Equipment needed for the Drops! activity are:
1. A cup with warmer than room temperature water
2. A cup with cooler than room temperature water
3. A pipet or dropper
4. A microencapsulated liquid crystal sheet (MELC)
5. A small towel
6. Calculator
7. The picture of a ruler inside a clear plastic sheet protector as seen in the figures. This allows for water drops to be measured without saturating the paper with water.

Figure 1: A picture of a ruler inside a sheet protector.

Figure 2: Example of measuring a water drop.
You should see a variety of items in front of you, including this packet and hopefully a writing utensil. Other items include a cup with warmer than room temperature water and a pipet, a cup of cooler than room temperature water with a pipet, a small colored rectangle, a small towel, a clear sheet protector with a picture of a ruler inside, and a calculator. For the beginning of this activity, you can ignore the ruler picture (it will come in handy in a few minutes).

The rectangle is called a **microencapsulated liquid crystal** sheet (MELC). All you need to know about this item is that it responds to temperature change with a color change. After the initial color change, it will return to its original color as the temperature input adjusts to room temperature. Fun fact: Liquid crystals are also used in cell phone and television displays!

**Step 1:** Familiarize yourself with the MELC sheet. Does the color change when you place your finger on it? Why or why not? What happens if you place the MELC sheet on top of your hand?

**Step 2:** Using the pipets, place a drop of the warm water and a drop of the cool water on the MELC (do not let the two drops touch). *Write down your observations about the color changes that you see:*

- **Warm drop:**
- **Cool drop:**

**Step 3:** After wiping off the MELC with the small towel and allowing it to return to its original color, place 2 drops of warm water on the MELC. Make one of the drops very small and the other drop much larger. Try not to let much time pass between placing the drops on the sheet. Now keep your eyes on the drops!

*Write down your observations about the color changes and about the differences in what you see between the small drop and the large drop (which one returns to the original color faster?):*

**Step 4:** Now repeat step 3 using the cool water.

*Write down your observations about the color changes and about the differences in what you see between the small drop and the large drop (which one returns to the original color faster?):*
The Sphere: Surface Area and Volume
Now you will only need the water/pipets, the ruler sheet, and the calculator.

The volume $(V)$ of a sphere is given by $V = \frac{4}{3}\pi r^3$ and the surface area $(SA)$ of a sphere is given by $SA = 4\pi r^2$.

Note: In this activity, we are assuming that the drops are perfect hemispheres, although in reality they are not perfect.

**Step 5:** Learn how to make drops of various sizes using the pipets and how to measure the diameters of the drops using the ruler. Try making a drop as small as you can! How big can you make a drop so that it still looks like a drop and not a puddle?

*What do you notice about the shape of the very small drops vs. the shape of the big drops?*

**Step 6:** We will be learning about the importance of the surface area to volume ratio calculation later in the activity. You can do this calculation by dividing the surface area of an object by its volume.

*Will the surface area to volume ratio of a sphere be the same as the surface area to volume ratio of a hemisphere (if we don’t include in the surface area the part of the hemisphere which is touching the paper)? Why or why not?*

For sphere: \[
\frac{SA}{V} = \frac{4\pi r^2}{4/3\pi r^3}
\]

For hemisphere: \[
\frac{SA}{V} = \frac{\text{[expression]}}{\text{[expression]}}
\]
**Step 7:** In the table below you will see that some boxes are already filled in for you and some are not. These boxes are filled in for diameter, radius, volume, surface area, and surface area to volume ratio for a SPHERE (not a hemisphere!) Complete the table by calculating the values that should go into the empty boxes. If an entire row is empty, fill it in using your own drop measurements (in mm)! Round to 2 decimal places.

<table>
<thead>
<tr>
<th>Drop #</th>
<th>Diameter</th>
<th>Radius ((r))</th>
<th>Volume ((V))</th>
<th>Surface Area ((SA))</th>
<th>(\frac{SA}{V})</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>1</td>
<td>4.19</td>
<td>12.57</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>14</td>
<td>7</td>
<td></td>
<td>615.75</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>2</td>
<td>33.51</td>
<td></td>
<td>1.50</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>16</td>
<td></td>
<td></td>
<td></td>
<td>0.38</td>
</tr>
<tr>
<td>8</td>
<td></td>
<td></td>
<td>523.6</td>
<td>314.16</td>
<td>0.6</td>
</tr>
</tbody>
</table>

Since these drops are not perfect hemispheres, do you think that if we were to cut the volume we got for the spheres in half (to represent a hemisphere) we would be overestimating or underestimating the actual volume of the drops? What about surface area?

At what diameter do you think the drops best represent a perfect hemisphere? (It may be helpful to put a few different sized drops on the ruler sheet again and look at it from the side)
**Step 8:** For each drop, create ordered pairs \((r, V)\) in Table 1 and \((r, SA)\) in Table 2.

<table>
<thead>
<tr>
<th>Drop #</th>
<th>((r, V))</th>
<th>Drop #</th>
<th>((r, SA))</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
<td>8</td>
<td></td>
</tr>
</tbody>
</table>

**Step 9:** Plot the data points above from Table 1 and Table 2 on the following graph to draw curves for volume and surface area (make sure you know which one is which!) You will need to number the axes so that you can fit all of the points on the graph. Make sure your graph doesn't only take up the bottom left corner of the paper, we want to fill the paper up! Don't forget to label axes and label which curve is which!

*What does the ordered pair \((0,0)\) represent?*
Circle the curve that increases at a faster rate: **Volume**  **Surface Area**

What does this mean about the relationship between surface area and volume as the radius of the sphere increases?

*How does the surface area to volume ratio (SA/V) change as the sphere gets bigger and bigger?*

**Step 10:** Think back to the activity you did at the beginning with the microencapsulated liquid crystals sheets.

*Now that you know more about the relationship between surface area to volume ratio, can you explain why the larger the drop became, the longer it took to cool? (Hint: Heat escapes from the drop through the surface and heat retention is also based on the volume of the drop)*

*Did the cold drops also take longer to return to room temperature the larger the drop became?*
Step 11: Let’s explore the surface area to volume ratio of differently shaped objects now!

First let’s look at a cylinder: the volume of a cylinder is given by the formula \( V = r^2h \) and the surface area of a cylinder is given by \( SA = 2\pi rh + 2\pi r^2 \). For the following calculations, you can round to 2 decimal places.

Cylinder 1: Calculate the volume, surface area, and SA/V ratio of a cylinder with a radius, \( r \), of 1 mm and a height, \( h \), of 2 mm:

\[
\text{Surface Area} = \quad \text{Volume} = \quad \text{Ratio} =
\]

Cylinder 2: Next, calculate the volume surface area, and SA/V ratio of a cylinder with a radius, \( r \), of 5 mm and a height, \( h \), of 10 mm:

\[
\text{Surface Area} = \quad \text{Volume} = \quad \text{Ratio} =
\]

Notice that the second cylinder has dimensions that are proportional to the first cylinder (the radius is half the height in each case). This means that we did not change the shape of the cylinder, we just made it bigger.

Circle the cylinder which has a larger surface area to volume ratio: Cylinder 1 Cylinder 2

Is this what you expected? Why or why not?
Now let's explore cubes!

Cube 1: Calculate the volume \( V = lwh \) and surface area \( SA = 6lw \) of a cube with side length 4 mm.

Surface Area = ____________  Volume = ____________

Ratio = ____________

Cube 2: What about a cube with side length 10 mm?

Surface Area = ____________  Volume = ____________

Ratio = ____________

Circle the cube which has a larger surface area to volume ratio:  
Cube 1  Cube 2

Is this what you expected? Why or why not?

Step 12 (Challenge Questions!):

- If a sphere has diameter of 86 mm, what would the height of a cylinder (with radius 29 mm) have to be in order for the 2 objects to have the same surface area to volume ratio?

- If a rectangular prism has length 4 mm, height 10 mm, and width 7 mm, what would the radius of a sphere have to be (in mm) in order for the 2 objects to have the same surface area to volume ratio?
Step 13: Below, you will see a few differently shaped objects. Describe what you think the surface area to volume ratio of each of these objects will look like. (Example: the surface area will be very small compared to the volume, so the SA/V ratio will be very small)

<table>
<thead>
<tr>
<th>Shape</th>
<th>Image</th>
<th>Surface Area to Volume Ratio Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Torus</td>
<td><img src="image1.png" alt="Torus Image" /></td>
<td></td>
</tr>
<tr>
<td>Saddle</td>
<td><img src="image2.png" alt="Saddle Image" /></td>
<td></td>
</tr>
<tr>
<td>Leaf</td>
<td><img src="image3.png" alt="Leaf Image" /></td>
<td></td>
</tr>
<tr>
<td>Mouse</td>
<td><img src="image4.png" alt="Mouse Image" /></td>
<td></td>
</tr>
<tr>
<td>Earth</td>
<td><img src="image5.png" alt="Earth Image" /></td>
<td></td>
</tr>
</tbody>
</table>

Why is surface area to volume ratio important in science??

As it turns out, surface area to volume ratio is a very important topic for living beings! (Yes, yourself included!)

As we saw for spheres, cylinders, and cubes, as the size of the object increases (but the shape does not change), the surface area to volume ratio decreases. Surface area to volume ratio is very different depending on the shape and size of the object that you are dealing with.
Step 14: Brainstorm for a few minutes with the people around you some examples of how the surface area to volume ratio plays a role in nature.

Step 15: Consider a few (of many) examples in nature:
Example 1:
Imagine that you walk outside into the snow with no gloves on. Immediately, your hands begin to feel cold. What is your immediate reaction? Are you going to stretch your fingers out or are you going to make a fist with your hand?

Now imagine that not only do you not have gloves, but you also have no coat on. After a few minutes of standing outside with no coat or gloves, what position do you think you'll find yourself in? Where will your arms be?

*Explain why this is your immediate reaction:*

*What does this have to do with surface area to volume ratio? (Hint: if you move your body around, what changes? Volume? Surface area?)*

Example 2:
Look at the two pictures below:

*What do you notice about the surface area to volume ratio of the ears when comparing these two rabbits? Do you think the climate that the rabbit lives in has anything to do with this? Explain.*
Example 3:
In Florida, the average weight range for a white-tailed deer is 77-110 lbs. In the northern regions of the United States, the weight of a white-tailed deer ranges from 100-300 lbs.

Try to explain this using the knowledge you’ve gained about surface area to volume ratio and climate. (Hint: how does heat escape from an animals body?)

Step 16: Now that you’ve seen a few examples, brainstorm again with your team to come up with more examples to share with the whole group!