Rates of reaction

Background information

A church was built on a hill; it was mainly made of marble and limestone. In 200 years the walls started to crack, and statues and carvings were not recognisable. It is believed that the cause of the reaction is acid rain.
In the area around the church, factories, vehicles and power stations all release acidic gases, which dissolve in rainwater.

One of the substances that cause acidic rain is sulphur dioxide; factories burn fuel containing this gas. When released, the sulphur dioxide reacts with water droplets. This makes an acid called sulphuric acid. However nitrogen oxides also cause acidic rain, acid rain is H2O, which has been reacted with nitrogen oxides or sulphur dioxide.

The chemical name of limestone and marble is calcium carbonate. This reacts slowly with acids releasing carbon dioxide. This is the process of chemical weathering, which has affected the church.

Problem / aim

The problem is to investigate the factors affecting the rate of weathering of calcium carbonate; we will investigate exactly what affects the rate of reaction. The chemical reaction we will conclude is, hydrochloric acid reacting with calcium carbonate. If they react, the bonds will break and a successful collision will take place.
The solution made is calcium chloride, and the gas, carbon dioxide will bubble off.

Word equation

Calcium carbonate + hydrochloric acid → calcium chloride + carbon dioxide + water

Symbol equation

$CaCo3(s) + HCL (aq) \rightarrow CaCl2 (aq) + CO2 (g) + H2O (l)$

Variables

I will measure the amount of gas that is produced by using a gas syringe; this will be measured in cm3. I will also record the amount of gas at regular time intervals.

The quantities that will remain the same will be the volume of hydrochloric acid. The variables will be:

1) The concentration of the acid, which will be the following range i) 0.1 molar ii) 0.5 molar iii) I molar iv) 1.5 molar v) 2 molar
2) The surface area of the calcium carbonate
3) The temperature at which the process takes place will also vary.

Prediction

I predict that with a more concentrated molar, such as 2 molar, the reaction will occur much faster than the 0.1 molar, 0.5 molar and the 1.5 molar acids. The bonds will collide and break, causing a successful collision. The 0.1 molar will be the slowest reaction as it is more dilute.

I think by changing the surface area of the calcium carbonate (marble) then the speed of the reaction will increase. If the marble is in the powder form, then this will react must faster than if the calcium carbonate is in a big chip, this would take much longer.

If the temperature in which the reaction takes place is at room temperature, this will take longer than if the reaction takes place at 50°c. The particles move quicker, and break bonds faster, however if the reaction takes place a 0°c, this will react much slower, the particles move less quickly, and it will take longer for a successful collision to occur.

Another way of affecting the rate of reaction is to add a catalyst. These will need to be experimented with, if these are going to be used. The type of catalyst will need to be experimented with to order to discover which one works best. Using a catalyst will speed up the rate of reaction.

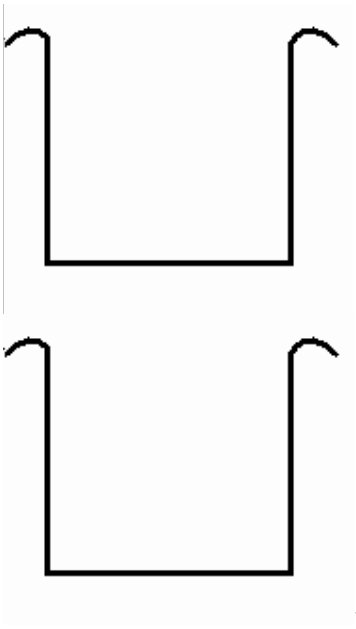
There for I believe that the fastest rate of reaction will take place at a high temperature, with a 2 molar acid and possible a catalyst, the surface area that will help the reaction to occur the most quickly is the powder calcium carbonate.

Apparatus

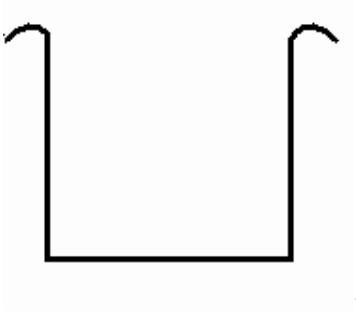
Hydrochloric acid
Calcium Carbonate chips (small and big), and powder
conical flask
Gas syringe
Rubber bung
Spatula
Clamp
Stand
Measuring cylinder
Stopwatch
Top pan balance

Diagram

Diagrams

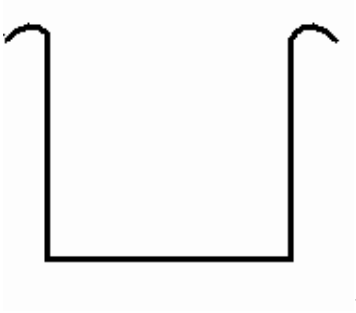


← Reaction taking place

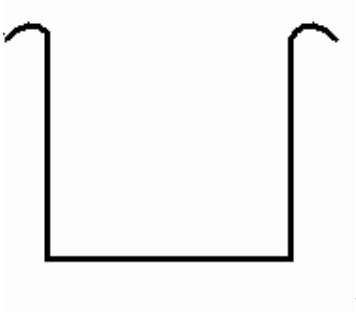


← No reaction

Prediction diagrams



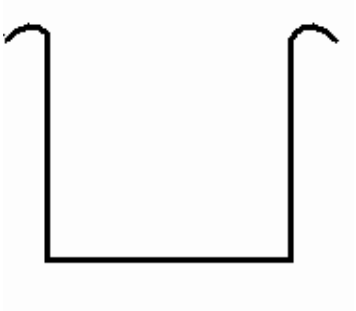
← 2 Molar acids



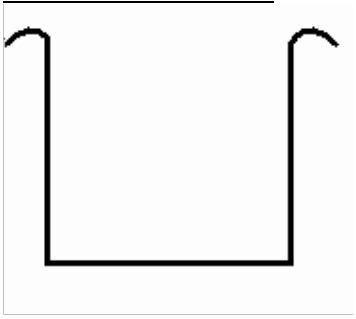
← 1 molar acid

Surface area

Large surface area



Small surface area



Method

1) The equipment was set out.
2) 30cm3 of hydrochloric acid was measured using a measuring cylinder.
3) Using a balance, 1g of calcium carbonate was measured.
4) Firstly the hydrochloric acid was poured into a conical flask, and then the calcium carbonate was placed in.
5) Immediately the bung was placed on the conical flask
6) At regular time intervals, the amount of gas produced was recorded into a table.

Concentration

For this experiment, I will measure the volume of hydrochloric acid, and the calcium carbonate. The surface area will remain he same, but the concentration of the acid will differ. The temperature will be constant at room temperature 23°c, and no catalyst will be added.

Surface area

For the second experiment, the surface area of the calcium carbonate will differ. There will be 3 types of this solid that will be used

1) Big chips
2) Small chips

3) Powder

The mass / weight of the calcium carbonate will remain the same, as will the temperature (23°c – room temperature) and no catalyst will be added, the molar will remain at 1M.

✧ Each experiment will be repeated 3 times for accuracy.

Safety

1. Always stand up when doing practical work, this ensures if anything is spilt then you can move quickly and easily.
2. Never run, this ensures that you don't trip
3. Always wear your safety goggles, this makes sure that nothing can damage your eye's
4. Always make sure that your bags are under the table, so that no one trips.
5. Always tuck in the stools; this is a way to ensure that the floor isn't cluttered.

Throughout this experiment, I will be aware of the equipment I will be using and I will recognise the fact that it is expensive glass equipment. As acid is being used, and a reaction will occur, I will protect my eyes using safety goggles and I will also clean up any spills, and be careful of acid.

Accuracy

My experiment will be accurate, because I will measure my substances precisely, and I will take accurate results. The experiment will be repeated 3 times, and all equipment will be fair.

Preliminary work

Surface area preliminary work

✧ I started off with 1g of calcium carbonate in a powder form, in a 30cm³ of 1M acids. This however went far too quickly so I decided to lower the acid volume.

✧ This time I had 1g of powder, in a 1M acid only, this time there was only 20cm³ in the conical flask. But this was again to fast. So the amount of calcium carbonate had to be lowered.

✧ The amount of acid was kept as 20cm³ and 1M was still used, but this time only 0.5g of powder was used. But this was a little to slow.

✧ For the small chips 0.5g of calcium carbonate was used and 20cm³ of 1M acids was used, but this was too slow so we

decided to increase the mass of the small chips to 1g, again this was too slow.

- ✧ This time 25cm³ of hydrochloric acid was used and 1g of calcium carbonate and but this was too fast, so . . .
- ✧ I decided that I would use 0.75g of calcium carbonate and 25cm³ of hydrochloric acid, this worked well with the powder, the large chips and the small chips, and they all went slow enough, but fast enough, to get a good reading.

Molar acid preliminary work

- ✧ For this experiment I tried 25cm³ of hydrochloric acid and 0.75g of calcium carbonate, I got these measurements from the surface area preliminary work, these results worked very well with all of the molar acids.

Results

1. For the concentration tests

seconds	1st trial	2nd trial	3rd trial	average
20	9	7	8	8
40	16	13	13	14
60	22	19	19	20
80	30	25	26	27
100	37	31	36	35
120	45	37	40	39
140	51	43	45	46
160	57	49	51	56
180	63	54	55	57
200	69	59	62	63
220	74	65	67	69
240	79	69	70	73
260	84	73	75	77
280	88	77	80	82
300	93	80	84	86
320	96	84	87	89
340	100	88	91	93
360	/	90	94	94
380	/	93	96	95
400	/	95	100	97
420	/	98	/	98
440	/	100	/	100

← 1 Molar acid, recorded every 20 seconds

- 0.75g of small chips
- 25cm³ of hydrochloric acid

seconds	1st trial	2nd trial	3rd trial	average
10	15	9	8	11
20	23	15	19	19
30	29	23	25	26
40	36	30	33	33
50	42	35	40	29
60	48	41	44	44
70	54	48	50	51
80	59	54	54	56
90	64	58	59	60
100	69	69	65	68
110	75	74	69	73
120	79	80	73	77
130	83	85	77	83
140	87	89	81	86
150	90	91	85	89
160	95	95	88	93
170	98	97	90	95
180	100	100	95	98
190			100	100

← 2 molar acid, recorded every 10 seconds

- 0.75g of small chips
- 25cm³ of hydrochloric acid

minutes	1st trial	2nd trial	3rd trial	average
1	8	7	6	7
2	16	12	12	13
3	23	17	19	20
4	29	25	25	26
5	35	29	29	31
6	40	34	35	36
7	44	38	40	41
8	48	42	46	45
9	51	49	49	50
10	60	60	55	58
11	63	65	63	64
12	69	67	68	68
13	77	77	74	76
14	81	80	81	81
15	85	85	85	85
16	89	88	91	89
17	91	92	94	92
18	96	95	96	96
19	97	100	100	99
20	100	/	/	100

← 0.5 Molar acid recorded every minute (60 seconds)

- 0.75g of small chips
- 25cm³ of hydrochloric acid

seconds	1st trial	2nd trial	3rd trial	average
20	11	9	8	9
40	18	16	15	16
60	29	23	24	20
80	39	31	31	34
100	49	39	39	42
120	59	47	46	51
140	68	55	55	59
160	76	61	61	66
180	84	68	66	73
200	90	75	74	80
220	94	80	80	85
240	98	85	85	89
260	100	89	90	93
280	/	93	95	94
300	/	97	99	98
320	/	100	100	100

← 1.5 Molar acid, recorded every 20 seconds

- 0.75g of small chips
- 25cm³ of hydrochloric acid

Tables for surface area

seconds	1st trial	2nd trial	3rd trial	average
10	40	32	45	39
20	55	41	47	48
30	64	59	52	58
40	69	65	59	64
50	72	71	67	70
60	75	76	75	76
70	77	80	79	79
80	80	83	85	83
90	83	87	89	86
100	87	88	91	89
110	89	92	93	91
120	91	94	97	94
130	95	96	100	97
140	100	98	/	99
150	/	100	/	100

← 1 molar acid, recorded every 10 seconds

- 0.75g of powder
- 25cm³ of hydrochloric acid

seconds	1st trial	2nd trial	3rd trial	average
30	12	13	10	12
60	19	20	19	19
90	33	29	27	30
120	37	32	35	35
150	42	41	45	43
180	49	49	50	49
210	53	57	57	56
240	65	69	70	68
270	74	76	75	75
300	82	81	80	81
330	87	89	87	88
360	93	92	94	93
390	100	100	100	100

← 1 molar acid, recorded every 30 seconds

- 0.75g of Big chips
- 25cm³ of hydrochloric acid

A	B	C	D	E
seconds	1st trial	2nd trial	3rd trial	average
20	10	12	9	10
40	17	15	13	15
60	23	19	17	20
80	29	22	21	24
100	32	23	25	27
120	35	31	29	32
140	42	35	35	37
160	47	39	39	42
180	52	45	42	46
200	53	51	47	50
220	61	59	52	57
240	65	62	57	61
260	79	69	62	70
280	82	72	69	74
300	84	77	73	78
320	92	81	79	84
340	97	87	82	89
360	100	92	89	94
380	/	97	95	96
400	/	100	100	100

← 1 molar acid, recorded every 20 seconds

- 0.75g of Small chips
- 25cm³ of hydrochloric acid

Evaluation/ conclusion

When predicting about this experiment, I stated that the more concentrated an acid was, the faster the reaction would take place. I found that this was actually true. I also said that when the acid was reacting with a bigger surface area, this would occur more slowly than if it was reacting with a smaller surface area, such as powder, I also found that this again was correct.
You can see from my results that what I predicted had actually happened, for example, the 1 molar acid took on average 440 seconds to finish, where as a 2 molar acid took on average 190 seconds to complete, this is double the amount if concentration, therefore decreasing the amount of reaction time. I also noticed, that decreasing the amount of surface area, made the rate of reaction increase, for example, for the powder experiment the reaction was at a gas volume of 100cm^3 in 150 seconds, whereas the big chips took 390 seconds to reach 100cm^3.
My predictions were pretty accurate, although I didn't actually say how much faster or slower each experiment would be in contrast to each other, all though my graphs indicate that there is no specific increase, between each result.
Averages made up the best and most accurate graph, this is because all of the averages together show, all of the results to the most accurate answer, this gives us an indication of how each experiment differs from one another, we can also use this to compare the results with each different experiment.

When actually doing the experiment, I discovered that most things went fairly well, such as accurate results, this was made easy because of the method of recording, and also because our preliminary work, was accurate enough to do the tests.
There were a few things that went wrong, such as; the bung didn't always go on the conical flask when it was needed, so that the experiment wouldn't be fair, this meant that we had to restart the testing.
The accuracy used in this experiment was very accurate, the timer was started at the right time, the results were recorded at the precise moment, and the substances were measured correctly and exactly to ensure that nothing other than rate of reaction would affect the experiments.
To improve this experiment, I could have used a catalyst or added heat, to discover what other than concentration and surface area, actually affected rates of reaction.
Overall I found that this experiment was very successful and I predicted pretty much exactly what happened. I was very safe, and followed the rules of safety every step throughout this experiment.