Hydrogen gas collection lab essay sample

A sample of solid magnesium ribbon, measuring approximately 2. 5cm and weighing 0. 037 g +/- 3% was allowed to react with an aqueous solution of hydrochloric acid, with a concentration of 6 mol dm-3 in a 1000cm3 graduated cylinder. The sample of magnesium was wrapped in a cage constructed of copper wire, and mounted on a holed rubber stopper, which was inserted into the end of a gas measuring tube, with 14. 90 cm3 +/- 0. 3% of 6 mol dm-3 HCl(aq) already in the tube with the rest of the gas measuring tube being filled with tap water. The gas measuring tube was then inverted into the 1000cm3 graduated cylinder, in which there was 790 cm3 +/- 0. 6% of tap water, and was allowed to react with the 6 mol dm-3 hydrochloric acid once it had descended down to where the magnesium strip lay since hydrochloric acid is denser than water (As told by teacher). This, in a vigorous reaction, produced a gas that ascended to the top of the gas measuring tube, and it can be said that it is mostly comprised of hydrogen gas, as per the following, balanced equation:

$Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$

(Michigan State University, n. d.)

Considering the main reactants are solid magnesium ribbon, and 6 mol dm-3 hydrochloric acid, the gas produced is hydrogen gas. The hydrochloric acid did not react with the copper wire that was holding the magnesium ribbon in place because of its position on the hydrogen side of the electrochemical series of metals (University of Siegen, n. d.).

Through stoichiometric calculations conducted in the data processing section of the investigation report, it was found that the theoretical yield of hydrogen

gas is 0. 0015 mol, since the reaction is limited by the amount of Mg(s) (ie. it is the limiting reactant).

It was found that, through using the ideal gas law and the observations recorded during the investigation (pressure, temperature, and volume) that the number of moles of hydrogen gas collected in the gas measuring tube were 0. 00156 mol +/- 2%, as calculated in the data processing section of the investigation report.

To determine the percentage yield of hydrogen gas in the reaction between 14. 90 cm3 +/- 0. 3% of 6 mol dm-3 HCl(aq) and 0. 0015 mol +/- 3% of Mg(s), the following equation is applied:

Percentage actual yield of hydrogen gas x 100

yield of = theoretical yield of hydrogen gas

hydrogen gas

= 0. 00156 mol x 100

0. 0015 mol

= 104%

Therefore, it can be said that that 4% too much hydrogen gas was collected during the investigation regarding the reaction between 14. 90 cm3 +/- 0. 3% of 6 mol dm-3 HCl(aq) 0. 037g +/- 3% of Mg(s).

To determine the percentage error in the investigation regarding the reaction of 14. 90 cm3 +/- 0. 3% of 6 mol dm-3 HCl(aq) and 0. 037g +/- 3% Mg(s), the following equation is applied:

Percentage

error in the

number of moles

of hydrogen gas

that should be

produced in = theoretical yield – experimental yield x 100

the reaction theoretical yield

observed in

the investigation = 0. 0015 mol – 0. 00156 mol x 100

between 6 mol dm-3 0. 0015mol

HCl(aq) and Mg(s)

= 4%

From the two calculations conducted, in regards to the percentage yield and percentage error of hydrogen gas collected, it can be said that since the percentage error exceeds the random uncertainty present in the measurements taken during the investigation and therefore the actual yield,

there exist some systematic errors that have caused the yield of hydrogen gas collected to be 4% too high. The uncertainty associated with the amount of hydrogen gas yielded is 2%, meaning that the excess amount of gas collected cannot be attributed to random error of measurements.

We cannot attribute the percentage difference to a lack of quality in the data collected, considering a highly accurate electronic balance was used for the massing of the magnesium, and all other measuring devices were appropriate to the data they were collecting. An example of the extensive care that was taken is the fume hood was dropped down when massing the magnesium over the electronic balance to prevent any movements in the surrounding air to adversely affect the result. Therefore, neither random uncertainty nor faulty equipment can be ascribed to the percentage error being greater than the random uncertainty associated with the actual yield of hydrogen gas collected. Considering these ideas, the sources of error must be consulted to gain some insight into the where the investigation procedure faltered.

Sources of Error:

Format:

–> Identifying source of error

–> Identifying and explaining effect of said source of error

–> Offering remedies/steps that could limit/eliminate said source of error

1. The final temperature that was taken after the reaction between the 6 mol dm-3 HCl(aq) and Mg(s) was of the 790 cm3 +/- 0. 6%, of tap water in the 1000cm3 graduated cylinder, which was surrounding the gas measuring tube. The temperature of the water is important in determining the temperature of the water vapour that will inevitably be present in the gas collected in the gas measuring tube, however since the reaction of hydrochloric acid and solid magnesium is exothermic, it can be assumed that the temperature in the gas measuring tube was somewhat higher than the rest of the water in the 1000cm3 graduated cylinder. (Johnson, n. d.)

Assuming the temperature within the gas measuring tube is higher than what was measured by the thermometer measuring from the side of the 1000cm3 graduated cylinder, and the tap water surrounding the gas measuring tube, that means that of the 102. 71 kPa +/- 0. 01, less pressure is actually being exerted by dry hydrogen gas, and more from the water vapour in the gas collected. This is because at higher temperatures, water vapour will exert higher pressures, for example: assume the temperature inside the gas measuring tube was 25ï¿½C, this would mean that the water vapour is then at a pressure of 3. 17 kPa. Therefore, less pressure is being exerted by the dry hydrogen gas, and through calculations with the ideal gas law, the number of moles of hydrogen gas would decrease, and reduce the percentage yield. In the case of the investigation, the pressure that was calculated, and assumed as being the pressure exerted by the dry hydrogen gas was likely too high, and therefore drove up the value for the actual yield of hydrogen gas.

This source of error can be remedied by placing the thermometer directly against the gas measuring tube, so as to get a more accurate reading of the temperature inside the tube. By doing so, the fact that heat is dispersed by the water bath surrounding the gas measuring tube is avoided to a greater extent, and a more accurate reading of the temperature inside the gas measuring tube can be taken.

(In fact, if the temperature was 25 degrees Celsius, this would bring the actual yield within 2% of the theoretical yield, and this discrepancy could therefore be attributed to random error of measurements.)

2. As was observed during the investigation, after the reaction between 6 mol dm-3 HCl(aq) and Mg(s) had ceased, a substantial number of pockets of clear liquid remained on the sides of the gas measuring tube that could not be shaken down. These pockets were situated in the part of the gas measuring tube that the hydrogen gas that was collected had settled.

The presence of these beads/pockets of liquids was likely a key factor behind the heightened percentage yield of hydrogen gas collected. Since they occupy volume in the gas measuring tube, namely in the space that was intended for only the hydrogen gas to be collected, these pockets of liquid will work to increase the measurement of what should be only the volume of hydrogen gas collected. Therefore, these pockets of liquid had the effect of increasing the percentage yield of hydrogen gas collected.

This source of error could be limited, but likely not eliminated, by reaching into the 1000cm3 graduated cylinder, and removing the holed rubber stopper with the solid magnesium/copper wire cage structure mounted on it,

and removing it. It would be safe to do so since by this point, the concentrated hydrochloric acid will have escaped through the hole of the stopper and settled at the bottom of the 1000cm3 graduated cylinder. Care should be taken that upon doing so, the lip of the gas measuring tube does not breach the surface of the water, to ensure the hydrogen gas collected stays in the tube, and no air pockets enter the gas measuring tube. After this has been done, a long, malleable wire/pipe cleaner with some bristles or other cleaning apparatus attached to the end of it, can be carefully inserted into the end of the gas measuring tube and run up to the end in an attempt to scrape out/dislodge the pockets of liquid that have attached themselves to the side of the gas measuring tube. Again, great care should be taken in ensuring the lip of the gas measuring tube does not breach the surface of the water, and that the tap water bath inside the 1000cm3 graduated cylinder is not too disturbed to as to keep the concentrated hydrochloric acid that remained in excess, at the bottom of the graduated cylinder. This will therefore more accurately represent the actual volume the gas collected is occupying.

3. As was also noted in the qualitative observations, even before the solid magnesium/copper wire cage structure, mounted on the holed rubber stopper, was inserted into the gas measuring tube whilst upright, there were small bubbles of gas along the inside of the gas measuring tube. This means they were not produced by the reaction between the solid magnesium and 6 mol dm-3 HCl(aq) since they had not yet come in contact. Even the bubbles towards the opening end of the gas measuring tube would have been dislodged and measured as part of the hydrogen gas collected, once the

reaction has started between the solid magnesium ribbon and 6 mol dm-3 HCl(aq) since the hydrogen gas produced by their reaction would bump into them, and both the hydrogen gas and the air bubbles would be counted as being part of the hydrogen gas collected by the reaction between solid magnesium ribbon and 6 mol dm-3 HCl(aq).

This would mean that not all of the gas collected by the gas measuring tube during the reaction of solid magnesium ribbon and 6 mol dm-3 HCl(aq) is in fact hydrogen gas. Therefore, this would cause the volume recorded to not be representative of the amount of hydrogen gas collected, since it is not all hydrogen gas. This would have the effect of increasing the actual yield of hydrogen gas measured, and can therefore be attributed as one of the systematic errors at play during the investigation that lead to the 104% percentage yield of hydrogen gas.

This source of error can be mitigated by performing a similar procedure with the source of error previously listed, except this time the gas measuring tube and its contents will be upright. This means running a cleaning utensil (pipe cleaner, etc…) down the length of the gas measuring tube once it has been filled with liquids. However, a procedural change will have to be applied: the hydrochloric acid will have to be added after the cleaning has been conducted, and therefore, only about 3/4 of the gas measuring tube should be filled – leaving enough room to add the hydrochloric acid. This remedy achieves two things: it prevents any of the hydrochloric acid from staying on the cleaning device and therefore loosing reactant, and two, it dislodges a significant amount of the air bubbles trapped in the gas measuring tube,

though likely not all, since once the hydrochloric acid fills in the remaining part of the gas measuring tube, some more bubbles will appear.

4. The value recorded for the pressure is that of the atmosphere in the region – meaning it was derived from a local organisation tracking atmospheric conditions. This is a source of error because the pressure may have changed from the time the measurement was taken, and the pressure within the investigation environment is likely not equal to the atmospheric pressure that was measured earlier, at a different location.

If the pressure in the investigation environment (class room) were to be lower than the stated value of 102. 71 kPa, then the actual yield of hydrogen gas would decrease from the actual yield calculated with the stated pressure. If the pressure in the investigation environment were higher than the stated value of 102. 71 kPa, then the actual yield of hydrogen gas would increase from the actual yield that was derived with the stated pressure. Therefore, it can be assumed that there likely were some elevated pressure levels in the investigation environment that contributed to the increased percentage yield of hydrogen gas.

This source of error could be limited by using a barometer in the investigation environment itself to determine the pressure in the immediate vicinity of the investigation. This will eliminate the delay in reporting/change of the pressure recorded by the weather reporting organisation consulted, and accounts for the discrepancy in distance from said barometer by measuring the pressure in the immediate vicinity of the investigation.

The above sources of error worked to increase the actual yield of hydrogen gas produced by the reaction of 0. 037mol +/- 3% solid magnesium ribbon and 14. 90 cm3 +/- 0. 3% 6 mol dm-3 HCl(aq). However, considering the likely volume of the air bubbles observed in the gas measuring tube before the solid magnesium ribbon/copper wire cage structure mounted on the holed rubber stopper was inserted into the upright gas measuring tube, and the likely volume of the pockets of clear liquid remaining on the sides of the gas measuring tube where the hydrogen gas had collected after the reaction, there are other sources of error that worked to decrease the percentage yield of hydrogen gas produced. Meaning, the above sources of error alone would likely produce a greater percentage error, therefore the following source of error must also be considered, since it too was at play during the investigation.

5. The impurity of one of the reactants must be considered as a source of error in this investigation. It is widely known that magnesium is often contaminated with magnesium oxide on its surface, and hence the likely reason behind cleaning it with the steel wool, which is mainly comprised of iron (Lenntech, n. d.) (Elmherst College, n. d.). However, this resulted in two things: one, the steel wool was likely not enough to completely clean the magnesium of the magnesium oxide on the surface, and two, some iron particles were thus added onto the magnesium ribbon as mass. The presence of magnesium oxide is further confirmed by the qualitative observations, which state that bubbling wasn’t vigorous immediately, thus attributable to the hydrochloric acid cleaning the surface of the magnesium

ribbon and producing water and aqueous magnesium chloride as observed by the following equation:

MgO(s) + 2HCl(aq) –> MgCl2(aq) + H2O(l)

(Southeast Missouri State University, n. d.)

Since the mass measurement of the magnesium ribbon was conducted after the cleaning with steel wool, this means the ribbon had magnesium, magnesium oxide (which is hygroscopic, and therefore attracted extra mass by pulling in the water molecules and carbon dioxide molecules from the atmosphere), and iron particles from the steel wool at the time of being massed out (Sciencelab, 2010). The iron reacts in the same stoichiometric proportions as the magnesium would, as seen by the following balanced equation:

Fe(s) + 2HCl(aq) –> FeCl2(aq) + H2(g) (Colling, n. d.)

However, the molar mass of iron is significantly higher than that of magnesium. For example, if there were 48. 62 g of magnesium ribbon cleaned with steel wool, and it contained 5. 59 g of iron, there would not be 2 mol of magnesium, but 1. 77 mol of magnesium and 0. 100 mol of Iron. 1. 77 mol + 0. 100 mol equals 1. 87 moles, and therefore, one would get less product, even though they react at the same mole ratios. This would work to reduce the percentage yield of hydrogen gas since there are actually less particles (Magnesium and Iron) that are able to react with the hydrochloric acid to produce hydrogen gas. This is because the theoretical yield assumes the mass of magnesium ribbon is purely magnesium. As for the magnesium

oxide, it does not produce any hydrogen gas when reacted with hydrochloric acid; instead, it produces aqueous magnesium chloride and liquid water.

This means, it was likely present to some extent on the magnesium ribbon even after cleaning with steel wool, was massed, and ended up only taking up mass on the magnesium ribbon in addition to the water and carbon dioxide molecules it had attached to itself. Therefore, it too contributed to decreasing the percentage yield of hydrogen gas collected in the gas measuring tube by the reaction of solid magnesium and concentrated hydrochloric acid by increasing the theoretical yield without producing any hydrogen gas since it was taken to be all magnesium. However, it was not enough to offset the volume of the bubbles present in the gas measuring tube before the reaction of the solid magnesium and concentrated hydrochloric acid, and the volume of the liquid pockets found in the area where the hydrogen gas had collected in the gas measuring tube.

To mitigate this source of error, a few steps should be followed. For one, a slightly larger piece of solid magnesium ribbon should be cut. This should be followed by a wash in distilled water, followed by a wash in less concentrated hydrochloric acid (0. 5 mol dm-3) to strip away the magnesium oxide from the surface of the magnesium. Another wash with distilled water and drying with paper towel, followed by immediate insertion into the copper wire cage and ultimately the gas measuring tube and its solution of concentrated hydrochloric acid, will thus circumvent the need for the presence of iron, while more effectively ridding the magnesium ribbon of its magnesium oxide surface.

Conclusion:

A sample of solid magnesium ribbon, cleaned with steel wool before massing, weighing 0. 037 g +/- 3% was allowed to react with 14. 90 cm3 +/- 0. 3% 6 mol dm-3 HCl(aq) in an inverted gas measuring tube, surrounded by 790 cm3 +/- 0. 6% of tap water. The magnesium ribbon was mounted on a copper wire cage, which had been held in place by running it through a hole in a rubber stopper and bending the protruding end to ensure it held in place. The reaction was allowed to continue until it had been deemed to have ceased, and five minutes was allotted to ensure the reaction had completed, after which point the final temperature and volume of the gas collected was recorded. The atmospheric pressure was also relied upon so that the number of moles of hydrogen gas produced could be calculated using the ideal gas law, PV= nRT, ie. the actual yield was 0. 0015 mol +/- 3%. The hydrochloric acid did not react with the copper wire cage holding the magnesium in place thanks to the copper’s position on the electrochemical series of metals and its placement as a noble metal.

It is worth noting that there was a change in temperature noticed in the of the 790 cm3 +/- 0. 6% tap water bath from before the gas measuring tube was inverted and inserted, and after the reaction had ceased between the solid magnesium ribbon attached in the copper wire structure, mounted on the holed rubber stopper and 6 mol dm-3 HCl(aq) of 0. 5 ï¿½C and thus further emphasizing the need for a more accurate temperature reading closer to the gas measuring tube itself so as to ensure a more accurate reflection of the temperature of the hydrogen gas collected.

The investigation appears to be riddled with systematic errors that resulted in a somewhat distorted result, with sources of error both working to the increase in percentage yield, and some decreasing it like impurity of reactants. It is as such that future investigations should take into account the above listed sources of error to improve the quality of data collected, and conduct more trials to improve precision.

It was found that reacting a piece of solid magnesium ribbon weighing 0. 037 g +/- 0. 001 with 14. 90 cm3 +/- 0. 05 of 6 mol dm-3 HCl(aq) in an inverted gas measuring tube, with a holed rubber stopper that had a copper wire cage mounted on it which held in place the solid magnesium ribbon, that 0. 00156 mol +/- 2% of hydrogen gas were produced. However, considering the sources of error above, the validity of the statement that 0. 00156 mol +/- 2% of hydrogen gas was present in the gas measuring tube after the reaction of solid magnesium ribbon and 6 mol dm-3 HCl(aq) as reacted in the trial, is highly unlikely considering the percentage error and thus the presence of systematic errors.

It can be said that the percentage yield of hydrogen gas from the reaction of a piece of Mg(s) ribbon, cleaned with steel wool, weighing 0. 037g +/- 0. 001 with 14. 90 cm3 +/- 0. 05 of 6 mol dm-3 HCl(aq) in an inverted gas measuring tube gave a percentage yield of hydrogen gas equal to 104%.

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