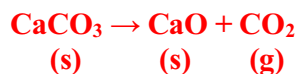


## Determining the Enthalpy change for the thermal decomposition of Calcium Carbonate

The aim of this investigation is to determine the enthalpy change for the following reaction:

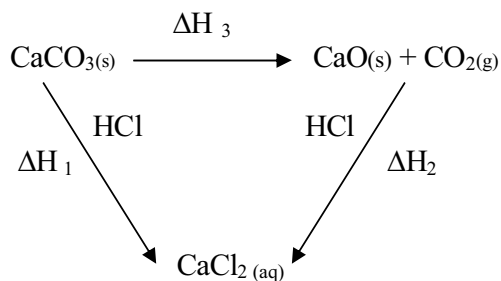


The above reaction takes place when calcium carbonate undergoes thermal decomposition. I will calculate the enthalpy change of the reaction by an indirect method based on Hess's law.

Enthalpy change  $\Delta H$  is the measure of heat change at a fixed pressure and temperature. It is known as the standard molar enthalpy change of a reaction and is measured in kilojoules per mole.

Hess's law states that the total enthalpy change for a chemical reaction is the same, whatever route is taken, provided that the initial and final conditions remain constant.

The diagram below outlines how I expect to calculate the enthalpy change of the reaction using an indirect method.



Calcium oxide and calcium carbonate both react readily with  $2\text{mol dm}^{-3}$  hydrochloric acid solutions. The temperature changes during these two reactions can be measured and the enthalpy changes  $\Delta H_1$  and  $\Delta H_2$  can be calculated.

$\Delta H_3$  can be calculated using the Hess's cycle above as  $\Delta H_1 - \Delta H_2 = \Delta H_3$

Below are the results tables that I recorded after carrying out the procedure for both calcium carbonate and calcium oxide.

Table 1

Mass of CaCO <sub>3</sub> and weighing bottle	5.7g
Mass of empty weighing bottle	3.1g
Mass of CaCO <sub>3</sub> used	2.6g
Initial temperature of acid	22.0°C
Final temperature of solution	23.0°C
Change in Temperature	1.0°C

Table 2

Mass of CaO and weighing bottle	4.5g
Mass of empty weighing bottle	3.1g
Mass of CaO used	1.4g
Initial temperature of acid	21.0°C
Final temperature of solution	32.0°C
Change in Temperature	11.0°C

From the data above you can see that the temperature values that are measured in °C have been recorded to the nearest whole number. I did this as it would be unlikely that I was able to identify a more accurate approximation using the thermometer which I had available. The mass values are measured to one decimal place; this was possible as the scales which I used had this appropriate degree of accuracy.

The results that I have recorded allow me to calculate the required enthalpy changes. To measure enthalpy change of a reaction I will use the following formula:

$$\Delta H = mc\Delta T$$

Where: **m** is the mass of the substance, **ΔT** is the temperature change and **c** is the specific heat capacity of the substance.

The specific heat capacity is the amount of heat needed to raise the temperature of a unit mass by 1K. In this experiment we will assume that the specific heat capacity of the substance is the same as water which is 4.2J g<sup>-1</sup>K<sup>-1</sup>.

I will first calculate the enthalpy change that occurs with the reaction between calcium carbonate and hydrochloric acid.

$$\Delta H = mc\Delta T$$

$$\Delta H_1 = 52.6 \times 4.2 \times 1$$

Here the mass, m, is 52.6g this is because I have combined both the mass of the calcium carbonate 2.6g to the mass of hydrochloric acid 50g.

$$\Delta H_1 = 52.6 \times 4.2 \times 1$$

$$= 220.92 \text{ J}$$

$$= 0.22092 \text{ KJ}$$

As enthalpy change is the standard molar enthalpy change I will need to calculate the number of moles in the substance.

$$\text{Number of Moles} = \text{Mass of Element (g)} / \text{Relative Atomic Mass of Element}$$

$$= 2.6 / 100.1$$

$$= 0.025974025$$

Here the mass of the element is 2.6 and relative atomic mass is the sum of the relative atomic masses of each of the elements of which calcium carbonate is composed of.

Relative atomic mass of Calcium carbonate:  $\text{CaCO}_3 = 40.1 + 12 + (16 \times 3) = 100.1$

$$\Delta H_1 = 0.22092 / 0.025974025$$

$$= 8.504650319 \text{ KJ mol}^{-1}$$

$$\Delta H_1 = \mathbf{-8.505 \text{ KJ mol}^{-1} \text{ (to 3.dp)}}$$

The value for the enthalpy change is negative because energy is lost to the surroundings hence it is an exothermic reaction.

I will now calculate the enthalpy change that occurs between the reaction of calcium oxide and hydrochloric acid.

$$\Delta H = mc\Delta T$$

$$\Delta H_2 = 51.4 \times 4.2 \times 11$$

$$= 2374.68 \text{ J}$$

$$= 2.37468 \text{ KJ}$$

$$\text{Number of Moles in CaO} = 1.4 / 56.1$$

$$= 0.024955436$$

$$\Delta H_2 = 2.37468 / 0.024955436$$

$$= 95.15682275 \text{ KJ mol}^{-1}$$

$$\Delta H_2 = \mathbf{-95.157 \text{ KJ mol}^{-1} \text{ (to 3.dp)}}$$

Now that I have calculated  $\Delta H_1$  and  $\Delta H_2$  I am able to calculate  $\Delta H_3$ .

$$\Delta H_3 = \Delta H_1 - \Delta H_2$$

$$= -8.505 - (-95.157)$$

$$\Delta H_3 = \mathbf{86.652 \text{ KJ mol}^{-1}}$$

From the result above we can see that the reaction when calcium carbonate is heated is an endothermic reaction. An endothermic reaction is when energy has been taken in from the surroundings. As the enthalpy change is a positive value the reaction must be an endothermic.

## Evaluation

In this evaluation section I will see how I could have improved my experiment whether it is regard to the procedure or recording methods.

The value that I have calculated for the enthalpy change may not be the same if I were to do the experiment again. This may be due to changes in procedure and measurements that I have taken.

Errors could have occurred in the procedures in a variety of different ways without any obvious anomalies during the experiment. These types of inaccuracies in the procedure could have occurred in such places as when pouring the hydrochloric acid into the beaker. Although I was careful not to spill any of the acid the likelihood is that not all the hydrochloric acid reacted with the calcium carbonate. This could have had an affect on my results as I may not have calculated the correct mass of hydrochloric acid. An improvement that I could have made in the procedure could have been making alterations with regards to the conditions under which the solution was stirred. As I was stirring the solution in a beaker that had an open top it means that some of the heat could have been lost to the surroundings at a faster rate. To minimise this I should have placed some sort of equipment on top of the beaker. Another improvement that could have been made in the procedure was the position of the thermometer in the solution when it was being stirred. The thermometer should have been situated in the centre of the solution to measure the heat of the surroundings, however this was sometimes neglected and so the temperature recorded might have been different than that recorded. I made sure that I recorded the temperature when all of the calcium carbonate had been dissolved in the hydrochloric acid as this would give me a more accurate reading of the temperature change during the reaction.

Errors could also have occurred with regards to my measurements that I recorded this may have been due to human error (myself) or limitations of the equipment used. Probably the biggest measurement error that occurred in the experiment was with regards to the temperature change that take place during a reaction. This was because it was virtually impossible to get a more reliable answer than that to the nearest whole number. It would have been very unlikely that the true values of the temperatures to be a whole value therefore this would have caused error in my result. To solve this problem I could have used a different type of thermometer, such as a digital thermometer that gives a reading which is more accurate than that to the nearest whole number. Another measurement error that could have taken place was when measuring the masses of my substances. I only measured the masses of the substance to one decimal place, which wasn't very accurate to give me a more reliable result I should have measured masses up to more significant figures. To make the experiment more accurate I could have repeated the investigation more times, from the results of each separate experiment I could then have been able to calculate an average of my enthalpy changes.

Overall I feel I that the experiment went relatively well as I have done some research and found that other people have come to the same conclusion as me, which is that the thermal decomposition of calcium carbonate is an endothermic reaction.