An Investigation into the Empirical Formula of a Copper Chloride Hydrate

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Academic Honesty Statement

I have read and agree to the terms of the Academic Honesty Statement.

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Introduction

This report investigates the impact of heating a hydrate salt and how that helps determine the empirical formula of said hydrate salt. A hydrate is an inorganic salt with a fixed ratio of water either bound to a metal center or crystalized within the metal complex (Sanders, 2019). A hydrate can have its water removed by heating, which changes it into an anhydride (Sanders, 2019). In this experiment, we heated an unknown copper chloride hydrate salt and used a single replacement reaction with aluminium to determine the percent composition of water, copper and chlorine (Sanders, 2019). Using the determined percent compositions of all the components of the hydrate salt, we can calculate an empirical formula for the hydrate salt (Sanders, 2019). The hypothesis is; if we heat the hydrate salt and, in this specific case, react the hydrate salt with aluminium, then with the information we obtain we can determine the hydrate salt’s empirical formula.

Methods

A crucible was massed before and after 1g of an unknown copper chloride hydrate was added (Sanders, 2019). The sample was gently heated with a Meker burner while being stirred until all of the sample turned brown (Sanders, 2019). After the sample turned brown, it was heated for an additional two minutes then left alone to cool (Sanders, 2019). Once the sample was cooled, it was massed and the results were recorded in table 10.1 (Sanders, 2019). A new 2g sample of the unknown copper chloride is dissolved in a 50mL beaker with 15mL of deionized water with the results recorded in table 10.1 (Sanders, 2019). A 0.3g piece of aluminium foil was obtained and massed with its weight recorded in table 10.1 (Sanders, 2019). The aluminium foil was torn into smaller pieces and slowly dissolved into the solution and stirred until completion (Sanders, 2019). Five drops of 6M HCl was added to the solution and stirred with a glass rod. Residue aluminium foil was removed with tweezers and the solution with precipitate was rinsed into a Büchner funnel using a portion of 20mL of deionized water (Sanders, 2019). The precipitate was vacuum filtered as the remainder of the 20mL of deionized water was used to wash it (Sanders, 2019). 10mL of ethanol was added for one minute before it was vacuum filtered for five minutes (Sanders, 2019). A watch glass was massed, and the value recorded in table 10.1, and the filtered precipitant was transferred to the watch glass to be dried by the GTA (Sanders, 2019). The dried precipitant in the watch glass was massed and the value was recorded in table 10.1 (Sanders, 2019). The entire experiment was repeated for a second trial (Sanders, 2019).

Results

Table 10.1 Results of Water of Hydration and Copper Determination

|  |  |  |  |
| --- | --- | --- | --- |
| Part A. Water of Hydration | Trial 1 | Trial 2 | Average |
| Mass of Crucible (g) | 23.467 | 23.466 | 23.4665 |
| Mass of Crucible + Hydrate sample (g) | 24.401 | 24.459 | 24.43 |
| Mass of Hydrate sample (g) | 0.934 | 0.993 | 0.9635 |
| Mass of Crucible + Anhydrous sample (g) | 24.227 | 24.317 | 24.272 |
| Mass of Anhydrous sample (g) | 0.76 | 0.851 | 0.8055 |
| Mass of Water Evolved (g) | 0.174 | 0.142 | 0.158 |
| Percent Composition of Water in Hydrate | 18.63% | 14.30% | 16.40% |
| Part B. Copper Determination | Trial 1 | Trial 2 | Average |
| Step 16 Observations | When dissolved, it is blue | | |
| Mass of Hydrate for part B (g) | 2.011 | 2.011 | 2.011 |
| Mass of Aluminium (g) | 0.304 | 0.305 | 0.3045 |
| Mass of Watch Glass (g) | 42.639 | 42.703 | 42.671 |
| Mass of Watch Glass + Copper (g) | 43.509 | 43.440 | 43.4745 |
| Mass of Copper (g) | 0.87 | 0.737 | 0.803 |
| Percent Composition of Copper in Hydrate | 43.26% | 36.65% | 39.96% |
| Percent Composition of Chlorine in Hydrate | 38.11% | 49.05% | 43.65% |

Equation 10.1

|  |  |  |  |
| --- | --- | --- | --- |
| Moles of H2O | 16.40 g H2O | 1 Mol H2O | =0.9104 Mol H2O |
|  |  | 18.015 g H2O |  |

This is the calculation to determine the number of moles of H2O assuming 100g of the hydrous copper chloride salt. According to the experiment, 16.40g of H2O would be present it every 100g of the hydrous salt, and according to literature, there are 18.015g of H2O for every mole of H2O (“Water”, 2019).

Equation 10.2

|  |  |  |  |
| --- | --- | --- | --- |
| Moles of Cu | 39.96 g Cu | 1 Mol Cu | =0.6288 Mol Cu |
|  |  | 63.55g Cu |  |

This is the calculation to determine the number of moles of Cu assuming 100g of the hydrous copper chloride salt. According to the experiment, 39.96g of Cu would be present it every 100g of the hydrous salt, and according to literature, there are 63.55g of Cu for every mole of Cu (“Copper”, 2019).

Equation 10.3

|  |  |  |  |
| --- | --- | --- | --- |
| Mol of Cl | 43.65 g Cl | 1 Mol Cl | =1.231 Mol Cl |
|  |  | 35.45g Cl |  |

This is the calculation to determine the number of moles of Cl assuming 100g of the hydrous copper chloride salt. According to the experiment, 43.65g of Cl would be present it every 100g of the hydrous salt, and according to literature, there are 35.45g of Cl for every mole of Cl (“Chlorine atom”, 2019).

Equation 10.4

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Mol ratio H2O | 0.9104 Mol H2O | =1.448 ≈1.5 | | 1.5\*2 =3 |
|  | 0.6288 Mol Cu |  |  | |

This is the calculation to determine the mole ratio of H2O in the hydrous copper chloride salt, where the moles are acquired from equation 10.1 above and represent the number of moles of H2O in a 100g sample of the hydrous salt.

Equation 10.5

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Mol ratio Cu | 0.6288 Mol Cu | =1 | 1\*2 =2 | |
|  | 0.6288 Mol Cu |  | |  |

This is the calculation to determine the mole ratio of Cu in the hydrous copper chloride salt, where the moles are acquired from equation 10.1 and 10.2 above and represent the number of moles of H2O and Cu respectively in a 100g sample of the hydrous salt.

Equation 10.6

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Mol ratio Cl | 1.231 Mol Cl | =1.958 ≈2 | 2\*2 =4 | |
|  | 0.6288 Mol Cu |  | |  |

This is the calculation to determine the mole ratio of Cl in the hydrous copper chloride salt, where the moles are acquired from equation 10.1 and 10.3 above and represent the number of moles of H2O and Cl respectively in a 100g sample of the hydrous salt.

Table 10.2 Comparison of Experimental and Literature Empirical Formula

|  |  |  |  |
| --- | --- | --- | --- |
| Experimental Empirical Formula: | | | Cu2Cl5.3H2O |
| Literature Empirical Formula: | | | CuCl2.H2O |
| Exp Percentage | Exp Mole Ratio | Literature Mole Ratio | Literature Percentage |
| H2O 16.40% | 3 | 1 | 11.82% |
| Cu 39.96% | 2 | 1 | 41.68% |
| Cl 43.65% | 5 | 2 | 46.50% |

Discussion

The results from the experiment and the literature value are comparable, with chlorine only being 2.85% smaller than the literature value, copper only being 1.72% smaller, and water being 4.58% larger (“Cupric chloride hydrate”, 2019). Our results do not support our hypothesis because our results imply there being more water in the hydrate crystal than there actually is while also implying there being less chlorine than there actually is. The error is likely due to mistakes during the experiment with potentially coming from overheating the hydrate causing some of the copper or chlorine to vaporize and giving water a disproportionately large percent composition while causing copper and chlorine to have a disproportionately small percent composition. This uncertainty could be mitigated with more trials to minimize the error from any one trial.

References

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