Formula of Unknown Hydrate Lab Report

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Contents

1 Pre-lab

1.1 Purpose

To determine the formula of an unknown hydrate.

1.2 Procedure Summary

1. Prepare a table to record all determined masses.
2. Heat a crucible and cover for 3 mins, then let it cool for 5 mins. Measure its mass.
3. Put 4g of the unknown hydrate in the crucible and determine the total mass.
4. Heat crucible for 5 mins, then increase heat and heat for another 5 mins.
5. Let the crucible cool and determine its mass.
6. Reheat the crucible for 3 mins, let cool, and determine its mass.

2 Data Tables

2.1 Collected Data

Table 1: collected experimental values

Variable	**Value**
Initial mass of crucible and cover	$24.87\text{g} \pm 0.01\text{g}$
Mass of crucible, cover, and hydrate before heating	$28.95\text{g} \pm 0.01\text{g}$
Mass of crucible, cover, and hydrate after heating	$26.96\text{g} \pm 0.01\text{g}$
Mass of crucible, cover, and hydrate after second heating	$26.93\text{g} \pm 0.01\text{g}$

2.2 Given Data

Table 2: molar masses of each potential salt

Hydrate	**Salt**	**Molar mass of salt**
$BaCl_2 \cdot 2\,H_2O$	$BaCl_2$	$208.23\text{g}\,\text{mol}^{-1}$
$CaSO_4 \cdot 2\,H_2O$	$CaSO_4$	$136.14\text{g}\,\text{mol}^{-1}$
$MgSO_4 \cdot 7\,H_2O$	$MgSO_4$	$120.37\text{g}\,\text{mol}^{-1}$
$CuSO_4 \cdot 5\,H_2O$	$CuSO_4$	$159.61\text{g}\,\text{mol}^{-1}$
$NiCl_2 \cdot 6\,H_2O$	$NiCl_2$	$129.60\text{g}\,\text{mol}^{-1}$

2.3 Calculated Data

Table 3: Calculated values for unknown hydrate

Variable	**Value**
Mass of hydrate before heating	$4.08\text{g} \pm 0.02\text{g}$
Mass of hydrate after (second) heating	$2.06\text{g} \pm 0.02\text{g}$
Mass of water	$2.02\text{g} \pm 0.04\text{g}$
Percentage water	$(49.51 \pm 1.22)\%$

Table 4: percentage water of each potential hydrate

Hydrate	$\%H_2O$
$BaCl_2 \cdot 2\,H_2O$	14.75%
$CaSO_4 \cdot 2\,H_2O$	20.93%
$MgSO_4 \cdot 7\,H_2O$	51.20%
$CuSO_4 \cdot 5\,H_2O$	36.08%
$NiCl_2 \cdot 6\,H_2O$	45.48%

3 Qualitative Observations

3.1 Before Heating

- hydrate is a white crystal substance
- grains of hydrate are larger than those of table salt
- individual grains are translucent

3.2 During First Round of Heating

- sizzling noise is apparent when heating
- hydrate appears to solidify from the center outwards
- sizzling is more faint after 5 minutes of heating
- during second 5 minutes of heating:
  - there is minimal sizzling
  - substance is less translucent and more opaque
  - crystals are much smaller
- after heating, crystals appear to have merged into one big solid structure

3.3 During Second Round of Heating

- not much difference in appearance during second heating
- after second heating, the substance has completely merged into one big solid

4 Calculations

4.1 Mass of Hydrate Before Heating

$$\begin{aligned} m_i &= m_{\text{hydrate + crucible}} - m_{\text{crucible}} \\ &= (28.95\text{g} \pm 0.01\text{g}) - (24.87\text{g} \pm 0.01\text{g}) \\ &= (28.95\text{g} - 24.87\text{g}) \pm (0.01\text{g} + 0.01\text{g}) \\ m_i &= 4.08\text{g} \pm 0.02\text{g} \end{aligned}$$

4.2 Mass of Hydrate After (Second) Heating

$$\begin{aligned} m_f &= m_{\text{hydrate + crucible}} - m_{\text{crucible}} \\ &= (26.93g \pm 0.01\text{g}) - (24.87 \pm 0.01\text{g}) \\ &= (26.93\text{g} - 24.97\text{g}) \pm (0.01\text{g} + 0.01\text{g}) \\ m_f &= 2.06\text{g} \pm 0.02\text{g} \end{aligned}$$

4.3 Mass of Water in Hydrate

$$\begin{aligned} m_{\text{H}_2\text{O}} &= m_i - m_f \\ &= (4.08\text{g} \pm 0.02\text{g}) - (2.06\text{g} \pm 0.02\text{g}) \\ &= (4.08\text{g} - 2.06\text{g}) \pm (0.02\text{g} + 0.02\text{g}) \\ m_{\text{H}_2\text{O}} &= 2.02\text{g} \pm 0.04\text{g} \end{aligned}$$

4.4 Experimental Percentage Water

$$\begin{aligned}
\%\mathrm{H_2O} &= \frac{m_{\mathrm{H_2O}}}{m_i} \times 100\% \\
&= \frac{2.02\mathrm{g} \pm 0.04\mathrm{g}}{4.08\mathrm{g} \pm 0.02\mathrm{g}} \times 100\% \\
&= \left(\frac{2.02\mathrm{g}}{4.08\mathrm{g}} \pm \left(\frac{0.04\mathrm{g}}{2.02\mathrm{g}} + \frac{0.02\mathrm{g}}{4.08\mathrm{g}}\right) \times 100\%\right) \times 100\% \\
&= (0.4951 \pm 2.47\%) \times 100\% \\
&= (0.4951 \pm 0.0122) \times 100\% \\
\%\mathrm{H_2O} &= (49.51 \pm 1.22)\%
\end{aligned}$$

4.5 Theoretical Percentage Water in Each Potential Hydrate

4.5.1 $\mathbf{BaCl_2 \cdot 2\,H_2O}$

$$\begin{aligned}
M_{2\,\mathrm{H_2O}} &= 2 \cdot 18.02\mathrm{g\,mol^{-1}} \\
M_{2\,\mathrm{H_2O}} &= 36.04\mathrm{g\,mol^{-1}} \\
M_{\mathrm{BaCl_2 \cdot\ 2\,H_2O}} = M_T &= M_{\mathrm{BaCl_2}} + M_{2\,\mathrm{H_2O}} \\
&= 208.23\mathrm{g\,mol^{-1}} + 36.04\mathrm{g\,mol^{-1}} \\
M_T &= 244.27\mathrm{g\,mol^{-1}}
\end{aligned}$$

$$\begin{aligned}
\%\mathrm{H_2O} &= \frac{M_{2\,\mathrm{H_2O}}}{M_T} \times 100\% \\
&= \frac{36.04\mathrm{g\,mol^{-1}}}{244.27\mathrm{g\,mol^{-1}}} \times 100\% \\
\%\mathrm{H_2O} &= 14.75\%
\end{aligned}$$

4.5.2 $\mathbf{CaSO_4 \cdot 2\,H_2O}$

$$\begin{aligned}
M_{2\,\mathrm{H_2O}} &= 2 \cdot 18.02\mathrm{g\,mol^{-1}} \\
M_{2\,\mathrm{H_2O}} &= 36.04\mathrm{g\,mol^{-1}} \\
M_{\mathrm{CaSO_4 \cdot\ 2\,H_2O}} = M_T &= M_{\mathrm{CaSO_4}} + M_{2\,\mathrm{H_2O}} \\
&= 136.14\mathrm{g\,mol^{-1}} + 36.04\mathrm{g\,mol^{-1}} \\
M_T &= 172.18\mathrm{g\,mol^{-1}}
\end{aligned}$$

$$
\begin{aligned}
\%\mathrm{H_2O} &= \frac{M_{2\,\mathrm{H_2O}}}{M_T} \times 100\% \\
&= \frac{36.04\mathrm{g\,mol^{-1}}}{172.18\mathrm{g\,mol^{-1}}} \times 100\% \\
\%\mathrm{H_2O} &= 20.93\%
\end{aligned}
$$

4.5.3 $\mathbf{MgSO_4 \cdot 7\,H_2O}$

$$
\begin{aligned}
M_{7\,\mathrm{H_2O}} &= 7 \cdot 18.02\mathrm{g\,mol^{-1}} \\
M_{7\,\mathrm{H_2O}} &= 126.28\mathrm{g\,mol^{-1}} \\
M_{\mathrm{MgSO_4 \cdot\,7\,H_2O}} = M_T &= M_{\mathrm{MgSO_4}} + M_{7\,\mathrm{H_2O}} \\
&= 120.37\mathrm{g\,mol^{-1}} + 126.28\mathrm{g\,mol^{-1}} \\
M_T &= 246.65\mathrm{g\,mol^{-1}}
\end{aligned}
$$

$$
\begin{aligned}
\%\mathrm{H_2O} &= \frac{M_{7\,\mathrm{H_2O}}}{M_T} \times 100\% \\
&= \frac{126.28\mathrm{g\,mol^{-1}}}{246.65\mathrm{g\,mol^{-1}}} \times 100\% \\
\%\mathrm{H_2O} &= 51.20\%
\end{aligned}
$$

4.5.4 $\mathbf{CuSO_4 \cdot 5\,H_2O}$

$$
\begin{aligned}
M_{5\,\mathrm{H_2O}} &= 5 \cdot 18.02\mathrm{g\,mol^{-1}} \\
M_{5\,\mathrm{H_2O}} &= 90.10\mathrm{g\,mol^{-1}} \\
M_{\mathrm{CuSO_4 \cdot\,5\,H_2O}} = M_T &= M_{\mathrm{CuSO_4}} + M_{5\,\mathrm{H_2O}} \\
&= 159.61\mathrm{g\,mol^{-1}} + 90.10\mathrm{g\,mol^{-1}} \\
M_T &= 249.71\mathrm{g\,mol^{-1}}
\end{aligned}
$$

$$
\begin{aligned}
\%\mathrm{H_2O} &= \frac{M_{5\,\mathrm{H_2O}}}{M_T} \times 100\% \\
&= \frac{90.10\mathrm{g\,mol^{-1}}}{249.71\mathrm{g\,mol^{-1}}} \times 100\% \\
\%\mathrm{H_2O} &= 36.08\%
\end{aligned}
$$

4.5.5 $\mathbf{NiCl_2 \cdot 6\,H_2O}$

$$\begin{aligned}
M_{6\,\mathrm{H_2O}} &= 6 \cdot 18.02\mathrm{g\,mol^{-1}} \\
M_{6\,\mathrm{H_2O}} &= 108.12\mathrm{g\,mol^{-1}} \\
M_{\mathrm{NiCl_2 \cdot 6\,H_2O}} = M_T &= M_{\mathrm{NiCl_2}} + M_{6\,\mathrm{H_2O}} \\
&= 129.60\mathrm{g\,mol^{-1}} + 108.12\mathrm{g\,mol^{-1}} \\
M_T &= 237.72\mathrm{g\,mol^{-1}}
\end{aligned}$$

$$\begin{aligned}
\%\mathrm{H_2O} &= \frac{M_{6\,\mathrm{H_2O}}}{M_T} \times 100\% \\
&= \frac{108.12\mathrm{g\,mol^{-1}}}{237.72\mathrm{g\,mol^{-1}}} \times 100\% \\
\%\mathrm{H_2O} &= 45.48\%
\end{aligned}$$

4.6 Finding the Unknown Hydrate

By comparing the percentage of water obtained experimental with each of the theoretical percentages of water for the potential hydrates, it can be proven that the unknown hydrate is most likely $\mathrm{MgSO_4 \cdot 7\,H_2O}$. 49.51% is the closest to 51.20%.

4.7 Percentage Error

The following calculations are based on the conclusion that the unknown hydrate is $\mathrm{MgSO_4 \cdot 7\,H_2O}$.

With $m_i = 4.08\mathrm{g} \pm 0.02\mathrm{g}$ of the hydrate, theoretically its mass after heating should be:

$$\begin{aligned}
m_{\mathrm{theoretical}} &= m_i \cdot \%\mathrm{MgSO_4} \\
&= m_i \cdot (100\% - \%\mathrm{H_2O}) \\
&= (4.08\mathrm{g} \pm 0.02\mathrm{g}) \cdot (100 - 51.20)\% \\
&= (4.08\mathrm{g} \pm 0.02\mathrm{g}) \cdot (48.80)\% \\
m_{\mathrm{theoretical}} &= 1.99\mathrm{g} \pm 0.01\mathrm{g}
\end{aligned}$$

$$
\begin{aligned}
\%\text{error} &= \frac{|m_{\text{theoretical}} - m_{\text{experimental}}|}{m_{\text{theoretical}}} \times 100\% \\
&= \frac{|m_{\text{theoretical}} - m_f|}{m_{\text{theoretical}}} \times 100\% \\
&= \frac{|(2.06\text{g} \pm 0.02\text{g}) - (1.99\text{g} \pm 0.01\text{g})|}{1.99\text{g} \pm 0.01\text{g}} \times 100\% \\
&= \frac{(2.06\text{g} - 1.99\text{g}) \pm (0.01\text{g} + 0.02\text{g})}{1.99\text{g} \pm 0.01\text{g}} \times 100\% \\
&= \frac{0.07\text{g} \pm 0.03\text{g}}{1.99\text{g} \pm 0.01\text{g}} \times 100\% \\
&= \left(\left(\frac{0.07\text{g}}{1.99\text{g}}\right) \pm \left(\frac{0.03\text{g}}{0.07\text{g}} + \frac{0.01\text{g}}{1.99\text{g}}\right) times 100\%\right) \times 100\% \\
&= (0.0352 \pm 43.36\%) \times 100\% \\
\%\text{error} &= (3.52 \pm 1.53)\%
\end{aligned}
$$

5 Post-lab Questions

9. **What is the purpose of the second heating and cooling in part E?**

   The second (and any further) round's purpose is to get rid of any remaining water in the hydrate. This causes the data to converge towards the theoretical value of the experiment.

10. **If your unknown hydrate had contained some crystals that already lost their water of hydration, how would the results of the experiment have been affected?**

    The calculated amount of water lost experimentally would have been greater if there was no water loss beforehand.