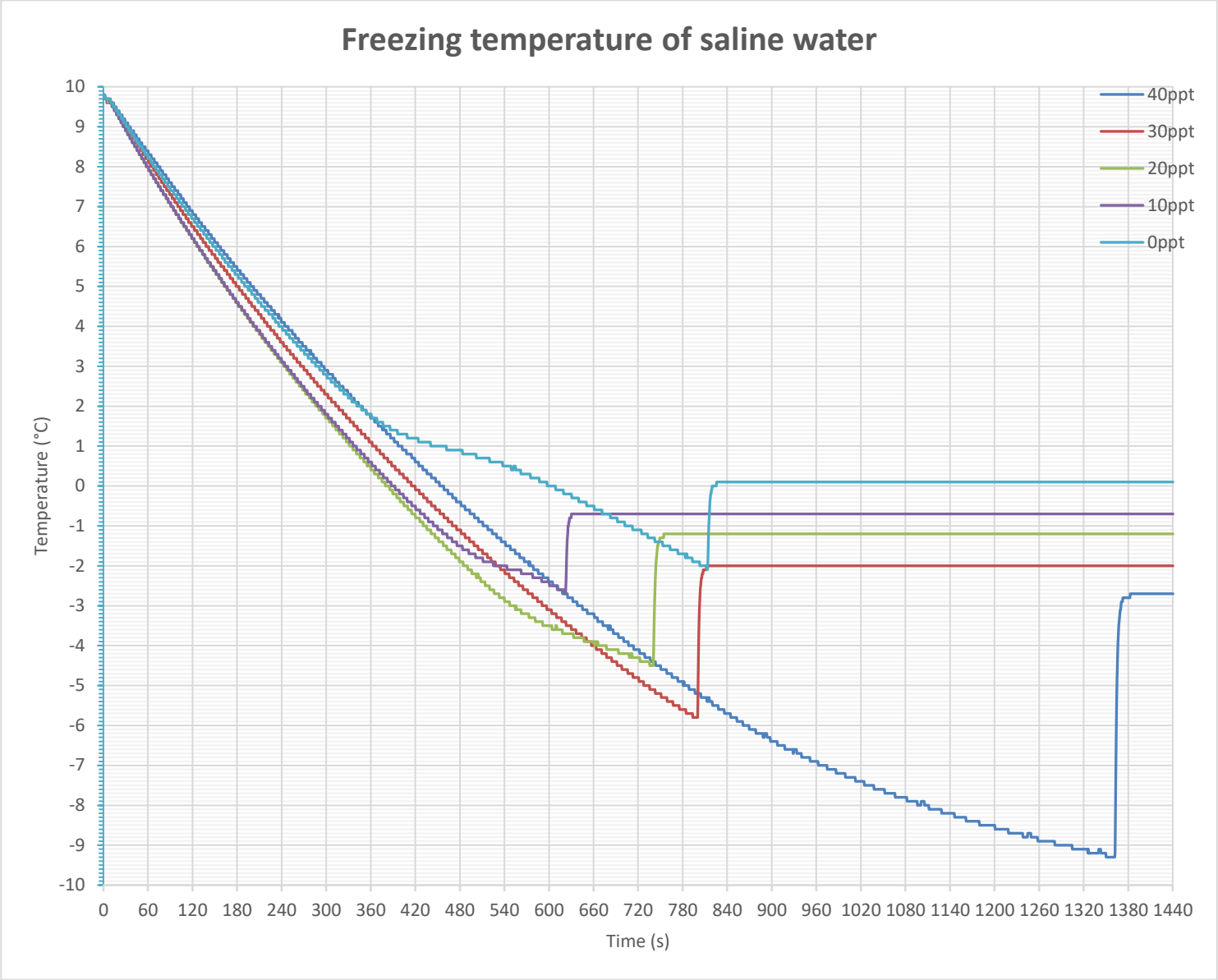
Run 1


Freezing temperature of saline water
Temperature (°C)
10
9
8
7
6
5
4
3
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
0 60 120 180 240 300 360 420 480 540 600 660 720 780 840 900 960 1020 1080 1140 1200 1260 1320 1380 1440
Time (s)
40ppt
30ppt
20ppt
10ppt
0ppt

Run 2


Freezing temperature of saline water
Temperature (°C)
10
9
8
7
6
5
4
3
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
0
60
120
180
240
300
360
420
480
540
600
660
720
780
840
900
960
1020
1080
1140
1200
1260
1320
1380
1440
Time (s)
40ppt
30ppt
20ppt
10ppt
0ppt

Run 3


Freezing temperature of saline water
Temperature (°C)
10
9
8
7
6
5
4
3
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
0 60 120 180 240 300 360 420 480 540 600 660 720 780 840 900 960 1020 1080 1140 1200 1260 1320 1380 1440
Time (s)
40ppt
30ppt
20ppt
10ppt
0ppt

Worksheet C Answers: Completed results table

Concentration / ppt	Freezing point / °C			
	Run 1	Run 2	Run 3	Mean
40	-2.6	-2.5	-2.7	-2.6
30	-1.9	-1.8	-2	-1.9
20	-1.1	-1	-1.2	-1.1
10	-0.6	-0.5	-0.7	-0.6
0	0.2	0.3	0.1	0.2

Cambridge Assessment International Education
The Triangle Building, Shaftesbury Road, Cambridge, CB2 8EA, United Kingdom
t: +44 1223 553554
e: info@cambridgeinternational.org www.cambridgeinternational.org