Experiment 2C

OBTAINING WATER FROM A MARTIAN ROCK

MATERIALS: 2 porcelain crucibles, 2 small clay triangles, crucible tongs, desiccator, Bunsen burner, striker, 2 ring stands, iron ring, weighing boat, unknown hydrate.

PURPOSE: The purposes of this experiment are: (1) to determine the percent by mass of water in a hydrate; and (2) to determine the feasibility of hydrates as possible water sources.

LEARNING OBJECTIVES: By the end of this experiment, the student should be able to demonstrate the following proficiencies:

1. Use a Bunsen burner to heat a hydrate.
2. Explain what a hydrate is and give examples of hydrates.
3. Name hydrates from their chemical formula and write a chemical formula from a name.
4. Calculate the percent by mass of water in an ionic solid hydrate.

PRE-LAB: Complete the pre-lab questions on page E2C-7 before lab.

DISCUSSION:

Ever since people have gazed into the night sky, there has been a fascination with outer space. In the 1870s, Italian astronomer Giovanni Schiaparelli reported seeing “channels” on Mars with his telescope, and soon began the questions about life on other planets. Next to Earth, Mars has the most hospitable climate in our solar system. Did it once support life? Could it support human exploration or colonization?

The environment on Mars is harsh, but not unlike Earth’s climate billions of years ago. Mars lacks a UV-protecting ozone layer, its thin atmosphere consists mainly of CO₂ (95%) and the average surface temperature is about -81°F (-63°C), ranging from 75°F to -100°F. Also, at present, there is no evidence of liquid water on Mars, a necessity for life (as we know it). However, despite its reputation as a dry planet, Mars does contain water, in the form of ice in its polar caps (beneath frozen CO₂), possibly underground, and trapped in mineral deposits called hydrates. In fact, these hydrates support claims that water was once abundant on Mars. The theory suggests that large bodies of water evaporated over a long period of time with most of the water becoming trapped within the structures of these ionic salts. NASA’s rover Opportunity recently revealed evidence of a hydrated iron sulfate mineral called jarosite from a rock dubbed “El Capitan” in the crater at Meridiani Planum. Professor Steven Squaryes from Cornell reported that “We have concluded that the rocks here were once soaked in liquid water. It changed their texture, and it changed their chemistry. We believe that this place on Mars for some period in time was habitable. It was a ground-water environment, the kind of place that would have been suitable for life. That doesn’t mean life was there. We don’t know that. But this was a habitable place on Mars at one point in time.”¹

Other minerals found on Mars (by NASA) include hydrates of magnesium sulfate and calcium sulfate as well as hematite (iron oxide) which gives Mars its red appearance and nickname as the Red Planet. While these hydrates may provide evidence of the existence of water on Mars, their presence may also prove to be very beneficial for future human exploration of the planet. These hydrates represent stored water that could be accessed to support life on Mars. One source claims that the cost for sending a gallon of water to the moon is $250,000. Expecting a spacecraft to carry enough water to support a crew would be unrealistic, so viable ways of producing one’s own water or extracting water from the environment must be found in order to make space exploration or colonization a reality.

In this experiment, you will determine the water content of an unknown hydrate. The unknown hydrates include some which have been discovered on Mars:

\[
\begin{align*}
\text{MgSO}_4 \cdot 7\text{H}_2\text{O} & \quad \text{Epsomite} \\
\text{CaSO}_4 \cdot 2\text{H}_2\text{O} & \quad \text{Gypsum} \\
\text{Li}_2\text{SO}_4 \cdot \text{H}_2\text{O} & \quad \text{evidence of other Li compounds found on Mars}^2
\end{align*}
\]

¹Cornell press release on 2 March 2004 at http://www.news.cornell.edu/releases/rover/Mars.jarosite.html
A hydrate is a chemical compound that contains a specific integer number of moles of water relative to each mole of the primary ionic solid. The water molecules are usually held loosely within the crystal. Moderate heating of the hydrate will drive off the water, leaving the anhydrous, or water-free, ionic solid.

The chemical formula for a hydrate is written in a special form, using a dot between the formulas for the ionic solid and the water. When naming hydrates, the ionic solid is named following standard rules of nomenclature. The number of water molecules is indicated using the Greek prefix (1 = mono; 2 = di; 3 = tri; 4 = tetra; 5 = penta; 6 = hexa; 7 = hepta; 8 = octa; 9 = nona; 10 = deca) with the water portion of the compound referred to as "hydrate". For example, CuSO₄·5H₂O is named copper(II) sulfate pentahydrate.

PROCEDURE:

Work with a partner to collect data for this experiment.

Part A. Crucible Preparation

1. Observe the correct usage of the Bunsen burner, as demonstrated by your instructor.

2. Determine a method for identifying each crucible so that you can distinguish between them. Do not use a grease pencil to mark the crucibles since markings will melt away during heating. If a crucible is broken or cracked, obtain another one. If solid was left in the crucible, wash it out with water.

3. The first step in this procedure involves heating the empty crucibles so that they are completely dry and free of all combustible materials such as fingerprint grease. Attach an iron ring to a ring stand. Place a small clay triangle in the center of the iron ring. Position a clean crucible on the clay triangle as in Figure 1. There should be enough equipment so that both of the crucibles can be heated simultaneously on 2 separate ring stands. Each lab partner should heat 1 crucible.

4. With a Bunsen burner, heat each crucible for at least five minutes using a hot flame that has been adjusted so that the tip of the inner cone is just below the crucible. To ensure adequate heating, the bottom of the crucible and clay triangle should have an orange-red glow.

5. Allow each crucible to cool for one minute on the clay triangle before placing it into the desiccator using the crucible tongs provided. Do not place hot crucibles on the bench top or on paper. This will cause them to pick up dirt and other contaminants (and possibly ignite the surface).

6. Immediately replace the lid of the desiccator and allow the crucibles to cool to room temperature. This will take as long as or longer than the five minute heating period. The dry environment within the covered desiccator will enable the crucibles to cool without absorbing water from the air. Keep the lid on the desiccator whenever possible to extend the life of the desiccant.

7. For the rest of the experiment, the crucibles should ONLY be handled with crucible tongs. While your crucibles are cooling, start work on the questions on page E2C-6, then remember to finish Part B.
Part B. Unknown Hydrate

Scenario:
The NASA rover Spirit has collected soil samples from various locations on Mars. These locations were chosen because they are possible sites where water once existed, are accessible by the rover, and are potential regions for future human exploration or colonization. The samples have been pre-analyzed and determined to be essentially a single hydrate material. Your group will be given one of the hydrate unknowns and your job is to determine its water content, identify the hydrate and decide which location\(^3\) on Mars would be most suitable for future human inhabitants.

Unknowns:  
- Martian Rock A from Utopia Planitia
- Martian Rock B from Gusev Crater
- Martian Rock C from Ares Vallis

1. Obtain an unknown hydrate (Martian rock) from your instructor. Record the sample’s unknown number!

2. Obtain a pre-weight of your unknown. To do this, put a medium weigh boat on a top-loading balance, and tare it. Add about 1.1 g of your unknown to the weigh boat. The exact mass does not matter but use at least 1.0 g and do not go over 1.2 g. You do not need to record this mass, this is a pre-weight (an estimated amount of the sample which you will weigh more accurately later). Save this sample for step 4.

3. Tare the analytical balance. Using tongs, place one of your dried, cooled crucibles (from Part A) on the analytical balance. Make sure you know which crucible this is. Record the mass of the dried crucible.

4. Remove the crucible from the balance and add your unknown (from step 2) to the crucible. Place the crucible on the analytical balance and record the mass. Return your crucible and sample to the desicooler.

5. Place this crucible on one of your clay triangle/ring stand setups.

6. Repeat steps 2-5 with your other crucible so that you have 2 replicates. Remember which sample was placed on which setup.

7. Heat both samples for at least 10 minutes ensuring the bottoms of the crucibles are glowing orange-red. Make sure to move the flame around and also apply heat to the side of the crucibles especially if there is solid on the sides of the crucible. For accurate results, it is important that all of the water contained in the solid hydrate is removed by the heat. You may not see any visible change in the hydrate (such as color change).

8. After heating, allow each crucible to cool for one minute on the clay triangle before placing it into the desicooler using crucible tongs. Remember which crucible is which.

9. Immediately replace the lid of the desicooler and allow the crucibles to cool to room temperature. This will take as long as or longer than the ten minute heating period. While you are waiting, finish your calculations on page E2C-6 or you could do the calculations for #2 on page E2C-4.

10. Once they are cool, weigh each crucible on the analytical balance. Record the mass.

Clean-up:
1. The hydrate residues can be flushed down the drain with plenty of water. Wash the crucibles with water only and if necessary, use a soft brush to remove any solids. Do not use soap on the crucibles. Leave the clean, wet crucibles inverted on a piece of paper towel in the hood to dry for the next student.

2. Return your unknown sample vial to the front of the room (unwashed).

3. Return all equipment to their original locations. Clean up your lab bench and balance areas.

**DATA AND ANALYSIS**

**Experiment 2C**

**Part B: Unknown Hydrate**

Unknown # ____________  
Record data with correct units and proper significant figures.

<table>
<thead>
<tr>
<th></th>
<th>Trial #1</th>
<th>Trial #2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass of empty crucible (dried)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mass of crucible + unknown hydrate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mass of unknown hydrate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mass of crucible + residue after heating</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1. Using your data, complete the following table. Below, show your work for the calculation of the mass % of water in the sample for Trial #1.

2. Determine the theoretical values for the % by mass of H₂O in each of the possible unknown hydrates. Fill out the table, reporting values with 4 significant figures. *Show your work below* for the first one (MgSO₄·7H₂O).

<table>
<thead>
<tr>
<th>Possible Unknowns</th>
<th>Theoretical Mass % of Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>MgSO₄·7H₂O Epsomite</td>
<td></td>
</tr>
<tr>
<td>CaSO₄·2H₂O Gypsum</td>
<td></td>
</tr>
<tr>
<td>Li₂SO₄·H₂O Lithium compound</td>
<td></td>
</tr>
</tbody>
</table>
3. Based on your experimental data, identify your hydrate from the possible unknowns above. Determine the %
difference between your experimentally determined average mass % and the theoretical mass % of water in the hydrate. **Show your work** below and **report your average value to your instructor today** before leaving lab.

\[
\% \text{ difference} = \frac{\text{experimental} - \text{accepted}}{\text{accepted}} \times 100
\]

**Record this value on the board.**

- Unknown # _________
- Average mass % = ______________

My Unknown hydrate is: (give formula)

% difference = ___________

4. Compile the class data.

<table>
<thead>
<tr>
<th>Unknown Martian Rock</th>
<th>Group Names</th>
<th>% Water reported by Group</th>
<th>Class Average % Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Martian Rock A from Utopia Planitia</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Martian Rock B from Gusev Crater</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Martian Rock C from Ares Vallis</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

5. Based on the class results, what location on Mars would be most suitable for future human colonization?
QUESTIONS

1. If a human consumes about 1.9 L of water a day, how many kg of Epsomite (MgSO$_4$·7H$_2$O) would need to be dehydrated to support a crew of 5 for a 1 week mission? Assume the density of water is 1.0 g/mL. Show your work.  (Hint: this is a conversion factor problem and you’ll need the balanced rxn below.)

   \[ \text{MgSO}_4\cdot 7\text{H}_2\text{O} \rightarrow \text{MgSO}_4 + 7\text{H}_2\text{O} \]

2. A sample of a hydrated compound, CuSO$_4$·xH$_2$O
   has a mass of 0.390 g. The sample is heated to drive off all of the water. The resulting anhydrous compound CuSO$_4$, has a mass of 0.249 g.

   \[ \text{CuSO}_4\cdot x\text{H}_2\text{O} \rightarrow \text{CuSO}_4 + x\text{H}_2\text{O} \]

   a. How many grams of water were lost upon heating the hydrate? __________________ (Conservation of mass)

   b. Convert the grams of water to moles of water. _________________________ moles H$_2$O

   c. Calculate the moles of CuSO$_4$ left after heating the hydrate. _________________________ moles CuSO$_4$

   d. The mole ratio of H$_2$O:CuSO$_4$ is the value x. Calculate x. \[ x = \______________ \text{()round to an integer} \]

   e. Give the chemical formula of the hydrated compound (once x is known): __________________________

   f. Give the name of the hydrated compound (once x is known): __________________________

E2C-6
PRE-LAB QUESTIONS
Experiment 2C

Complete these questions before lab.

1. Name the following hydrates following standard chemical nomenclature rules:
   a. CuSO₄·5H₂O
   b. MgSO₄·7H₂O
   c. Li₂SO₄·H₂O
   d. CaSO₄·2H₂O
   e. What does “anhydrous” mean?

2. Based on its chemical formula, calculate the mass % of water in CuSO₄·5H₂O.

3. When CuSO₄·5H₂O is heated to drive off its water, the anhydrous form remains. If 1.00 g of CuSO₄·5H₂O is heated to over 150°C, how many grams of the anhydrous solid (CuSO₄) remains assuming the dehydration process is complete?

   1 CuSO₄·5H₂O → 1 CuSO₄ + 5 H₂O

   How many grams of water were removed in this process?