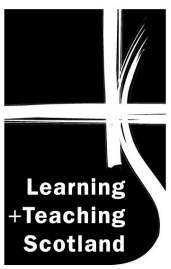
NATIONAL QUALIFICATIONS CURRICULUM SUPPORT

Chemistry

Researching Chemistry: Evaluating and Drawing Conclusions

Student's Guide

[HIGHER]



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Acknowledgement
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Contents

Student's guide

The aim of this resource is to develop the skills of evaluating and drawing conclusions within the context of investigative research in chemistry.

Introduction

We are constantly evaluating situations in our everyday lives and then drawing conclusions based on the available evidence to help decide the best way forward. Most of the time we do this subconsciously.

For example, imagine baking a cake. We might evaluate how the finished cake looks. If it is too pale, then it probably should have been left in the oven for a bit longer. If it is burnt around the edges, however, then a cooler oven should have been used or perhaps the cake should have been removed from the heat sooner. We will probably also evaluate how the cake tastes. If it is not moist enough, then perhaps some extra liquid ingredients should have been added or maybe less flour should have been used. If the cake is very heavy, it is likely that the ingredients should have been stirred for longer to introduce more air to the mixture.

Evaluating an experimental procedure allows us to assess its effectiveness, to plan for future modifications and to judge whether an alternative method might be more suitable.

Evaluating experimental results allows us to spot trends and patterns in the data, to make predictions in similar situations in the future and to assess and explain the relevance of the results obtained.

The skill of evaluating experimental procedures and data and then drawing relevant, evidence-based conclusions is crucial for carrying out effective investigative research in chemistry. The Researching Chemistry unit of the revised Higher Chemistry requires you to demonstrate these skills whilst writing your scientific communication.

Top tips

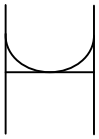
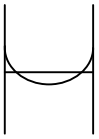
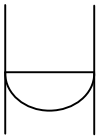
Evaluate experimental data and procedures as you go along. Don't wait until you are writing up your scientific communication – it will be too late to fix any problems at that stage.

Your conclusion(s) should relate back clearly to the aim(s) of the investigation. Make sure you are very clear about what you are setting out to do from the start – it will make life much easier when you are producing your scientific communication.

Make sure your conclusion is both *accurate* (gives the correct result) and *reproducible* (could be achieved again if the experiment was repeated).

Activity 1: Evaluating procedures

1. Humphrey is using a burette to measure volume during a redox titration. He is not sure where to read off the level of the meniscus on the burette. Circle the diagram below that correctly shows where Humphrey should take his meniscus reading.

(a)  (b)  (c) 

2. Humphrey obtains the results in the table below during his titration:

Titration	**Volume (ml)**
Rough	25.0
1	24.5
2	25.5
3	24.6

He wants to work out the average titre value. Which results in the table should he discard before calculating the average titre? Why should he discard these values?

_____

_____

Calculate the average titre for Humphrey's experiment.

_____

_____

3. Millie is bewildered! She is planning her Researching Chemistry investigation but isn't sure which piece of volumetric apparatus she should be using to carry out the different tasks involved. Circle the piece of apparatus that would be most suitable for carrying out each of the tasks in Millie's investigation and explain your selection.

(a) Accurately measuring exactly 50 ml of hydrochloric acid (0.5 mol l^{-1}) into a volumetric flask for a titration experiment involving a neutralisation reaction.

50 ml pipette	50 ml measuring cylinder
50 ml beaker	50 ml burette

Why? _____

_____

_____

(b) Measuring about 100 ml of water to be used in the hot water bath during an esterification reaction.

100 ml pipette	100 ml measuring cylinder
100 ml beaker	dropper pipette

Why? _____

_____

_____

(c) Adding about 1 ml of starch indicator solution to the volumetric flask being used in a redox titration involving iodine.

10 ml graduated pipette 10 ml measuring cylinder
graduated plastic dropper pipette

Why? _____

_____

_____

(d) Accurately measuring the volume of potassium permanganate solution (0.2 mol l^{-1}) required to react with 25 ml of oxalic acid (0.4 mol l^{-1}).

50 ml burette	50 ml measuring cylinder
50 ml pipette	50 ml beaker

Why? _____

_____

_____

4. Many different heating methods are available in a chemistry laboratory. Match up the most appropriate heating method to each task in the table below.

Task	**Heating method**
Distillation of ethanol at 78°C	Bunsen burner
Maintaining an enzymatic reaction at about 40°C	Water bath
Heating water quickly to about 60°C	Heating mantle

5. Why would it be inappropriate to use a Bunsen burner to warm a chemical reaction between an alcohol and a carboxylic acid?

_____

_____

6. What is the advantage of heating water with a Bunsen burner compared to heating it with a heating mantle?

_____

_____

7. Horace wants to collect and measure the volume of carbon dioxide gas being given off in his experiment. He decides to collect the gas over water, using an upturned measuring cylinder.

(a) Why is Horace likely to be unsuccessful in obtaining an accurate measurement using this method?

_____

_____

(b) Name a gas that could be successfully collected and measured over water.

_____

_____

(c) Suggest a more appropriate method that Horace could use to collect and measure the volume of carbon dioxide gas.

_____

_____

8. Jeremy and Edna are carrying out a distillation to separate ethanol and water. The instructions say that the distillation should be carried out using a heating mantle set at about 80°C, but Jeremy wants to speed the reaction up by increasing the temperature to the maximum setting of 150°C. Use your skills of evaluation to explain why Jeremy's suggestion would be unsuccessful.

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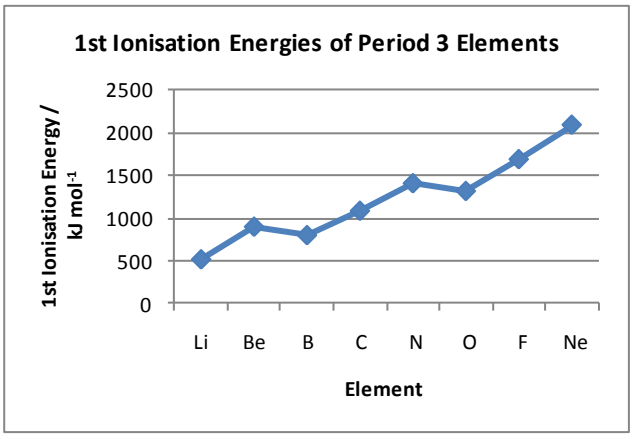
Activity 2: Evaluating results and drawing conclusions

1.



What general trend can be observed in the graph above?

_____

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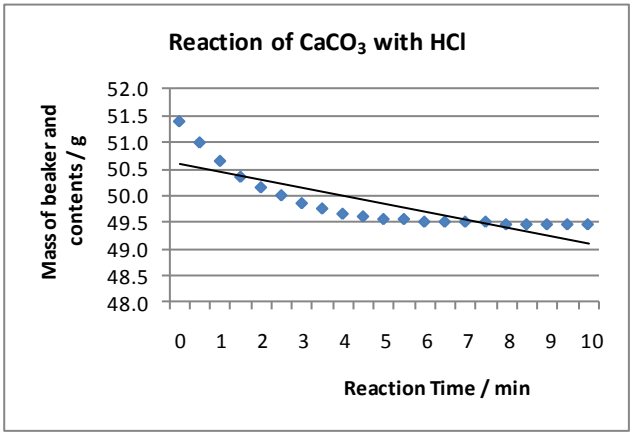
2.



Identify the problem with the graph above and suggest how this problem could be fixed.

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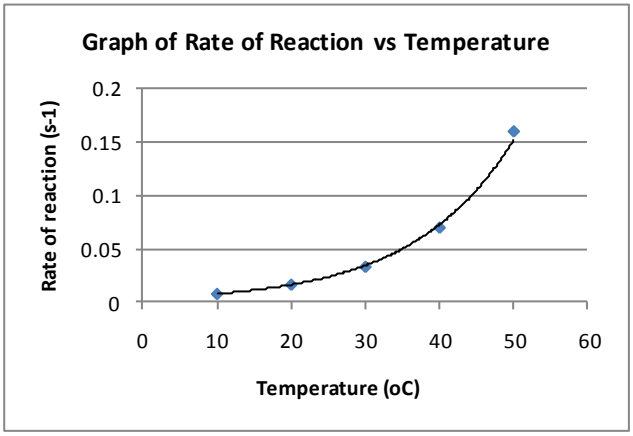
3.



What trend is shown in the graph above?

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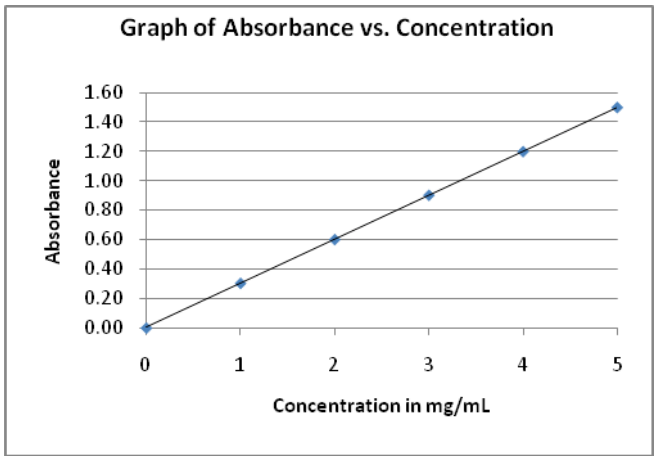
Why would this reaction be unlikely to be successful if it was carried out at room temperature?

_____

_____

4.



Describe the relationship between the variables in the graph above.

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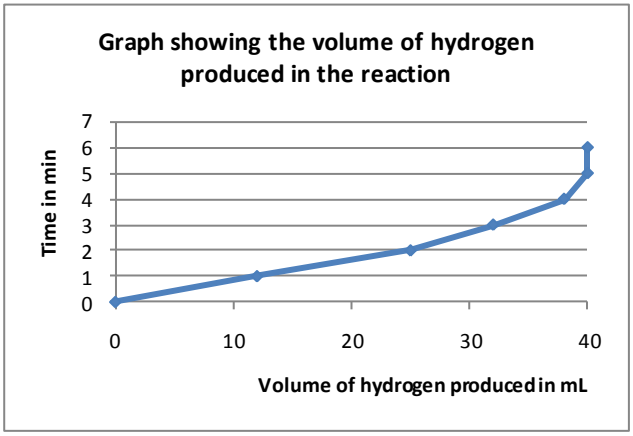
From the graph, what would be the absorbance value for a solution with concentration 2.5 mg ml^{-1}?

_____

_____

5.



What is the problem with the graph above and how could it be corrected?

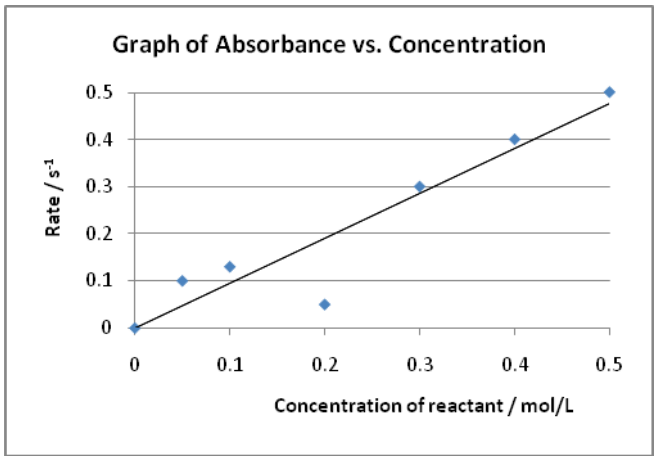
_____

_____

_____

_____

6.



(a) Circle the 'rogue point' in the graph above.

(b) Suggest a check that should be carried out before the 'rogue point' is discarded from the data.

_____

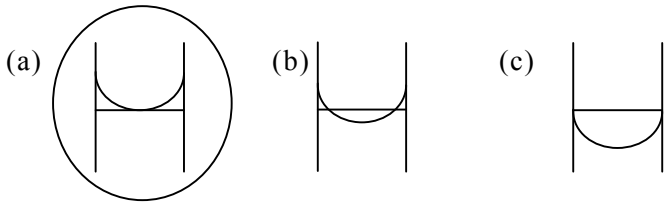
_____

_____

Solutions

Activity 1: Evaluating procedures

1. Humphrey is using a burette to measure volume during a redox titration. He is not sure where to read off the level of the meniscus on the burette. Circle the diagram below that correctly shows where Humphrey should take his meniscus reading.



2. Humphrey obtains the results in the table below during his titration:

Titration	Volume (ml)
Rough	25.0
1	24.5
2	25.5
3	24.6

He wants to work out the average titre value. Which results in the table should he discard before calculating the average titre? Why should he discard these values?
He should discard 25.0 and 25.5 ml. These values are not concurrent. To be concurrent they need to be 0.2 ml or less apart.

Calculate the average titre for Humphrey's experiment.
The average titre is (24.5 + 24.6)/2 = 24.55 = 24.6 ml

3. Millie is bewildered! She is planning her Researching Chemistry investigation but isn't sure which piece of volumetric apparatus she should be using to carry out the different tasks involved. Circle the piece of apparatus that would be most suitable for carrying out each of the tasks in Millie's investigation and explain your selection.

(a) Accurately measuring exactly 50 ml of hydrochloric acid (0.5 mol l^{-1}) into a volumetric flask for a titration experiment involving a neutralisation reaction.

50 ml pipette	50 ml measuring cylinder
~~50 ml beaker~~	50 ml burette

Why? *An accurate measurement of exactly 50 ml is required. A pipette will achieve this more quickly than a burette.*

(b) Measuring about 100 ml of water to be used in the hot water bath during an esterification reaction.

~~100 ml pipette~~	100 ml measuring cylinder
100 ml beaker	dropper pipette

Why? *The volume required does not need to be measured accurately.*

(c) Adding about 1 ml of starch indicator solution to the volumetric flask being used in a redox titration involving iodine.

~~10 ml graduated pipette~~	10 ml measuring cylinder
graduated plastic dropper pipette	

Why? *As the indicator is not taking part in the reaction, a volume of roughly 1 ml will be adequate. A dropper pipette is cheap and quick to use.*

(d) Accurately measuring the volume of potassium permanganate solution (0.2 mol l^{-1}) required to react with 25 ml of oxalic acid (0.4 mol l^{-1}).

50 ml burette	50 ml measuring cylinder
~~50 ml pipette~~	50 ml beaker

Why? *An accurate volume measurement is required. As the accurate volume being measured is not fixed, a burette is the most appropriate piece of apparatus to be used.*

4. Many different heating methods are available in a chemistry laboratory. Match up the most appropriate heating method to each task in the table below.

Task	Heating method
Distillation of ethanol at 78°C	Bunsen burner
Maintaining an enzymatic reaction at about 40°C	Water bath
Heating water quickly to about 60°C	Heating mantle

5. Why would it be inappropriate to use a Bunsen burner to warm a chemical reaction between an alcohol and a carboxylic acid?
Both of these chemicals are flammable. Using a naked flame to heat them would cause a fire!

6. What is the advantage of heating water with a Bunsen burner compared to heating it with a heating mantle?
Heating with a Bunsen burner is much faster (but it is more difficult to control the temperature).

7. Horace wants to collect and measure the volume of carbon dioxide gas being given off in his experiment. He decides to collect the gas over water, using an upturned measuring cylinder.

   (a) Why is Horace likely to be unsuccessful in obtaining an accurate measurement using this method?
   Carbon dioxide is soluble in water so some will dissolve in the water and therefore not be collected/measured.

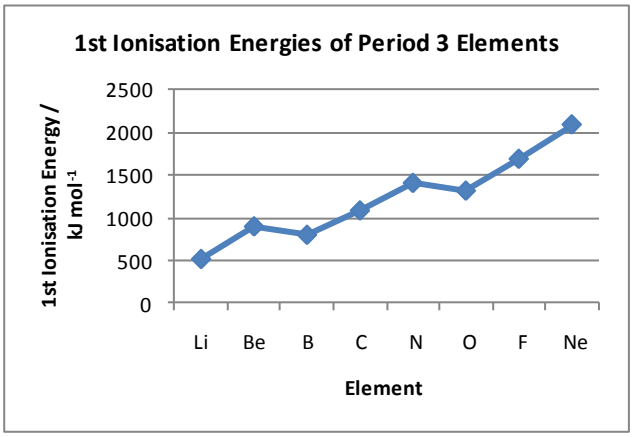
   (b) Name a gas that could be successfully collected and measured over water.
   Hydrogen (or any water insoluble gas)

   (c) Suggest a more appropriate method that Horace could use to collect and measure the volume of carbon dioxide gas.
   Using a gas syringe.

8. Jeremy and Edna are carrying out a distillation to separate ethanol and water. The instructions say that the distillation should be carried out using a heating mantle set at about 80°C, but Jeremy wants to speed the reaction up by increasing the temperature to the maximum setting of 150°C. Use your skills of evaluation to explain why Jeremy's suggestion would be unsuccessful.
Distillation separates liquids according to their different boiling points. At 80°C ethanol boils and turns into a gas, whilst water remains below its boiling point (100°C) and therefore remains as a liquid. At 150°C, both ethanol and water would turn to gases and therefore separation by distillation would be unsuccessful.

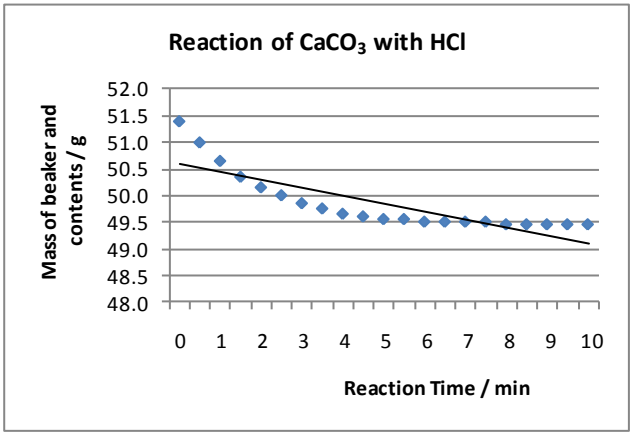
Activity 2: Evaluating results and drawing conclusions

1.



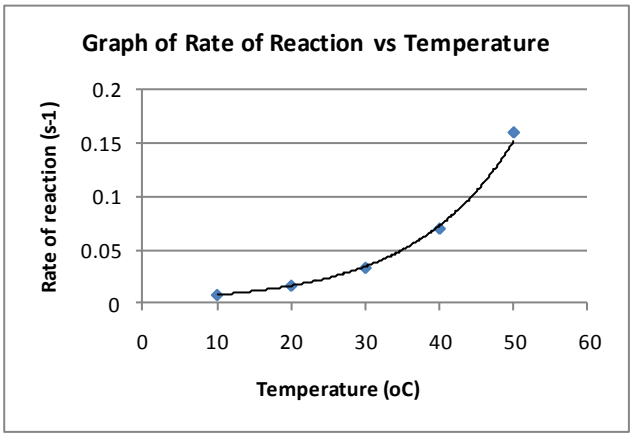
What general trend can be observed in the graph above?
As we cross Period 3, the first ionisation energy increases.

2.



Identify the problem with the graph above and suggest how this problem could be fixed.
The best-fitting straight line should be replaced by a best-fitting curve, to best fit with the data.

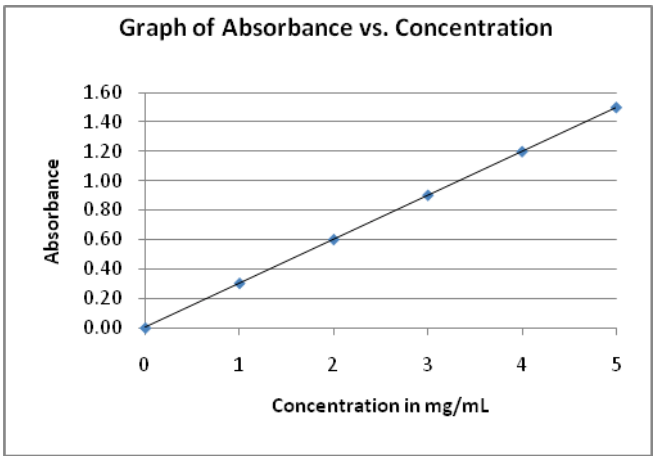
3.



What trend is shown in the graph above?
As temperature increases, reaction rate increases.

Why would this reaction be unlikely to be successful if carried out at room temperature?
At room temperature (about 20°C) the reaction rate will be very low and therefore the reaction will take too long.

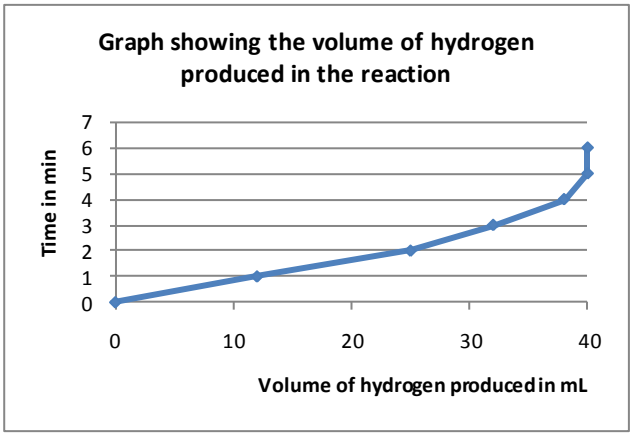
4.



Describe the relationship between the variables in the graph above.
As concentration increases, absorbance increases.

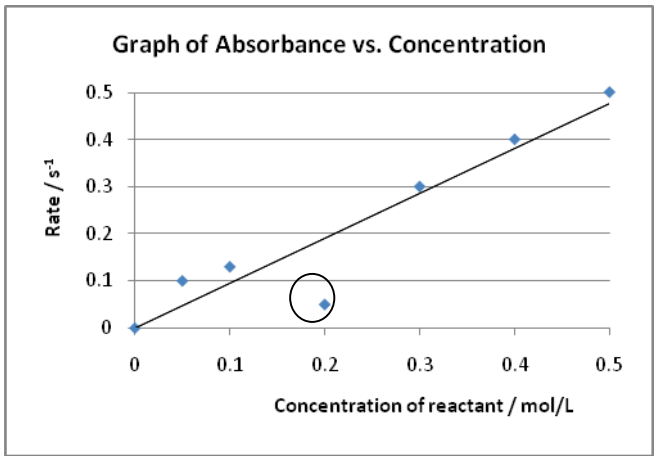
From the graph, what would be the absorbance value for a solution with concentration 2.5 mg ml^{-1}?
Approximately 0.7.

5.



What is the problem with the graph above and how could it be corrected?
The independent variable should be plotted on the x-axis, and the dependent variable on the y-axis. In this graph, time is the independent variable and should be on the x-axis. The volume of hydrogen is dependent on the time and therefore should be on the y-axis.

6.



(a) Circle the 'rogue point' in the graph above.

(b) Suggest a check that should be carried out before the 'rogue point' is discarded from the data.
Before removing the rogue point completely, it would be a good idea to repeat the measurement to see if the reading had been taken correctly. It might also be a good idea to prepare the sample of concentration 0.2 mol l^{-1} freshly and to repeat the test.