NATIONAL QUALIFICATIONS CURRICULUM SUPPORT

Chemistry

Researching Chemistry: Planning and Carrying Out an Investigation

Student's Guide

[HIGHER]

Learning
+Teaching
Scotland

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Introduction for teachers

Outcome 2 of the Researching Chemistry unit of the revised Higher Chemistry requires students to demonstrate that they can 'effectively plan and carry out investigative practical work relating to a topical issue in chemistry'.

Despite the skill of effective planning being essential for life, learning and work, there is very little in the way of formal resources to support teachers and students with the development of this skill within an investigative scientific context.

The purpose of this resource is to allow students to consider the essential stages involved in planning a scientific investigation at Higher Chemistry level, and then to actively develop their own planning skills by completion of a number of focused exercises and activities set in a researching chemistry context. It is hoped that completion of the range of tasks within this resource prior to undertaking independent investigative work will allow students to have an increased appreciation of the importance of planning in advance before carrying out practical activities within a science laboratory.

Students could work through this resource independently or as part of a pair or a small group, although regular opportunities for whole class discussion and reflection are recommended throughout the activity.

Answers to questions and other activities are contained at the end of the resource.

Student's guide

Planning a scientific investigation

Planning is an essential skill for life, learning and work. Effective planning enables priorities to be dealt with in a controlled manner instead of simply reacting to things as they come along. Planning ahead enables good organisation and saves time, effort and resources.

The ability to plan effectively will also be crucial when undertaking your scientific investigation during the Researching Chemistry unit of Higher Chemistry. Indeed, in order to achieve Outcome 2 of this unit you must show that you can 'effectively plan and carry out investigative practical work relating to a topical issue in chemistry'.

Planning a scientific investigation can be a daunting prospect, however. Where should you start? What are the planning priorities? Which technique should you use? What apparatus and chemicals will be required? How can you ensure the safety of yourself and others during the practical aspects of the investigation?

This resource pack will help you to develop the skills of effectively planning a scientific investigation at Higher Chemistry level. By completing the exercises and activities within the pack, you will develop the skills and confidence to enable you to:

- think of an investigation in terms of a number of key stages
- identify the key stages in planning and carrying out a scientific investigation
- select the appropriate practical technique(s) and apparatus for a particular procedure
- recognise that there are always significant safety risks when carrying out scientific procedures that must be taken into account in the planning stages
- appreciate the importance of planning before starting the experiment.

Identifying the key stages

What are the key stages involved in effectively planning and carrying out a scientific investigation? Let's try to work them out by first identifying the key stages in a more familiar procedure – making a cup of tea!

Exercise 1: Planning and carrying out an everyday procedure

You can probably make a cup of tea without really thinking about the stages involved. However, imagine you need to write a list of instructions for someone who has *never* made a cup of tea before.

(a) Write down a list of the key stages involved in making a cup of tea. You have 1 minute to complete this task!

Compare your list with those of the others in your group. Have you all written the same steps? Have any important steps been missed out? Are some steps not always required? What does this tell you about the importance of planning ahead?

(b) The table below shows the stages involved in making a cup of tea. Number these stages in the order in which they should be carried out to successfully make a cup of tea.

Decide to have a cup of tea	Put water in kettle
Turn on tap	Get out the sugar
Stir with teaspoon	Switch on kettle to boil water
Get out the cup	Get out the teabag
Get out the teaspoon	Add sugar
Get out the milk	Turn off tap
Add boiling water to cup	Leave for 2 minutes
Wash dishes	Put teabag in cup
Tidy up	Add milk
Drink tea	Remove teabag with teaspoon
Put teabag in bin	Put teaspoon in cup

Compare your list with those of others in your group and discuss the questions below. Are there any variations in the order in which you would carry out the stages? Are some of the stages not required in every case? Would the order be dependent on the location in which you are making the cup of tea? Which method makes the most effective use of time and resources? Could you group any of the stages together to save time? Why is it important to plan ahead when carrying out a complex procedure?

An everyday procedure such as making a cup of tea can be summarised as a series of stages. The more complicated process of planning and carrying out a scientific investigation can also be broken down into a similar series of stages.

Exercise 2: Planning and carrying out an investigation

The stages involved in making a cup of tea could be grouped into the broad categories listed in the table below.

Fill in the blanks to show the equivalent categories involved when planning and carrying out of a scientific investigation.

Making a cup of tea	**Scientific investigation**
Decide to have a cup of tea	
Source ingredients	
Collect kitchen equipment	
Make tea	
Drink tea	
Tidy up	

Assessing the safety risk

A crucially important part of the planning process for any everyday procedure involves assessing how to safely carry out the procedures involved. For example, when making a cup of tea it is important to take precautions to ensure that water and electricity are kept apart, and to avoid spilling boiling water on your skin.

Each chemical you plan to use in your investigation will have an associated risk. This risk will be described on the **hazard warning label** on the chemical. The use of hazard symbols is regulated by law, and the symbols used are internationally agreed.

Exercise 3: Understanding hazard warning labels

The table below contains a number of hazard warning labels. Use the internet or look up a chemical catalogue to help you identify which hazard is represented by each warning label.

Warning label	Hazard
	
	
	
	
	
	
	
	

Note: Some chemicals are too hazardous to be used in schools, therefore not all of these warning labels will be found in your chemistry laboratory!

Once the hazards associated with a particular chemical have been identified, a **risk assessment** must be carried out. The risk assessment allows appropriate precautions to be put in place to allow the chemical to be handled safely.

Note: It is appropriate to **wear safety glasses at all times** when handling chemicals.

Exercise 4: Risk assessment

Complete the table below to identify the precautions that should be taken in order to safely carry out each laboratory situation.

Laboratory situation	**Precaution(s) required**
Pouring a corrosive chemical	
Weighing out a toxic chemical	
Heating a reaction mixture involving a flammable reactant	
A chemical reaction for which one of the products is a toxic gas	
Disposal of chemical waste which is harmful to the environment	

Note: The safety precautions required for each experiment and investigation will be different. If you are in any doubt whatsoever about the safety procedures required for your investigation, make sure you speak to your teacher *before* you start practical work!

Identifying practical techniques and equipment

A crucial stage in planning a scientific investigation is to identify the most appropriate practical technique to allow you to safely carry out your experiment.

Exercise 5: Common laboratory techniques

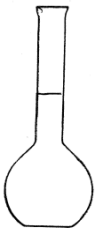
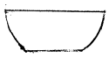
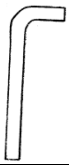
Match up each laboratory technique in the table below to its most appropriate use.

Technique	**Use**
Filtration	Weighing out chemicals
Heating using a water bath	Determining the concentration of a solution
Distillation	Heating an aqueous solution rapidly to 60°C
Use of balance	Separating a mixture of liquids
Heating using a Bunsen burner	Collecting a gas that is insoluble in water
Use of a gas syringe to collect a gas	Separating a solid from a liquid
Titration	Heating a flammable liquid to 120°C
Collecting a gas over water	Maintaining an enzymatic reaction at 37°C
Heating using a heating mantle	Collecting a water-soluble gas

Having identified the most appropriate technique for a particular scientific investigation, apparatus must then be selected to allow that technique to be carried out effectively and safely.

Exercise 6: Identifying appropriate apparatus

Name the pieces of apparatus in the table below. Do you know what each one is used for?

Apparatus			
Name			
Apparatus			
Name			
Apparatus			
Name			
Apparatus			
Name			

The importance of planning ahead

Planning ahead is essential for safe and effective practical experimentation in chemistry. For example, some of the stages required to successfully carry out an experimental procedure may be implied, rather than explicitly written in the text. Consider the following procedure for testing solubility:

The solubility in water of ammonium sulfate, potassium nitrate, sodium nitrate, calcium phosphate and ammonium phosphate was tested by adding a spatula of each compound to 10 cm^3 of water. The results for each compound were recorded as soluble or insoluble.

This procedure could be broken down into simpler stages to assist with planning. For example:

1. Place five test-tubes in a test-tube rack.
2. Pour 10 cm^3 of water from a measuring cylinder into each test-tube.
3. Add a spatulaful of ammonium sulfate to one of the test-tubes.
4. Gently agitate the test-tube to identify whether or not the ammonium sulfate dissolves.
5. Record whether the ammonium sulfate is soluble or insoluble.
6. Repeat steps 3 to 5 for each of the remaining compounds.

Exercise 7: Why is planning ahead essential?

Answer the questions below in discussion with a partner.

1. Which of the stages in the list of instructions above were *not* specifically mentioned in the original experimental procedure?

2. What types of issues could arise during practical work if proper planning has not been carried out in advance?

Exercise 8: Making a detailed plan from an experimental procedure

Consider the following procedure for separating salt from rock salt.

Five spatulafuls of rock salt and 50 cm^3 of water were added to a beaker and stirred for approximately 5 minutes. The mixture was subsequently filtered, and the filtrate transferred to an evaporating basin. The filtrate was then evaporated almost to dryness using a Bunsen burner. The heat was removed and the salt crystals were left to dry overnight at room temperature.

Now break the procedure down into a logical and detailed series of stages. In order to do this, you will have to plan ahead**. (***You may in particular wish to consider which apparatus and chemicals you will need to collect, and at what point in the procedure it would be most appropriate to collect and assemble them).*

Answer

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Planning checklist

The checklist below will help you to successfully plan and carry out the practical aspects of your Researching Chemistry investigation.

Checklist	√
Choose a topic	
Identify the most appropriate technique	
Plan the stages of the experiment	
Assess risks and plan to safely overcome these risks*	
Identify and collect the required chemicals	
Identify and collect the required apparatus	
Carry out the experimental procedure to produce and collect results	
Clean up	

*Safety considerations must be revisited throughout all planning and practical stages.

Good luck with planning and carrying out your Researching Chemistry investigation!

Solutions

Exercise 1 (parts a and b)

Specimen answer

1. Decide to have a cup of tea
2. Turn on tap
3. Put water in kettle
4. Turn off tap
5. Switch on kettle to boil water
6. Get out the cup
7. Get out the teaspoon
8. Put teaspoon in cup
9. Get out the teabag
10. Put teabag in cup
11. Get out the sugar
12. Add sugar
13. Add boiling water to cup
14. Leave for 2 minutes
15. Get out the milk
16. Add milk
17. Stir with teaspoon
18. Remove teabag with teaspoon
19. Put teabag in bin
20. Drink tea
21. Wash dishes
22. Tidy up

Note: There may be more than one way to sensibly carry out this procedure! Some stages may not always be required (for example, not everyone takes milk or sugar in their tea). There can be some flexibility in the order in which some of the stages are carried out (for example, some people may prefer to add the sugar after the milk, others before the milk). The order of collection of equipment may be dependent on its location within the kitchen. However, in general, planning ahead ensures that all the appropriate ingredients and equipment are available, that no key steps are missed out and that the procedure is carried out smoothly and quickly.

Exercise 2

Making a cup of tea	**Scientific investigation**
Decide to have a cup of tea	*Decide on topic for investigation*
Source ingredients	*Collect chemicals required*
Collect kitchen equipment	*Collect apparatus*
Make tea	*Carry out the procedure*
Drink tea	*Collect results*
Tidy up	*Put away apparatus and dispose of chemicals safely*

Exercise 3

Warning label	Meaning
	Flammable substance
	Toxic substance
	Hazardous to the environment
	Oxidising substance
	Explosive substance
	Irritant Harmful
	Corrosive
	Radioactive

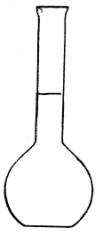
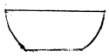
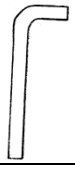
Exercise 4

Laboratory situation	**Precaution(s) required**
Pouring a corrosive chemical	Rubber gloves to protect hands Lab coat to protect clothing
Weighing out a toxic chemical	Use the chemical on a small scale Rubber gloves to protect hands Carry out in a fume-cupboard
Heating a reaction mixture involving a flammable reactant	Keep away from naked flames
A chemical reaction for which one of the products is a toxic gas	Carry-out in a fumehood
Disposal of chemical waste which is harmful to the environment	Use the chemical on a small scale Disposal in an appropriate waste container

Exercise 5

Technique	**Use**
Filtration	Separating a solid from a liquid
Heating using a water bath	Maintaining an enzymatic reaction at 37°C
Distillation	Separating a mixture of liquids
Use of balance	Weighing out chemicals
Heating using a Bunsen burner	Heating an aqueous solution rapidly to 60°C
Use of a gas syringe to collect a gas	Collecting a water-soluble gas
Titration	Determining the concentration of a solution
Collecting a gas over water	Collecting a gas which is insoluble in water
Heating using a heating mantle	Heating a flammable liquid to 120°C

Exercise 6

Apparatus			
Name	Conical flask	Burette	Dropper pipette
Apparatus			
Name	Thermometer	Measuring cylinder	Volumetric flask
Apparatus			
Name	Evaporating dish	Delivery tube	Funnel
Apparatus			
Name	Test-tube	Boiling-tube	Pipette and safety-filler

Exercise 7

1. Steps 1 and 2 are not mentioned explicitly in the written paragraph.

2. Issues due to lack of planning could include running out of chemicals in the middle of the experiment, not having the required apparatus to hand at the appropriate time, working unsafely because inappropriate apparatus has been selected, running out of time to complete practical work, etc.

Exercise 8

Specimen answer

1. Measure out five spatulafuls of rock salt into a 100 cm^3 beaker. Measure out 50 cm^3 of water using a measuring cylinder.

2. Add the water to the beaker of rock salt.

3. Stir the mixture for 5 minutes using a glass stirring rod.

4. Fold a filter paper into a cone and put it in a filter funnel. Put the filter funnel into a conical flask.

5. Filter the salt solution through the filter funnel.

6. Pour the filtrate (liquid) from the conical flask into an evaporating basin.

7. Set up a tripod on a heatproof mat and put the evaporating basin onto the tripod.

8. Light a Bunsen burner and place it under the tripod to heat the salt solution in the evaporating basin. Heat the solution until most of the water has gone.

9. Turn off the gas and let the salt dry at room temperature.