**Enthalpy**

Student Guide



 

**Researching Chemistry**

**Higher**

Photo: Wikipedia, GDFL

Higher Physics Topical Investigation Skin Cancer—Prevention and Cure

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**Investigation Brief**

Suntan creams stop harmful UV radiation reaching the skin. Manufacturers’ products are rated with a Sun Protection Factor (SPF). Suntan creams can have SPF values from 6 to over 50.

UV radiation monitors normally measure irradiance in output intensity per unit area. Thus, a typical low intensity UV lamp may emit approximately 10 mWcm-2.

The aim of this investigation is to determine the effect of various suntan creams on the transmission of UV radiation. In particular, the relationship between SPF and absorption should be found.

**Investigation Notes**

UV lamps can be harmful. Make sure that you read the safety leaflet which is supplied with the UV lamp. Some cheap UV monitors do not measure the irradiance of UV radiation. Rather, they give an indication of UV index. It is possible to undertake this investigation with such a monitor, but results will be less reliable and accurate. UV radiation does not pass through many transparent materials (including glass). However, UV transparent acrylics are readily available.

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Page 19 **Investigation C** – “Study the role of enthalpy in influencing the design of a chemical reaction. Find the enthalpy of neutralisation for a variety of combinations of strong acid/base and weak acid/base by experiment and calculation.

**INTRODUCTION**

All chemical reactions involve energy changes. The study of energy changes is an important part of chemistry. Fundamental to the thermo-chemistry is the law of conservation of energy, which states that the energy is neither created or destroyed, but can be converted from one form to another.

**For industrial processes, it is essential that chemists can predict the quantity of heat energy taken in or given out. If reactions are endothermic, costs will be incurred in supplying heat energy in order to maintain the reaction rate. If reactions are exothermic, the heat produced may need to be removed to prevent the temperature rising.**

**Endothermic Reaction.**

Endothermic reactions are those that absorb heat energy. Energy is needed to break apart the bonds of the reactants and this is greater than the energy released when the chemicals recombine to form products. Hence the enthalpy of products is greater than that of the reactants, as indicated in this energy profile below.



 **Exothermic Reaction**

An exothermic reaction is one in which stored chemical energy is converted to heat energy (heat is released to the surroundings). Some energy is needed to start the reaction, to break apart the bonds of reacting compounds ( the reactants) but then as the chemicals recombine to form products of the reaction more energy is given out to the surroundings. The enthalpy of the products is lower than that of the reactants, as indicated in the energy profile below.



Chemical energy is also known as **enthalpy**. The change in chemical energy associated with chemical reactions can be measured. The specific heat capacity, mass and temperature can be used to calculate the enthalpy change for a reaction.

 The equation for calculating the enthalpy change (heat change) is given by

 ∆ H = - c m ∆T

Where c is the specific heat capacity, m is the mass of the sample and ∆T is the change in temperature. The sign ∆H indicates the direction of the heat flow, positive for endothermic processes and negative for exothermic processes.

The heat absorbed or released during a chemical reaction is equal to the enthalpy change (delta H) for the reaction, at constant pressure. **Calorimetry is the measurement of heat absorbed or released during chemical and physical processes.**

*Definition: The standard enthalpy change of neutralisation is the enthalpy change when solutions of an acid and an alkali react together under standard conditions to produce 1 mole of water.*

*Example:*

*Hydrogen ions from the HCl react with hydroxide ions from the Na OH in a one-to-one ratio to produce water in the overall reaction:*

*H+(aq) + Cl–(aq) + Na+(aq) +OH–(aq)  H2O(l) + Na+(aq) + Cl–(aq)*

**Assessment Overview:**

This assignment has two stages:

* A **research** stage
* A **communication** stage

The Research Stage

The first stage of carrying out research in chemistry is to review what is already known about the topic of interest.

You may choose to use books, scientific papers, journals and the internet to carry out background research.

You should independently carry out background research into one of the focus questions listed below, which will be assigned to you by your teacher.

Focus questions to consider:

1. Investigate the enthalpy of neutralisation reactions involving three different strong acids with the strong base NaOH.Why do strong acids reacting with strong bases give closely similar values?
2. Investigate the enthalpy of neutralisation involving weak acids or weak bases. Why do these neutralisation reactions have values which differ from those involving strong acids or bases?
3. Investigate the enthalpy of neutralisation and explain differences in the values using a variety of lab strong/weak acids and strong/weak bases.

|  |  |
| --- | --- |
| Investigation | Title |
| A | Study the role of enthalpy in influencing the design of a chemical reaction. Find and compare the enthalpy of neutralisation for the **strong acid**s ( HCl,H2SO4 and HNO3 ) using Na OH as the **strong base**. |
| B | Study the role of enthalpy in influencing the design of a chemical reaction. Find the enthalpy of neutralisation for a **weak acid (ethanoic acid) and NaOH** and a **weak base(ammonia solution) with HCl** and compare these values to theory based data for **strong acids /bases reacting with strong acids/bases.**  |
| C | Study the role of enthalpy in influencing the design of a chemical reaction. Find the enthalpy of neutralisation for a variety of combinations of **strong acid/base** and **weak acid/base** by experiment and calculation. |

You may consider the following in your background research :

\* Heat

\* Heat content

\* Enthalpy

\* Enthalpy changes

\* Endothermic

\* Exothermic

\* Enthalpy of reaction

\* Enthalpy of neutralisation

\* Calorimetry and use in society.

\* Study the role of enthalpy in influencing the design of a chemical reaction.

Advice on using the internet for background research.

The web allows a huge amount of information- don’t get side tracked! Promising sites should be bookmarked so that you can return to them later. Tables, graphs and pictures can be copied into a folder. It is worthwhile spending a few moments considering which key words may be the best to enter into your search engine. For more advice on effective web-based research see the LTS resource on

<http://www.ltscotland.org.uk/nationalqualifications/resources/r/nqresource_tcm4629006.asp>.

Planning your Assessment Task:

When you have completed background research the following tasks should be completed:

a. Record at *least two* sources of information relevant to the topic. Sufficient detail should be given to allow someone else to find the sources easily. For a website the following URL is perfectly adequate.

[**http://www.biodieselfillingstations.co.uk/**](http://www.biodieselfillingstations.co.uk/)

b. Write a *brief* summary of the information of relevance contained in each of the sources you have identified.

c. Plan and carry out appropriate experimental procedures that will allow them you to determine your aim(s)

When planning this experiment you should consider:

* which acids and bases to use.
* how to accurately measure the actual heat energy produced during a neutralisation reaction.
* what apparatus will be required.
* the hazards that might be involved and how to minimise risk.

d. Carry out experimental work

**INVESTIGATION A**

*Study the role of enthalpy in influencing the design of a chemical reaction. Find and compare the enthalpy of neutralisation for the* ***strong acid****s ( HCl,H2SO4 and HNO3) using NaOH as the* ***strong base****.*

Focus Question:

Why do strong acids reacting with strong bases give closely similar values?

Two methods are given below.

Both methods may be used and an evaluation given in your report as to which method was more accurate. However, you may wish to use one method only.

**Safety!** Wear safety goggles throughout the practical investigations. Acids and alkalis are corrosive. Handle with care. Wash splashes immediately with running water.

You will need:

|  |
| --- |
| **Chemicals and Apparatus** |
| 200cm3 of a 1mol l-1 solution of your chosen acid, for example:HCl (aq), HNO3 (aq), H2SO4(aq), CH3COOH(aq) |
| 200cm3 of a 1mol l-1 solution of your chosen base, for example;NaOH(aq), NH4OH(aq) |
| Thermometer or temperature probe |
| Polystyrene foam cup with lid |
| 50cm3 burette x2 |
| Filter funnel. |
| 25cm3 pipette |
| Pipette filler |
| 100cm3 beaker |

**Method 1:**

1. Collect a dry polystyrene foam cup.

2. Collect and set up two burettes filled with 1.0 M NaOH and 1.0 M HCl respectively.

3. Record the initial burette readings.

4. Drain the specific volume of base solution for Experiment 1 into the polystyrene foam cup according to the table below.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Experiment | 1 | 2 | 3 | 4 | 5 |
| Volume of 1M base (aq) (cm3) | 25 | 20 | 15 | 10 | 5 |
| Volume of 1M acid (aq) (cm3) | 5 | 10 | 15 | 20 | 25 |

5. Allow the content of the polystyrene cup to equilibrate for a few minutes before the initial temperature is taken.

6. Quickly drain the specific volume of acid for Experiment 1 into the polystyrene cup.

7. Swirl the reaction mixture gently and record the maximum temperature when reached.( A specimen result table is provided for you to record your results)

8. Empty the contents of the polystyrene cup.

9. Repeat steps1-8 for H2SO4 and HNO3.

10 Using the results plot a graph ‘change in temperature against volume of base’ for each strong acid.

11 Extrapolate the graphs to find the maximum temperature rise for the three acids.

12 Use the maximum temperature rise and ∆H = - cm ∆ T to deduce the enthalpy of neutralisation for Hydrochloric acid, Sulphuric Acid and Nitric acid with Sodium Hydroxide.

**Result Tables: Investigation A: Method 1**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Experiment | 1 | 2 | 3 | 4 | 5 |
| Volume of 1M NaOH(aq) (cm3) | 25 | 20 | 15 | 10 | 5 |
| Volume of 1M HCl (aq) (cm3) | 5 | 10 | 15 | 20 | 25 |
| Initial temperature (o C) |  |  |  |  |  |
| Maximum temperature (o C) |  |  |  |  |  |
| Change in temperature(o C) |  |  |  |  |  |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Experiment | 1 | 2 | 3 | 4 | 5 |
| Volume of 1M NaOH(aq) (cm3) | 25 | 20 | 15 | 10 | 5 |
| Volume of 1M H2SO4 (aq) (cm3) | 5 | 10 | 15 | 20 | 25 |
| Initial temperature (o C) |  |  |  |  |  |
| Maximum temperature (o C) |  |  |  |  |  |
| Change in temperature(o C) |  |  |  |  |  |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Experiment | 1 | 2 | 3 | 4 | 5 |
| Volume of 1M NaOH(aq) (cm3) | 25 | 20 | 15 | 10 | 5 |
| Volume of 1M HNO3 (aq) (cm3) | 5 | 10 | 15 | 20 | 25 |
| Initial temperature (o C) |  |  |  |  |  |
| Maximum temperature (o C) |  |  |  |  |  |
| Change in temperature(o C) |  |  |  |  |  |

**Method 2:**

1. Use a pipette to place 25cm3 of the base solution into a dry polystyrene foam cup.

2. Measure and record the temperature of the solution.

3. Using the burette add 2cm3 of the first acid solution to the polystyrene cup.

4. Swirl the reaction mixture gently and record the maximum temperature when reached.

5. When the maximum temperature is reached, add another 2cm3 acid.

6. The maximum temperature should be recorded again. Repeat step 5 & 6 until a total volume of 40cm3 of acid is added.

7. Using the results plot a graph change in temperature against volume of acid.

8. Extrapolate the graph to find the maximum temperature rise

9. Use the maximum temperature rise and ∆H = - cm ∆ T to deduce the enthalpy of neutralisation.

10. Repeat the above procedure for sulphuric acid and nitric acid.

**Result Tables: Investigation A: Method 2**

Acid HCl

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Vol of acid (cm3) | 0 | 2 | 4 | 6 | 8 | 10 | 12 |
| Max Temp oC |  |  |  |  |  |  |  |
| Vol of acid (cm3) | 14 | 16 | 18 | 20 | 22 | 24 | 26 |
| Max Temp °C |  |  |  |  |  |  |  |
| Vol of acid (cm3) | 28 | 30 | 32 | 34 | 36 | 38 | 40 |
| Max Temp oC |  |  |  |  |  |  |  |

Acid H2SO4

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Vol of acid (cm3) | 0 | 2 | 4 | 6 | 8 | 10 | 12 |
| Max Temp oC |  |  |  |  |  |  |  |
| Vol of acid (cm3) | 14 | 16 | 18 | 20 | 22 | 24 | 26 |
| Max Temp °C |  |  |  |  |  |  |  |
| Vol of acid (cm3) | 28 | 30 | 32 | 34 | 36 | 38 | 40 |
| Max Temp oC |  |  |  |  |  |  |  |

Acid HNO3

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Vol of acid (cm3) | 0 | 2 | 4 | 6 | 8 | 10 | 12 |
| Max Temp oC |  |  |  |  |  |  |  |
| Vol of acid (cm3) | 14 | 16 | 18 | 20 | 22 | 24 | 26 |
| Max Temp °C |  |  |  |  |  |  |  |
| Vol of acid (cm3) | 28 | 30 | 32 | 34 | 36 | 38 | 40 |
| Max Temp oC |  |  |  |  |  |  |  |

**Investigation B**

*Study the role of enthalpy in influencing the design of a chemical reaction. Find the enthalpy of neutralisation for a* ***weak acid (ethanoic acid) and NaOH*** *and a* ***weak base(ammonia solution) with HCl*** *and compare these values to theory based data for* ***strong acids /bases reacting with strong acids/bases.***

Focus Question:

*Why do these neutralisation reactions have values which differ from those involving strong acids or bases?*

**Method 1:**

1 Collect a dry polystyrene foam cup.

2 Collect and set up two burettes filled with 1.0 M NaOH and 1.0 M CH3COOH respectively.

3 Record the initial burette readings.

4 Drain the specific volume of base solution for Experiment 1 into the polystyrene foam cup according to the table below.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Experiment | 1 | 2 | 3 | 4 | 5 |
| Volume of 1M NaOH (aq) (cm3) | 25 | 20 | 15 | 10 | 5 |
| Volume of 1M CH3COOH (aq) (cm3) | 5 | 10 | 15 | 20 | 25 |

5 Allow the content of the polystyrene cup to equilibrate for a few minutes before the initial temperature is taken.

6 Quickly drain the specific volume of acid for Experiment 1 into the polystyrene cup.

7 Swirl the reaction mixture gently and record the maximum temperature when reached.( A specimen result table is provided for you to record your results)

8 Empty the contents of the polystyrene cup.

9 Repeat steps1-8 for the following acid /base combination HCl and NH3 (aq)

10 Using the results plot a graph change in temperature against volume of each base/ acid combination

11 Extrapolate the graphs to find the maximum temperature rise for the combinations.

12 Use the maximum temperature rise and ∆H = - cm ∆ T to deduce the enthalpy of neutralisation for NaOH and ethanoic acid and Ammonia solution and HCl respectively.

13 Compare these values to theory based values for strong acid /strong bases.

**Results tables: Investigation B: Method 1**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Experiment | 1 | 2 | 3 | 4 | 5 |
| Volume of 1M NaOH(aq) (cm3) | 25 | 20 | 15 | 10 | 5 |
| Volume of 1M CH3COOH (aq) (cm3) | 5 | 10 | 15 | 20 | 25 |
| Initial temperature (o C) |  |  |  |  |  |
| Maximum temperature (o C) |  |  |  |  |  |
| Change in temperature(o C) |  |  |  |  |  |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Experiment | 1 | 2 | 3 | 4 | 5 |
| Volume of 1M NH3(aq) (cm3) | 25 | 20 | 15 | 10 | 5 |
| Volume of 1M HCl (aq) (cm3) | 5 | 10 | 15 | 20 | 25 |
| Initial temperature (o C) |  |  |  |  |  |
| Maximum temperature (o C) |  |  |  |  |  |
| Change in temperature(o C) |  |  |  |  |  |

**Method 2:**

1. Use a pipette to place 25cm3 of the base solution(NaOH) into a dry polystyrene foam cup.

2. Measure and record the temperature of the solution.

3. Using the burette add 2cm3 of the ethanoic acid solution to the polystyrene cup.

4. Swirl the reaction mixture gently and record the maximum temperature when reached.

5. When the maximum temperature is reached, add another 2cm3 acid.

6. The maximum temperature should be recorded again. Repeat step 5 & 6 until a total volume of 40cm3 of acid is added.

7. Using the results plot a graph change in temperature against volume of acid.

8. Extrapolate the graph to find the maximum temperature rise

9. Use the maximum temperature rise and ∆H = - cm ∆ T to deduce the enthalpy of neutralisation.

10. Repeat the above procedure for ammonia solution and hydrochloric acid.

11. Compare these values to theory based values for strong acid /strong bases.

**Results tables: Investigation B: Method 2**

*NaOH and ethanoic acid*

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Vol of acid (cm3) | 0 | 2 | 4 | 6 | 8 | 10 | 12 |
| Max Temp oC |  |  |  |  |  |  |  |
| Vol of acid (cm3) | 14 | 16 | 18 | 20 | 22 | 24 | 26 |
| Max Temp °C |  |  |  |  |  |  |  |
| Vol of acid (cm3) | 28 | 30 | 32 | 34 | 36 | 38 | 40 |
| Max Temp oC |  |  |  |  |  |  |  |

*Ammonia solution and HCl*

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Vol of acid (cm3) | 0 | 2 | 4 | 6 | 8 | 10 | 12 |
| Max Temp oC |  |  |  |  |  |  |  |
| Vol of acid (cm3) | 14 | 16 | 18 | 20 | 22 | 24 | 26 |
| Max Temp °C |  |  |  |  |  |  |  |
| Vol of acid (cm3) | 28 | 30 | 32 | 34 | 36 | 38 | 40 |
| Max Temp oC |  |  |  |  |  |  |  |

**INVESTIGATION C***.*

*Study the role of enthalpy in influencing the design of a chemical reaction. Find the enthalpy of neutralisation for a variety of combinations of* ***strong acid/base*** *and* ***weak acid/base*** *by experiment and calculation.*

Focus question:

*Investigate the enthalpy of neutralisation and explain differences in the values using a variety of lab strong/weak acids and strong/weak bases.*

*It is important to choose a suitable acid /base combination.*

*Suggested combinations:*

|  |
| --- |
| HCl and Na OH |
| HNO3 and NaOH |
| H2 SO4 and NaOH |
| CH3 COOH and NaOH |
| HCl and NH3 |
| HNO3 and NH3 |
| H2 SO4 and NH3 |
| CH3 COOH and NH3 |

**Method 1:**

1 Collect a dry polystyrene foam cup.

2 Collect and set up two burettes filled with 1.0 M NaOH and 1.0 M CH3COOH respectively.

3 Record the initial burette readings.

4 Drain the specific volume of base solution for Experiment 1 into the polystyrene foam cup according to the table below.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Experiment | 1 | 2 | 3 | 4 | 5 |
| Volume of 1M NaOH (aq) (cm3) | 25 | 20 | 15 | 10 | 5 |
| Volume of 1M CH3COOH (aq) (cm3) | 5 | 10 | 15 | 20 | 25 |

5 Allow the content of the polystyrene cup to equilibrate for a few minutes before the initial temperature is taken.

6 Quickly drain the specific volume of acid for Experiment 1 into the polystyrene cup.

7 Swirl the reaction mixture gently and record the maximum temperature when reached.( A specimen result table is provided for you to record your results)

8 Empty the contents of the polystyrene cup.

9 Repeat the same procedure for Experiment 2-5.

**Results Tables : Investigation C: Method 1**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Experiment | 1 | 2 | 3 | 4 | 5 |
| Volume of 1M base(aq) (cm3) | 25 | 20 | 15 | 10 | 5 |
| Volume of 1M acid (aq) (cm3) | 5 | 10 | 15 | 20 | 25 |
| Initial temperature (o C) |  |  |  |  |  |
| Maximum temperature (o C) |  |  |  |  |  |
| Change in temperature(o C) |  |  |  |  |  |

**Method 2:**

1. Use a pipette to place 25cm3 of the base solution(NaOH) into a dry polystyrene foam cup.

2. Measure and record the temperature of the solution.

3. Using the burette add 2cm3 of the ethanoic acid solution to the polystyrene cup.

4. Swirl the reaction mixture gently and record the maximum temperature when reached.

5. When the maximum temperature is reached, add another 2cm3 acid.

6. The maximum temperature should be recorded again. Repeat step 5 & 6 until a total volume of 40cm3 of acid is added.

7. Using the results plot a graph change in temperature against volume of acid.

8. Extrapolate the graph to find the maximum temperature rise

9. Use the maximum temperature rise and ∆H = - cm ∆ T to deduce the enthalpy of neutralisation.

10. Repeat the above procedure for other acid and base combinations.

**Results Tables : Investigation C: Method 1**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Vol of acid (cm3) | 0 | 2 | 4 | 6 | 8 | 10 | 12 |
| Max Temp oC |  |  |  |  |  |  |  |
| Vol of acid (cm3) | 14 | 16 | 18 | 20 | 22 | 24 | 26 |
| Max Temp °C |  |  |  |  |  |  |  |
| Vol of acid (cm3) | 28 | 30 | 32 | 34 | 36 | 38 | 40 |
| Max Temp oC |  |  |  |  |  |  |  |

**Communication Stage**

This will be conducted under a high degree of supervision. This means that:

* You will be in the direct sight of the assessor/teacher
* You must not discuss your work with each other.

During the communication stage you will have access to the following resources:

The material collected during the research stage. This may include, for example, statistical, graphical, numerical or experimental data; data/information from the internet; published articles or extracts; notes taken from a visit or talk; notes taken from a written or audio-visual source.

**Requirements of the assignment**.

Once you have agreed the format of your scientific communication with your teacher, you should produce a report on your investigation containing the following key features:

|  |  |  |
| --- | --- | --- |
| Criteria | Mark | Expected response |
| Aim | 1 | The aim must be clearly stated and appropriate to the investigation undertaken. |
| Apply knowledge and understanding of chemistry | 4 | Provide correct explanations of the topic researched using chemistry terms/ideas which are at a depth appropriate to Higher Chemistry. The response might include: a statement of the principles involved, formulae, chemical equations, calculations, chemical properties related to bonding present. |
| Risk assessment | 1 | State the majority of appropriate safety measures taken during the experimental work. |
| Select information | 2 | The data/information selected by the candidate for presentation/processing/analysis is both relevant and sufficient. |
| Process and present | 4 | Processing can include, for example; performing calculations; manipulating data, summarising referenced text.It must be clear where the raw or extracted data/information came from. Presenting processed data/information can include for example appropriate formats from; summary, graph, table,chart or diagram ( one must be a graph, table ,chart or diagram) In each case, sufficient detail should be included to convey the data/information. The source of the original data must be clearly referenced. |
| Analyse data/information | 2 | Analysis will include interpreting data/information included in the report( which may or may not have been processed by the student) to identify relationships. This may include further calculations. |
| Conclusion | 1 | State a valid conclusion that relates to the aim(s) and is supported by evidence from the students research. |
| Evaluation | 3 | Students must make judgements based on criteria. The criteria, upon which judgements of the investigation are made, may include the following* Robustness of findings
* Validity of sources
* Reliability of data/information
* Evaluation of experimental procedure.
 |
| Presentation | 2 | An appropriate title and structure must be given. The references to at least two sources used in the report are given in sufficient detail to allow them to be retrieved by a third party. If one of the sources is an experiment/practical activity, then the title and the aim should be recorded. |