Experiment 3.1A - Candidate Instruction Sheet

A Study of Energy Changes - the indirect determination of the enthalpy change of reaction of magnesium oxide with carbon dioxide to form magnesium carbonate by thermochemical measurement and Hess's law

Introduction

Millions of tons of chemicals are reacted each year, not to form a product but to obtain energy from chemical reactions. Most of these involve the combustion of hydrocarbons and other fuels by the oxygen in air. Measurements of the energy liberated in such reactions are very important but require the use of bomb calorimeters and oxygen under pressure which makes them unsuitable for advanced level work in schools.

However the principles involved can be readily seen by using quieter and more easily controlled reactions such as the one you are to carry out. As well as measuring the heat liberated and calculating the enthalpy changes for your reactions, you will be able to use your values to find the enthalpy change for a reaction that cannot be measured directly.

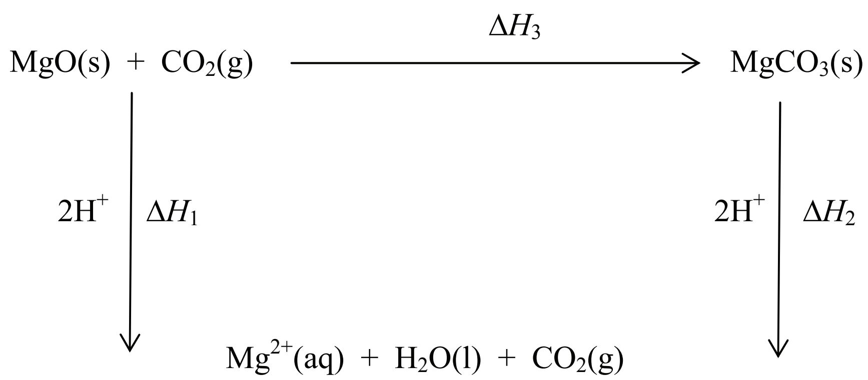
Aim

Your aims in this exercise are:

(a) to gather information and plan your work with due regard to safety considerations;
(b) to carry out the experiment;
(c) to calculate, analyse and evaluate your results;
(d) to answer the questions in the pro forma relating to the experiment.

Background Information

You are to measure the enthalpy changes of reaction of magnesium oxide and of magnesium carbonate with dilute hydrochloric acid. By applying Hess's law to your results you will be able to calculate the enthalpy change above, which is difficult to measure directly, as shown in the cycle given below.



The method involves carrying out the reactions in separate experiments in insulated calorimeters, calculating the heat evolved - correcting for heat losses to the surroundings - and scaling up to molar amounts of the solids used.

Apparatus and chemicals

You will need safety goggles, a thermometer graduated in 0.2 or 0.5 degree divisions (or a digital thermometer), a simple calorimeter, a 50 cm^3 burette and a weighing bottle. You are provided with a suitable quantity of dry magnesium oxide, dry magnesium carbonate and 2 mol dm^{-3} hydrochloric acid.

You will need to weigh out **accurately** about 0.90 g of magnesium oxide (i.e. between 0.85 and 0.95 g) for the first measurement and 3.5 g of magnesium carbonate (i.e. between 3.40 and 3.60 g) for the second. It will be appropriate to use 50 cm^3 of dilute hydrochloric acid in any experiment you perform: the acid must be in excess.

Safety Considerations

No special precautions are necessary for spillage of the solids. If large quantities are involved, mix with sand to sweep up.

If you splash any of the hydrochloric acid onto your skin, notify your supervisor and wash the affected area with copious water.

Should you break a mercury-in-glass thermometer, try to retain the liquid mercury. The vapour is very poisonous, with cumulative effects. If necessary, droplets of mercury can be sucked up using a small aspirator and pump. If mercury is spilled into floor cracks, the volatility can be reduced by brushing in sulfur or zinc dust.

At the end of the experiment, small quantities of the chemicals can be diluted with running water and run to waste.

Procedure

After absorbing all the information available to you, write a plan, which will enable you to determine, as accurately as possible, the required enthalpy change of reaction of magnesium oxide with carbon dioxide to form magnesium carbonate. After having your plan checked by the teacher, carry out the experiment according to the plan and plot appropriate temperature/time graphs for any sets of data.

Analysis of Results

1. Calculate the heat evolved in each case.
   This equals the corrected temperature rise (ΔT) × the mass of acid (water) heated (50 g) × the heat capacity of this acid (water) (4.18 J g^{-1}). [ΔT is positive if T increases]

2. This heat was for the mass of metal oxide or carbonate used, so scale up to 1 mol of oxide or carbonate to obtain the molar enthalpy change for the reactions (ΔH_1 and ΔH_2).

3. Study the energy cycle given and see that the required enthalpy change (ΔH_3) equals ΔH_1 minus ΔH_2.

Conclusion, Evaluation and Question

1. Estimate the precision in your values and record your three enthalpy change values with a number of significant figures which corresponds with your estimate. Comment on their values and signs.

2. How do the signs of the temperature changes relate to the signs of the enthalpy values calculated for your two experiments?

Allocation of marks

The 30 available marks for this experiment are allocated in the following manner:

Planning [5]; Implementing [15]; Analysing [5]; Evaluating [5].

Experiment 3.1A - Marking Scheme

All marks are AO3 except where indicated.

Planning [5]

An effective detailed plan is recorded (2)

Answers to questions:

1.	$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O$	(1)	AO1
2.	Propane has 3C atoms, so gives 3 mol CO_2 $3 \times 44 = 132$g	(1)	AO1
3.	Combustion of hydrogen $2H_2 + O_2 \rightarrow 2H_2O$	(1)	AO2

Implementing [15]

Accurately weighs samples within required range (1)
Ensures temperature is constant before mixing (shown by graph) (1)
Mixes reactants rapidly (shown by graph) (1)
Completes table of results legibly (1)
Records results to appropriate level of precision (1)

Accuracy of two ΔT values against teacher's results based on:
for a thermometer reading to 0.2 ^{o}C or better
within 0.4 ^{o} 5/5, decreasing by one mark for each 0.2 ^{o} increase in deviation to 1/5 for 1.2 ^{o} and 0/5 above that;
for a 0.5 ^{o}C thermometer
within 0.6 ^{o} 5/5, within 0.75 ^{o} 4/5, within 0.9 ^{o} 3/5,
within 1.0 ^{o} 2/5, within 1.2 ^{o} 1/5 and 0/10 above that.
This is for each experiment giving a maximum mark of (10)

Analysis [5]

Quality of graph plotting (1)
Accurate calculation of ΔT from graphs (1)
Calculation of the two ΔH values (2)
Correct application of Hess's law for final ΔH (1)

Evaluation [5]

Estimates precision of ΔH values and restates results to a sensible number of significant figures (1)
Explains relationship between sign of temperature changes and enthalpy values (1)

Answer to question:

Ethane would be better, giving more energy per mol	(1)	AO1
Ethanol is a renewable resource in this case (bioethanol)	(1)	AO2
Ethane is a non-renewable resource from fossil fuels	(1)	AO2

Maximum Mark [30]

Experiment 3.1A - Technical Advice Notes for Teachers and Technicians

Indirect determination of the enthalpy change of reaction of magnesium oxide with carbon dioxide to form magnesium carbonate by thermochemical measurement and Hess's law

The apparatus, chemicals and solutions required are listed below.

Universally available items may not be listed.

Each student will require:

safety goggles
thermometer graduated in 0.2 / 0.5 degree divisions / digital
simple calorimeter
50 cm^3 burette
2 mol dm^{-3} hydrochloric acid
dry magnesium oxide
dry magnesium carbonate

The masses of the solids to be used are governed to some extent by the thermometers or other temperature measurers used. If 0.5 rather than 0.2 degree divisions are used, larger temperature changes are preferable to increase precision, even though this will increase the heat loss correction. Probably about 0.9 g of magnesium oxide and 3.5 g of carbonate would represent a suitable compromise, giving temperature changes of around 10 degrees while still having excess acid, which is necessary to ensure rapid and complete reaction. In general, to optimise precision, temperature changes of around 10 degrees should be aimed for and a burette should be used to measure the acid volume since errors using measuring cylinders can be substantial.

Note:
Only one determination is required for each of the reactions, i.e. a total of two runs.

Magnesium carbonate is available in light (magnesia alba levis) or heavy (magnesia alba ponderosa) forms. It has been reported that some light material may be lost from the liquid due to frothing, so that it is better, if possible, to use the heavy version.

Similarly the heavy form of magnesium oxide is preferred if there is a choice.

The purchased carbonate is likely to be a basic carbonate: this has no effect on the experiment but means that the calculated final enthalpy change may not match the literature value. Marks are, however, based on the teacher's value and not that in the literature.

EXPT 3.1A

TEACHER RESULTS SHEET

Centre Name: ……………………………............... Centre Number: ………..........

This form should be completed, as appropriate, by the subject teacher and accompany the work of the candidate sent for assessment

The indirect determination of the enthalpy change of reaction of magnesium oxide with carbon dioxide to form magnesium carbonate by thermochemical measurement and Hess's law

Precision of thermometer in experiment ……….^{o}C

MgO Corrected ΔT is ……….^{o}C for ……….g of Mg;

ΔT/g = ……….^{o}C/g

$MgCO_3$ Corrected ΔT is ……….^{o}C for ……….g of MgO;

ΔT/g = ……….^{o}C/g

Signed: ……………………………………… **Date: ……………..**
(Subject teacher)

Examiner only

PRO FORMA EXPT 3.1A SUMMER 200…..

Centre Name …………………………………………… Centre Number ……………………

Candidate's Name ……………………………………… Candidate's Number ………………

Enthalpy change of reaction of magnesium oxide with carbon dioxide to form magnesium carbonate

(Attach another sheet, in the appropriate position, if you need more space)

Plan
Before proceeding to carry out your plan you must have the plan checked by your teacher.

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……… P_1

[2]

P_2

Questions

1. Write a balanced equation for the combustion of methane gas. [1]

P

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2. Calculate the mass of carbon dioxide produced when one mole of propane is completely combusted. [1]

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…………………………………………………………………...……………………………………

3. Suggest a possibly useful combustion reaction that does not form carbon dioxide. [1]

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Examiner only

Results

MgO + acid

mass container + MgO = ……………….. g

mass container = ……………….. g

∴ mass MgO = ……………….. g

Temperature/time table

The thermometer used was graduated in …………… degree divisions. I_1
[*state thermometer precision here*]

$MgCO_3$ + acid I_2

I_3

mass container + $MgCO_3$ = ……………….. g

mass container = ……………….. g I_4

∴ mass $MgCO_3$ = ……………….. g

I_5

Temperature/time table I_6

I

Examiner only

Analysing Results

(show your working in the calculations)

MgO - please restate mass of MgO used …….. ………….. g

maximum temperature if no heat lost = ………………..

initial temperature = ……………….

temperature change = ……………….

Calculation of heat change in expt.

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Calculation of ΔH_1

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$MgCO_3$ - please restate mass of $MgCO_3$ used ………………g

maximum temperature if no heat lost = ………………..

initial temperature = ……………….

temperature change = ……………….

Calculation of heat change in expt.

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Examiner only

Calculation of ΔH_2

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……… A_1

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Calculation of ΔH_3, the enthalpy change of reaction A_2

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……… A_3

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……… A_4

A

Evaluation and question

Include (a) your estimate of the precision of your results and a consequent restating your results to a sensible number of significant figures, and

(b) a statement of how the signs of the temperature changes relate to the signs of the enthalpy values calculated in the two experiments.

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……… E_1

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[2] E_2

Examiner only

Question

Motor vehicle environmental effects are judged on the grams of carbon dioxide emitted per kilometre of travel.

The combustion equations for bioethanol and the alkane ethane and the energy liberated are

$C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O$, $\Delta H = -1371$ kJ mol^{-1}

and

$C_2H_6 + \frac{7}{2}O_2 \rightarrow 2CO_2 + 3H_2O$, $\Delta H = -1560$ kJ mol^{-1}.

Bearing in mind that the car is driven by the energy liberated, state which fuel would be more environmentally friendly per mol on the basis of these results, giving your reason.

There is, however, another factor to be considered. Discuss this and state whether or not your initial conclusion should be altered. [3]

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E_3

Remember that any graphs must be attached to your work.

E

Allocation of marks

The 30 available marks for this experiment are allocated in the following manner:

Planning [5]; Implementing [15]; Analysing [5]; Evaluating [5].

		Examiner only
	Maximum Mark	Candidate Mark
Planning	5	
Implementing	15	
Analysing	5	
Evaluating	5	
Total Mark	**30**	