IA Script G

The Relationship Between the Different Surface Areas of the Beaker and the Evaporation Levels of Water

I. Introduction:

Evaporation happens below the boiling point of a liquid and it happens when this liquid changes state to a gas[1]. The particles in the liquid have different kinetic energy and are constantly moving. Heating the water makes some particles have enough kinetic energy to overcome the intermolecular forces of attraction from the other particles and therefore they can leave the surface of the liquid to become a gas. A way to increase the evaporation of a liquid is to increase the surface area[2] so that more liquid is exposed to the air and therefore more particles can escape at a time. This means that there is a greater volume change of water when the surface area of the beaker is increased. Covering the surface area of the beaker instead of placing the cardboard cover on the actual liquid will prevent the cardboard from absorbing some of the water and providing inaccurate results, but it will still reduce the exposure of water to the air, and it will still provide a decrease in the surface area of the beaker allowing evaporation to happen.

II. Research Question:

I am interested in investigating the link between the evaporation levels of water at its boiling point and the different surface areas. The expected relation would be that more water evaporates with an increase in surface area of the beaker. This is why I would like to conduct an experiment in the school laboratory with the use of beakers filled with heated water and cut out cardboard pieces with different sector areas to research the question:

How does different surface areas of the beaker affect the amount of water evaporated?

To make the different covers, I would use the equation of the area of a circle which is πr^2 since I am covering the rounded top of the breaker. Then for each sector I would use the equation: $\pi r^2 - ((\Theta/360°) \times (\pi r^2))$. Each time changing the angle by adding $36° \pm 0.08°$ to the cover which reduces the surface area of the beaker.

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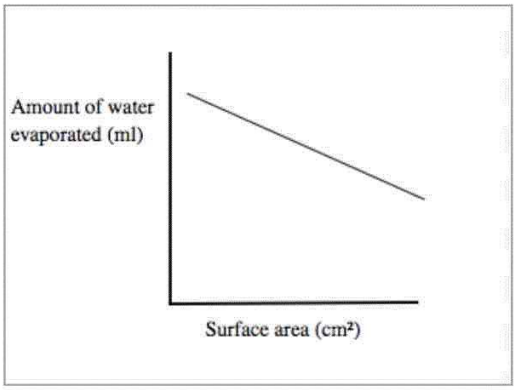
[1] "The Difference Between Vaporization & Evaporation" Rosann Kozlowski and Lana Bandoim, B.S.(2020), visited on March 10th 2023

[2] "Evaporation and Factors Affecting It" Toppr, visited on March 10th 2023

III. Theory & Hypothesis:

There is more evaporation taking place when the water is at higher temperatures and at larger surface areas. The largest surface area will allow the water levels to drop more than in smaller surface areas, made by covering the top of the beaker, in the same 5 minutes with the water at the same temperature. This happens because the beaker having a larger surface area will provide more exposure of the water to the air allowing the particles to escape easier. The water is set to a temperature of 98°C ±0.5°C each time, since it is not completely pure water and it cannot get to 100°C. Heating the water will increase the kinetic energy of particles and therefore speed up the evaporation, since these particles escape quicker, and therefore making it possible to measure the change in volume in those 5 minutes. I made this diagram below to show the expected graph of the relation between the different surface areas of the beaker and how much water evaporated. If the amount of evaporation decrease once the surface area of the beaker gets smaller, then the expected graph would be like this:

Diagram 1: Prediction of Expected Graph of the Amount of Water Evaporated in Relation to the Surface Area of the Beaker



IV. Variables:

Independent variable: Surface area of the beakers with the different covers

- Surface area is measured in cm^2
- The different covers were placed at the top of the beaker
- Measured using a metre rule and a protractor for the angles
- The surface area will decrease since new cardboard covers will be added and each cover will have the sectors increase by angles of 36° ± 0.08°.
- It is important to only change the surface area in the experiment so that the relation between it and the evaporation of the water is as accurate as possible with no extraneous variables modifying it.

Dependent variable: The amount of water evaporated

- The volume of water left after the evaporation will be measured in cm^3.
- The water will be passed to a measuring cylinder after the five minutes to measure the ending levels of the water.
- It is important to avoid the parallax error so the readings can be more accurate.
- Three trials for the same surface area will be done to reduce the random and systematic errors of time ± 0.005s, volume ±0.1cm^3 and the thermometer ± 0.5°C. With these three trials an average can be found.

Controlled variables:

1. Starting temperature of water:
    a. Reason: The different water temperatures could alter the difference in volumes since warmer water evaporates faster than cooler temperatures of water.
    b. Method: Make sure that the water in all the beakers in all the trials before starting the stopwatch for the evaporation, is at 98°C±0.5°C which is the starting temperature.

2. Size of beaker:
    a. Reason: The main reason is to make sure that the original surface area is the same and therefore the calculated surface areas are all accurate. It also helps the water always reach the same level and therefore help the water evaporate at the same rate
    b. Method: Make sure all the beakers used are the same size, 2,000cm^3 , and they have the same surface area.

3. Volume of water at the start:

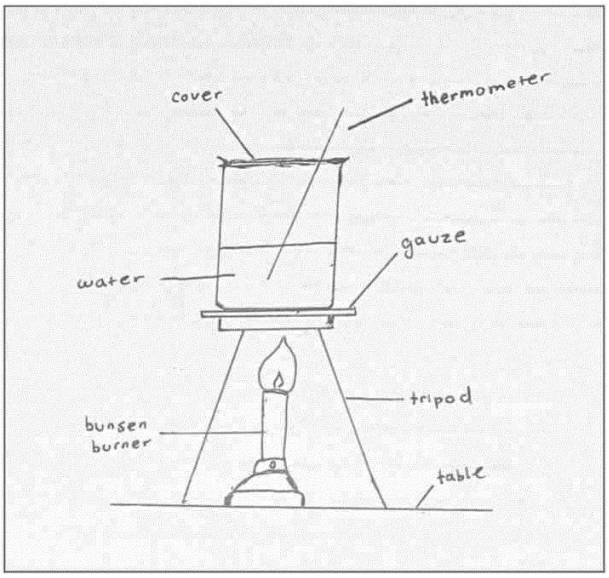
a. Reason: Having the same volume of water at the start is crucial for the readings and measurements after the evaporation took place. Different starting volumes can cause a change in the levels of water evaporated and can therefore cause an inaccuracy in the calculations. This could affect the relation between the levels of the water evaporated and the surface area.
b. Method: Measuring the volume of the water in a measuring cylinder and then transferring the water to the beaker avoiding parallax error.

4. Temperature of room:
    a. Reason: The different temperatures in a room can cause air drafts that could affect the evaporation of the water since they could move particles in the air to clear it up and make space for more particles, increasing the evaporation rate or the water.
    b. Method: Check that the room is always at room temperature throughout the experiment and that the water therefore is always at 22°C ± 0.5°C before boiling it. Make sure to check the water before starting to boil it every time.

5. Reaction time to start stopwatch
    a. Reason: Different stopwatch start times can alter the time and therefore alter the evaporation rates of the water because if more time goes by than necessary, more evaporation will occur and that would not be precise in the different readings.
    b. Method: Use the same stopwatch, and the same person should start the stopwatch always since it is more likely that their reaction time is closer.

V. Diagram:

Diagram 2: Set Up of the Experiment with Labels of Materials used



The tripod and the gauze are important for safety measures so that burning of the skin because of the heat does not take place. The lid reduces evaporation because it shields the water from cooler air that could potentially cool the water and cause air drafts. The temperature of water and air drafts are both factors that affect evaporation. If the water levels are cooler and there are no air drafts to clear up particles and leave space for others, not a lot of evaporation will occur.

VI. Apparatus:

- 5 2 litre beakers
- A 500 cm^3 measuring cylinder
- Scissors
- Water
- Compass
- Cardboard paper
- Pipette
- Thermometer
- Stopwatch

VII. Method & Procedure:

1. With a compass, create 10 circles with a radius of 7 cm ± 0.05cm and a diameter of 14 cm ± 0.05cm. Calculate the area of the circle with the formula $A= \pi r^2$, all circles should have the same surface area to start with. Measure different angles in each circle and increase the angle each time by adding 36°± 0.08° to each one.
2. Use the equation $A = \Theta/360° \times (\pi r^2)$ o get the sector area and later subtract the sector area result from the area of the full circle. For each of the different surface areas, substitute the different angles.
3. Pour 500 cm^3 ±0.1cm^3 of water into a measuring cylinder and then transfer it to a 2,000 cm^3 beaker to have a large surface area. Keep in mind that a lot of air above the liquid can cause the evaporation to decrease since there is more air pressure acting on the water.
4. Heat the water to 98°±0.5 almost to boiling temperatures and once it reaches that temperature, pour the water back into the measuring cylinder to check how much water evaporated while it was being heated (100°- 98° = 2° ±0.5) and then pour it again into the 2,000 cm^3 beaker to start the evaporation time on the stopwatch. The volume of the water will now be at 498 cm^3 ±0.1cm^3 and this is the volume that is used before starting the five minutes for the evaporation to take place.
5. Place the previously cut out sector of cardboard on top of the beaker and secure it with tape, immediately start the stopwatch and wait five minutes for the water to evaporate. This cover does not touch the water since the cardboard could absorb some of the water and therefore affect the relationship that is actually being measured.
6. Once the stopwatch reaches those five minutes, pour the water back into the measuring cylinder to measure how the levels of water change, recording this new level of water.
7. Repeat steps 3-6 with the different sectors cut out with different sector areas creating different surface areas on the beaker.
8. Make sure to keep flammable objects away from the fire and to turn off the bunsen burner when it is not being supervised. Use gloves to protect hands from boiling water.

VIII. Raw data:

Table 1: Raw Data of Volume of Water Depending on the Different Surface Areas

Surface Area / cm^2 ± 0.05cm	Trial 1 Volume of water after 5 minutes/ cm^3 ±0.1cm^3	Trial 2 Volume of water after 5 minutes/ cm^3 ±0.1cm^3	Trial 3 Volume of water after 5 minutes/ cm^3 ±0.1cm^3
138. 54	473.0	472.0	473.0
123.15	468.0	467.0	470.0
107.76	464.0	465.0	464.0
92.36	461.0	460.0	459.0
76.97	452.0	455.0	454.0
61.58	449.0	447.0	446.0
46.18	444.0	443.0	444.0
30.79	442.0	442.0	441.0
15.39	440.0	437.0	439.0
0.00	430.0	431.0	433.0

IX. Processed Data:

Table 2: Processed Data of the Change of Volume of Water and Averages

Surface Area / cm^2 ± 0.05cm	Trial 1 The Change in Volume of the Water/ cm^3 ±0.1cm^3	Trial 2 The Change in Volume of the Water/cm^3 ±0.1cm^3	Trial 3 The Change in Volume of the Water/ cm^3 ±0.1cm^3	Average / cm^3
138. 54	25.0	26.0	25.0	25.33 ±0.5
123.15	30.0	31.0	28.0	29.67 ±1.5
107.76	34.0	33.0	34.0	33.67 ±0.5
92.36	37.0	38.0	39.0	38.00 ±1.0
76.97	46.0	43.0	44.0	44.33 ±1.5
61.58	49.0	51.0	52.0	50.67 ±1.5
46.18	54.0	55.0	54.0	54.33 ±0.5
30.79	56.0	56.0	57.0	56.33 ±0.5
15.39	58.0	61.0	59.0	59.33 ±1.5
0.00	68.0	67.0	65.0	66.67 ±1.5

Example Calculations:

- To calculate the change of volume from the beginning to after the five minutes of evaporation:
  Initial Volume of Water - Final Volume of Water = Change in Volume
  498 - 473 = 25 cm^3
  This initial volume of water is measured before starting the stopwatch

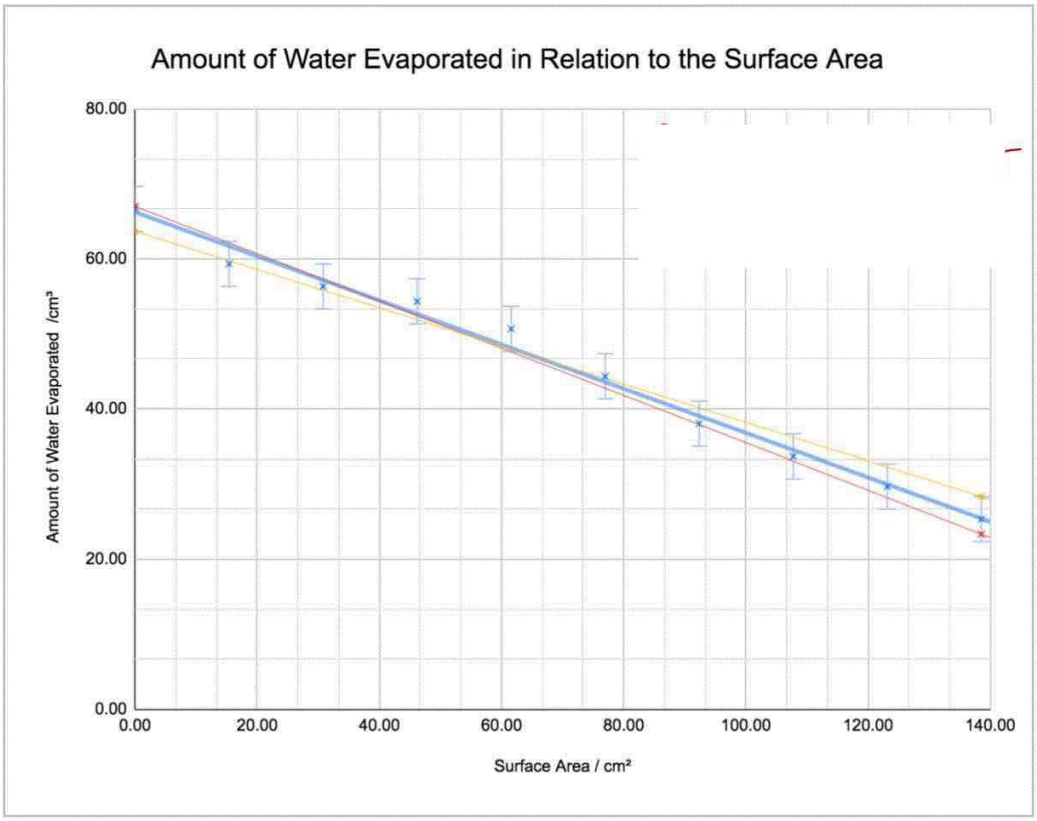
- To calculate the average:
  (Trial 1 + Trial 2 + Trial 3) / 3
  (30.0 + 31.0 + 28.0) / 3 = 29.67 cm^3

Reading error for time: ± 0.005 s

Reading error for thermometer: ± 0.5°C

X. Graph:

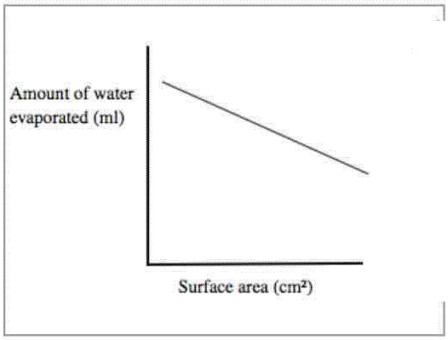
Graph 1: Graph of the Amount of Water Evaporated Against the Surface Area



XI. Analysis & Conclusion:

The hypothesis stated that the expectation was that the levels of water evaporated would decrease if the surface area was also decreased. This means that the smaller the surface area of the beaker, the less difference in volume there would be. Therefore this graph I made would be a representation of the actual graph that was expected to look like this:

Diagram 3: The Expected Graph of the Amount of Water Against the Surface Area



In the actual graph, the line does not pass through the origin, as expected, which shows that the graph is not proportional. The constant points going down the line of best fit demonstrate this trend that matches the hypothesis since it shows that an increase of area coverage of the beaker given by the different cardboard lids, decreases the original surface area of the beaker. This therefore shows how it reduces the change in volumes which means that it decreases the amount of evaporation taking place. The overall results can be adequately accurate and reliable given that all the points of the graph are close to the line of best fit. There are a few points like surface area = 46.18 cm² and surface area = 61.58 cm² that were a little further away, but this best fit straight line passes through all the error bars, including these.

Overall, if the surface area of the beaker decreases, the amount of water evaporated will also decrease. This connects to the ideas in the background research stating the fact that the surface area has an effect on the levels of evaporation since a larger uncovered surface area will provide a greater change in the volumes of water, meaning that more evaporation took place.

XII. Evaluation:

The method of this experiment was designed to include the appropriate amount of trials to obtain the fitting amount of results to later average and create an applicable conclusion. These different trials allowed a range of data to have more accurate results in the experiment making the graph as precise as possible.

Weaknesses:

- One significant weakness in this experiment was that there was a lot of air between the water and the lid at the top of the beaker. This provides more air pressure making the evaporation go slower since it makes it harder for the particles to escape the water and this can therefore affect the readings of the levels of water. [3] An improvement would be increasing the volume of water so that the liquid sits closer to the edge of the beaker.

- The transfer of water from the beaker to the measuring cylinder a couple of times to measure the volume changes of the water before the evaporation, could have an effect on the overall final volume. This could happen since some evaporation could have taken place and some water could have been lost, but these values could be estimated as an uncertainty so it is not a really significant weakness.

Strengths:

- The experiment had many controlled variables which is a strength because it means that not a lot of extraneous variables affected the independent variable and therefore did not affect the overall results of the amount of evaporation in relation to the surface area of the beaker. This makes discussion of cause and effect easier.

- Another strength is that there were three trials to measure the volume of water. This helped create an average for the readings to make the values more accurate and to establish patterns to support the hypothesis made.

- This experiment is relatively a simple experiment to be replicated by others to validate these results.

[3] "The Process of Evaporation" Kim Rutledge et al, visited on March 12th 2023

If conducted the experiment again, consider using more water so that the water levels are closer to the top of the beaker so that there are no other variables, like the air pressure, that could potentially make the experiment inaccurate.

XIII. References:

1.

"The Difference Between Vaporization & Evaporation" Rosann Kozlowski and Lana Bandoim, B.S.(2020), visited on March 10th 2023
https://sciencing.com/differences-between-vaporization-evaporation-12052824.html

2.

"Evaporation and Factors Affecting It" Toppr, visited on March 10th 2023
https://www.toppr.com/guides/chemistry/matter-in-our-surroundings/evaporation-and-factors-affecting-it/#:~:text=in%20wind%20speed.-,Evaporation%20increases%20with%20an%20increase%20in%20the%20surface%20area,with%20a%20wider%20surface%20area.

3.

"The Process of Evaporation" Kim Rutledge et al, visited on March 12th 2023
https://education.nationalgeographic.org/resource/process-evaporation/