Science Investigation Into What Affects The Rate That An Aspirin Dissolves At In Water

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I am investigating how two different factors will separately affect the rate at which a single aspirin dissolves in water, these are:

- Temperature of water.
- Surface area of aspirin.

I could investigate the effects of stirring/agitating the solution and the use of a possible catalyst. However I feel it would be to hard to do the former accurately and fairly and regarding the latter there is no known catalyst that will speed up the dissolution of an aspirin in water, according to many science sites on the Internet. Concentration of water and aspirin would not affect the dissolution rate as at any time only the water touching the aspirin's outside can cause it to dissolve, this amount is always the same regardless of the amount of water, (providing the surface area remains constant).

Temperature

Method:

1) I will place 50ml of water in a beaker with a thermometer.
2) I will heat the water until it reaches the required temperature.
3) I will remove the beaker from the heat, take out the thermometer and put one aspirin into the water.
4) I will time how long it takes for the cross, drawn underneath the beaker, to disappear, and then record it on a table.

I will move up in ten-degree steps between each successive experiment from a range of 30-90ºC. These temperatures will be easy to achieve, it would be harder to get colder temperatures and with temperatures higher than one hundred degrees the water will start boiling which will interfere with the fairness of the experiment. I will repeat the experiment at each temperature three times then take an average for greater accuracy. I will remove the water from the heat as soon as the required temperature is reached then drop the aspirin in, immediately starting the clock as it comes into contact with the water. If I take the water away and the temperature is a little too low or high I will make a note of that on my results table. To make the experiment a fair test I will keep the volume of water used and surface area of the aspirin constant. I will not stir the solution and will use 50ml of water and a single whole aspirin of the same mass each time. The independent variable will be the temperature of the water. 1/time is proportional to the rate of dissolution so I will plot a graph of this quantity against temperature and so be able to observe the correlation between them. I believe that this set up for the experiments is the best approach and will offer reasonable accuracy. I do not have the equipment to maintain the temperature at exactly the right level or reach sub-zero levels, which would also take a long time to observe. The thermometer I will use is quite reliable and I will read it off correctly each time.

Prediction:

I think that as the temperature of the water increases the rate of dissolution of the aspirin will increase proportionally. This is because as the molecules of water get hotter they will get more energy and so the number of collisions with the aspirin's molecules will increase as they can move around faster, this will make the aspirin dissolve faster as there will be more energy present to break the attraction between the aspirin molecules. From a previous investigation I found out that increasing the temperature of a solution of sodium thiosulphate increased the rate at which it reacted with hydrochloric acid. I believe that this can be applied to the rate of dissolution of the aspirin in water in this investigation. The graph I expect to see of temperature against 1/time will look like this:

Surface Area

Method

1) I will place 50ml of water in a beaker over a cross that is easily visible.
2) I will cut an aspirin until I have the required surface area on it exposed.
3) I will place the pieces of aspirin in the water and time how long it takes until the cross is no longer visible, and then record the result in a table.

In the first experiment I will use a whole aspirin, then two halves, three thirds, four quarters, eight eighths and finally a finely ground power, made from one aspirin. As in the other half the investigation I will repeat each experiment three times and get an average to make the final results more accurate. Each time I will start the clock as the aspirin comes into contact with the water and stop as soon as the cross is no longer visible to me with the water being too cloudy to see it, I will use the same cross every time To make the experiment a fair test the temperature and volume of water will remain constant, at room temperature (23ºC approx) and 50ml respectively. For each experiment I will use 50ml of water, and a number of pieces of aspirin with the equivalent mass of a whole one, e.g. four quarters, and not agitate the solution in any way. The independent variable will be the surface area of the aspirin used in the experiment. 1/average time is proportional to the rate of dissolution so I will plot a graph of this quantity against surface area to observe what the correlation is between them. This experiment set up is the simplest and most accurate way for me to carry out the investigation in view that I cannot maintain the temperature absolutely with any apparatus and cannot cut the aspirin in to too many sections with a knife. In between eighths and powder the sections are too small to be cut and it would be impractical and inaccurate to attempt this.

Prediction

I think that as the surface area of the aspirin increases it will dissolve more quickly in the water. The rate of dissolution increasing proportionally with the surface area, e.g. if the surface area doubles the aspirin will be dissolved twice as fast. This is because with more surface area exposed to the water there will be more water molecules in contact with the aspirin's molecules so more collisions will occur and the rate of dissolution will be faster. I found out in a previous investigation that as the surface area of chips of calcium carbonate increased so did the rate of reaction they reacted with hydrochloric acid, with a proportiona1 relationship. I therefore believe that the same will be true for increasing the aspirin's surface area so I expect to see the rate of dissolution increase in proportion. The graph I expect to see of surface area against 1/time will look like this:

Safety

To be safe in both sets of experiments I will wear goggles, avoid burning or cutting myself, avoid spillage and not ingest any aspirins.

Results

Temperature Investigation

Temperature of water.	Time taken for cross to disappear- **one** (Seconds).	Time **two** (Seconds)	Time **three** (Seconds).	Average time (Seconds).	1/average time.
30ºC	25.56	25.93	25.61	25.70	0.04
40ºC	16.32	15.49	15.27	15.69	0.06
50ºC	15.45	13.27	14.95	14.55	0.07
60ºC	7.25	7.12	7.64	7.35	0.14
70ºC	4.65	4.72	4.66	4.68	0.21
80ºC	2.74	2.96	1.99	2.56	0.39
90ºC	2.67	1.51	2.50	2.25	0.44

Surface Area Investigation

Relative fractions of aspirin used.	Total surface area of aspirin (mm^2)	Time taken for cross to disappear- **one** (seconds).	Time **two** (seconds).	Time **three** (seconds).	Average time (seconds).	1/average time.
1	339.3	50.17	53.35	51.62	51.71	0.02
1/2	411.3	31.52	30.64	32.47	31.54	0.03
1/3	447.3	27.34	26.82	25.40	26.52	0.04
1/4	483.3	21.84	22.59	23.40	22.61	0.04
1/8	627.3	12.84	15.54	12.66	13.68	0.07
Powder	$\rightarrow\infty$	8.96	6.80	9.67	8.48	0.12

Conclusions

Temperature Investigation

Looking at the second graph, showing rate (1/time) against temperature, as the temperature increases so does the rate of dissolution. . My prediction was that the relationship between temperature and rate of dissolution would be proportional however this is not the case, as the gradient of the curve gets increasingly steeper. I think this occurs because at higher and higher temperatures the time taken for an aspirin to dissolve in the water is almost instantaneous so the rate branches off getting closer to infinity and it is harder to get an accurate time. I think this pattern occurs because when the water molecules are heated they get more kinetic energy, they therefore move about faster colliding with the aspirin's molecules more frequently and with greater energy can pull them apart from each other faster and so the aspirin dissolves faster.

Surface Area Investigation

The bar chart shows that as the aspirin is spilt into smaller and smaller fractions the time taken for the cross to disappear decreases. This occurs because when the aspirin is broken down into smaller parts it has more surface area available, e.g. a large cube with surface area $6x^2$ when split in half will have a larger surface area of $6x^2 + 2x^2$.

The graph of rate of dissolution (1/time) against surface area shows a straight line can be drawn through most of the points meaning that there is a proportional relationship between the rate of dissolution and the surface area of the aspirin. This agrees with my prediction almost exactly. I included powder on the graph and assumed that its surface area was very large, as with temperature when the surface area gets to a very high number it will dissolve almost immediately. I found the gradient of the graph to be 0.0058secs $^{1}/mm^{2}$, meaning that for every square millimetre the aspirin's surface area increased by the time taken for the cross to disappear decreased by 0.02 seconds.

I think this relationship occurs because with more surface area of the aspirin in contact with the surrounding water there are more aspirin molecules present for the water molecules to attract and pull apart from each other, so causing the aspirin to dissolve more quickly.

Evaluation

I believe that my two investigations worked quite well and enabled me to draw a good conclusion. By using my planned methods I was able to alter and control the right variables and answer the original question.

Temperature

The temperature experiments worked well and I believe that the method I used gave results that were quite accurate and a reliable conclusion. This is because all my colleagues who did the same experiment as me got similar results and many chemistry textbooks support my evidence. I feel my results were quite accurate as I took them over a fairly wide range and repeated each measurement three times at each stage to get an average. The highlighted measurement taken at 90ºC may have been out of line with the pattern because at temperatures approaching boiling point the aspirin dissolved in the water almost instantaneously so it was very hard to get an accurate time using a stopwatch. Any other error made, such as at 50ºC, may have happened because I had to rely on my eyes to tell me when the cross-had disappeared and sometimes it was hard to tell if it had completely or not. Sometimes when the aspirin was dropped in the beaker it stuck to one side and so the dissolving material did not spread over the whole cross, which meant it, was more difficult for me to judge when to stop timing. My method was the best way of doing the experiment with the equipment available, to improve it I could do a number of things. I could use a more accurate stopwatch and thermometer but I would still be relying on my eyes to make the important observations, so I could investigate whether its possible to place something in the water that will stop the timer when the concentration of aspirin gets to a certain level, which would be more accurate than the simple cross. To improve the accuracy of my results I could extend the range of them to get a more complete graph, this might involve the use of ice and cold water to reach temperatures beneath room temperature. I could also take even more measurements for each experiment to decrease their inaccuracy. To extend my investigation further and gain more supporting evidence I could investigate what affects the dissolution rate of other materials in water, such as sugar and salt, I could also find out about the way materials dissolve in liquids other than water and whether or not a change in temperature produces similar results from them.

Surface Area

I also think this investigation worked well and produced reliable results. The method was very simple, but worked well and produced clear results that enabled me to answer the original question. I think my results were quite accurate as I repeated each experiment three times for an average, however I would have liked to investigate over a larger range but this was not possible as cutting the aspirin smaller and smaller resulted in a loss of some aspirin material and irregular pieces that it was impossible to calculate the surface area for. My colleagues who also did the surface area investigation produced results that were very similar to mine and all the chemistry textbooks I have read also agree with my conclusion and results. Therefore I think I carried out the investigation quite accurately and carefully. The only result that does not fit the pattern quite as well is the measurement taken using quarters, this may have been because I did not cut the aspirin up accurately or cleanly and some of it was lost. Another area for error is, as mentioned in the temperature investigation the use of a cross as a method of measuring the dissolution rate. Unfortunately this was the only method available to me given the equipment I had. To improve my investigation I could find another, more accurate way of measuring the dissolution rate and also use a more cleaner and accurate instrument for cutting the aspirin with. I could also get a better stopwatch. To improve my results I could take more measurements at each stage for greater accuracy and also try and expand the range and number of results taken. I could do this by using more than one aspirin at a time and investigating the surface area of say, one and a half aspirins. I could also calculate the area of the little pieces more thoroughly and make cuts in different places to obtain results for a greater number of different surface areas. To extend my investigation I could use a different material, such as a sugar cube, and investigate the effects of changing its surface area. I could also see how using a different liquid changes the graph of surface area against one/time.