Experiment 3.1C - Candidate Instruction Sheet

A Study of Energy Changes - the indirect determination of the enthalpy change of formation of magnesium oxide by thermochemical measurement and Hess's law

N.B. A THREE-PLACE BALANCE OR BETTER IS ESSENTIAL FOR THIS EXPERIMENT

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.

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.

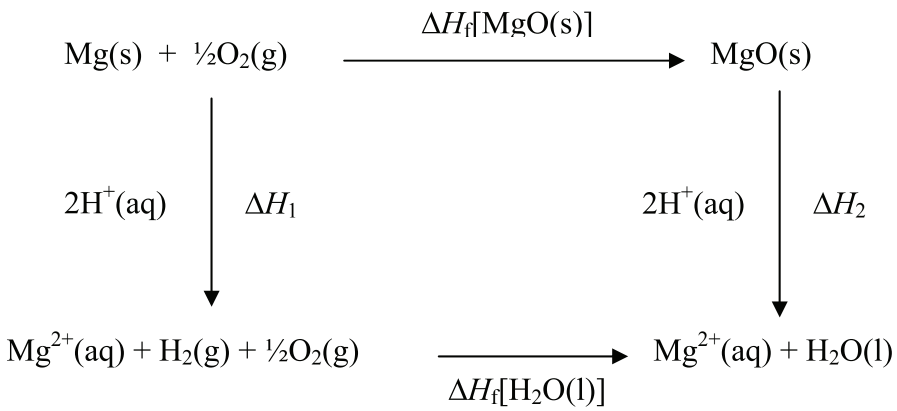
Aim

Your aims in this exercise are:

(a) to gather information and plan your work;
(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 metal and of magnesium oxide with dilute hydrochloric acid. By applying Hess's law to your results, and using some supplied data, you will be able to calculate the enthalpy change of formation of magnesium oxide, which is impossible 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 and a 50 cm^3 burette. You are provided with a suitable quantity of clean magnesium, dry magnesium oxide and 2 mol dm^{-3} hydrochloric acid.

You will need to weigh out **accurately** about 0.1 g of magnesium (i.e. between 0.090 and 0.110 g) and 0.9 g of magnesium carbonate (i.e. between 0.850 and 0.950 g). 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 sulphur 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, state the aim of the experiment and write a plan, which will enable you to determine, as accurately as possible, the enthalpy change of formation of magnesium oxide. 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 or oxide used, so scale up to 1 mol of metal or oxide to obtain the molar enthalpy change for the reactions (ΔH_1 and ΔH_2).

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

Note that to obtain a balanced cycle we need more terms since the hydrogen from the Mg/acid reaction ends up as water in the cycle.
Thus the enthalpy change of formation of MgO equals ΔH_1 minus ΔH_2 plus the enthalpy changes of formation of liquid water (−286 kJ mol^{-1}).

Conclusion, Evaluation and Questions

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?

3. Answer the questions given.

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 3.1C - Marking scheme

Planning [5]

An effective detailed plan is recorded (2)

Answers to questions:

1.	$CH_4 (g) + 2O_2 (g) \rightarrow CO_2 (g) + 2H_2O(l)$	(1)	AO1
2.	Propane has three C atoms to give three mol CO_2 3 × 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 ^oC 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 ^oC 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 source in this case (bioethanol)	(1)	AO2
Ethane is a non-renewable source from fossil fuels	(1)	AO2

Maximum Mark [30]

Experiment 3.1C - Technical Advice Notes for Teachers and Technicians

Indirect determination of the enthalpy change of formation of magnesium oxide by thermochemical measurement and Hess's law

NB Three place-balance essential to give acceptable precision, otherwise use 3.1A

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
supply of clean magnesium
dry magnesium oxide

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 0.10 g of magnesium and 0.9 g of oxide 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.

If there is a choice between light and heavy magnesium oxide, the heavy form is preferred in order to reduce the risk of loss of powder by frothing.

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

EXPT 3.1C

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 formation of magnesium oxide by thermochemical measurement and Hess's law

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

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

ΔT/g = ……….^{o}C/g

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

ΔT/g = ……….^{o}C/g

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

Examiner only

PRO FORMA EXPT 3.1C SUMMER 200…..

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

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

Enthalpy change of formation of magnesium oxide

(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.

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

[2] P_1

P_2

Questions

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

……………………………………………………………………………………………………

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

……………………………………………………………………………………………………

……………………………………………………………………………………………………

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

……………………………………………………………………………………………………

Examiner only

Results

Mg + acid

mass container + Mg = ……………….. g
mass container = ……………….. g
∴ mass Mg = ……………….. g

Temperature/time table

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

MgO + acid I_2

I_3

mass container + MgO = ……………….. g

mass container = ……………….. g I_4

∴ mass MgO = ……………….. g

I_5

Temperature/time table I_6

I

Examiner only

Analysing Results

(show your working in the calculations)

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

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

initial temperature = ……………….

temperature change = ……………….

Calculation of heat change in expt.

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

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

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

......…….....

Calculation of ΔH_1

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

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

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

……………………………………………………………...

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

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

initial temperature = ……………….

temperature change = ……………….

Calculation of heat change in expt.

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

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

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

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

Examiner only

Calculation of ΔH_2

……

……

……

…… A1

Calculation of ΔH_f[MgO(s)]

…… A2

……

…… A3

……

A4

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.

……

……

……

……

……

……

…… E1

……

[2] E2

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

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

and

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

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]

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

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**	