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A Study on the Impact of Temperature on the Contact Angle of a Liquid

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***Abstract*—** Contact angle, θ (theta), is a quantitative measure of wetting of a solid by a liquid. The contact angle is geometrically defined as the angle formed by a liquid at the three-phase boundary where a liquid, gas, and solid intersect [1]. The study of mine was conducted to know that how the contact angle of water changes when a drop of 0.1 ml of a water drop is subjected to an already heated hard-glass beaker tub. I hypothesized that the contact angle of water must decrease subsequently when we subject it to the already heated equipment with time, but to my surprise I noted that the contact angle kept on increasing when the temperature was increased with time. I was carrying out this research for nearly 2 years to collect all the required data and images to come to this conclusion and derive a general equation by modifying the Young's equation, to know the contact angle of any liquid when it is being subjected to any heated vessel with time. If my experimental strategy were employed at a larger scale, the data generated could help scientists to better understand the factors on which contact angle of a liquid depends [2].

***Keywords*—** Contact Angle of a liquid, Contact angle relation of a liquid with time and temperature, Modification of Young's equation.

I. INTRODUCTION

In many industries wettability is a key parameter measure to describe liquid and substrate interactions, standard paper testing procedures usually do not include characterization of the surface chemistry and thus the wettability of paper. The study of mine although being new in this field, has a various applications, like: it can be used by the research industry to calculate the contact angle of a liquid during a particular time interval at different temperatures and carry forward their research, it can be used by the food industry to make various food products, keeping the composition of it more accurate, etc. One reason might be that it is difficult to measure the wettability of paper because of its rough, anisotropic and inhomogeneous surface. Therefore a set of instruments are introduced in this paper in order to allow a fast evaluation on a larger surface areas to obtain statistically significant average values. The local variations are also measured by these instruments to identify in homogeneities which are related to print mottling and similar printing and converting problems [3]. The set of instrument were chosen in order to try to bridge the gap between classical measuring systems and scientific analysis to develop a relation between contact angle with time and temperature. So therefore the objectives of the study of mine includes:

(1) To study the relation between contact angle with temperature.
(2) To study the relation between contact angle with time.
(3) To know that at what temperature water has a contact angle greater than 90°.
(4) To modify the Young's equation from the knowledge gained in objective '2' and '3'- and hence, estimate a general equation to find the contact angle of a liquid when temperature and time of an experiment are provided.

II. RELATED WORK

The study of mine as I mentioned is new in this field and hence a very less number of research papers is available in the web, but I have tried my best to accommodate all the result that I have found and had tried to verify my result with it. Notable works of **" A. AZOULAY, P. GARZON, M.J. EISENBERG, COMPARISON OF THE MINERAL CONTENT OF TAP WATER AND BOTTLED WATERS,". JOURNAL OF GENERAL INTERNAL MEDICINE, VOL.16, ISSUE.3, PP. 168–175, 2001.". Contact angle and related measurements-insights into paper surface characterization, and Aparup Roy, "Thermal Conversion of Water`s Adhesive Force to Cohesive Force," International Journal of Scientific Research in Chemical Sciences, Vol.8, Issue.4, pp.19-22, 2021"** has been proved very much helpful for my research [4].

III. METHODOLOGY

Experiments were conducted in a standard science lab within a glass chamber measuring 140x120x60 m to facilitate the right temperature and pressure inside the room to minimize the chances of errors in the experiment.

Since, our experiment is slightly different from the other experiments researchers had done before so, an 'Optical tensiometer' cannot be used to determine the results of the experiment [5]. Hence, we need to set up our own apparatus as being shown in Figure (1).

Requirements to do the experiments:

- 1ml of tap water.
- A Bunsen burner or a normal gas oven used at home.
- A hard-glass beaker tub.
- A beaker to keep the 30ml water.
- A dropper to drop the water droplets on the hard-glass beaker tub.
- A stop watch.

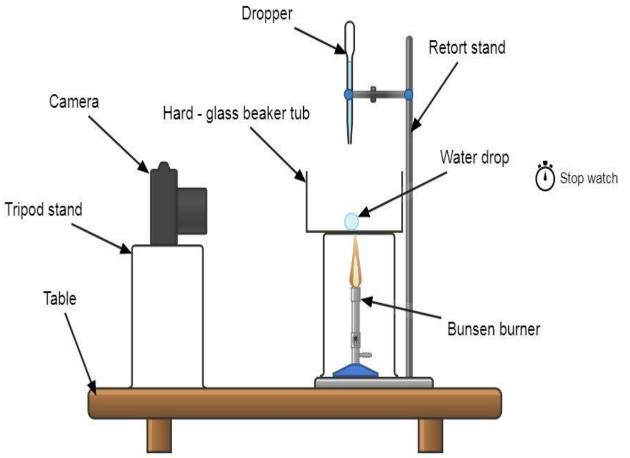

Fig 1: Experimental setup for the experiment number '1 to 5'

We, did three different experiments before encountering any conclusion and had processed all the images of the water droplets in the software known as 'ImageJ' to know the contact angle at different instant of time. After, we concluded doing our experiments we were surprised, to know the fact that when a water droplet was subjected in the hard-glass beaker tub- which is already been heated to 100° C beforehand, the contact angle was seem to increase drastically with an increase in temperature with time. Also, the result seems more surprising since we know that when a droplet of a liquid kept in surface is heated, the contact angle seems to decrease which doesn't matches our result since we have heated the tube beforehand and then had subjected the water droplet which caused the previously known result flip up 180°!!

[Note: We continuously took photographs of the water droplet subjected at different temperatures during our experiment and then once the experiment has been concluded we refined our photographs and then some of the selected photographs has been used for coming to the result of the experiment, hence the quality of the image may look a little blur. Since, no matter what quality of camera we use, it becomes impossible to capture the image of the droplet, perfectly].

IV. RESULTS AND DISCUSSION

It was noticed that the contact angle of water was 64.954° in the initial phase when the experiment was not started [6]. Then, we started heating the hard-glass beaker tub to 100°C and subjected a drop of 0.1ml of water in the tub and it was noticed that the contact angle of water was increased to 66.82° and in this way we continued to take pictures of the experiment and processed it in the 'ImageJ' software to know the contact angle of water at a various temperature. At last, we formulated all of our experimental data into the (Table1), to get back to any conclusion of the experiment. All the images of the water droplets at different temperature say 20°C, 100°C, 110°C ,120°C, 130°C and 140°C are given in Figure (2), Figure (3), Figure (4), Figure (5), Figure (6) and Figure (7), given sequentially (in a collage format, below).

Table 1: Increasing temperature effect with the contact angle.

Experiment	Temperature (in Degree Celsius)	Contact angle (in Degrees)
Initial phase	20	64.954
Experiment: 1	100	66.82
Experiment: 2	110	85.601
Experiment: 3	120	88.264
Experiment: 4	130	102.995
Experiment: 5	140	108.747

Hence, from the above experimental value we can say that contact angle (Cosθc) of water or any liquid increases with an increase in temperature, or contact angle (Cosθc) is directly proportional with the change in temperature (Δt) (Figure 8) i.e.,
$\cos\theta_c \propto (\Delta t)$ ... (i)

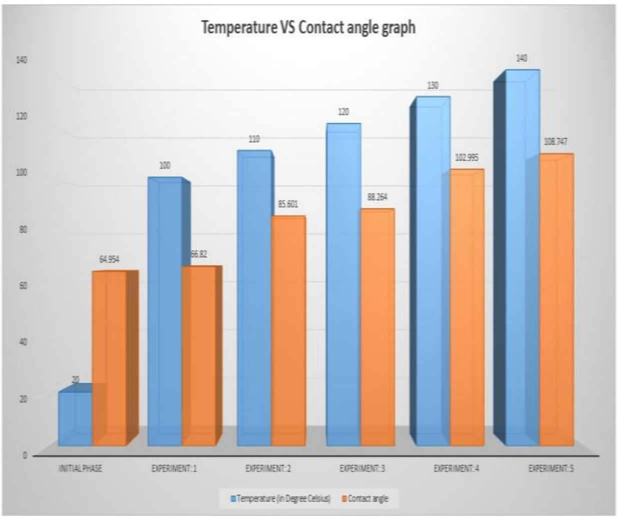

Fig 8: Graph of temperature vs contact angle

Also, from the reading of the stopwatch we noted the time lapse of all the experiments and formulated the table as given in (Table 2).

Table 2: Increasing time effect with the contact angle.

Experiment	Time (in second)	Contact angle (in Degrees)
Initial phase	0	64.954
Experiment: 1	10	66.82
Experiment: 2	20	85.601
Experiment: 3	30	88.264
Experiment: 4	40	102.995
Experiment: 5	50	108.747

Hence, from the above experimental value we can say that contact angle ($\cos\theta c$) of water or any liquid increases with time, or contact angle ($\cos\theta c$) is directly proportional with time (S)
(Figure 9) i.e.,
$\cos\theta c \propto S$ ... (ii)

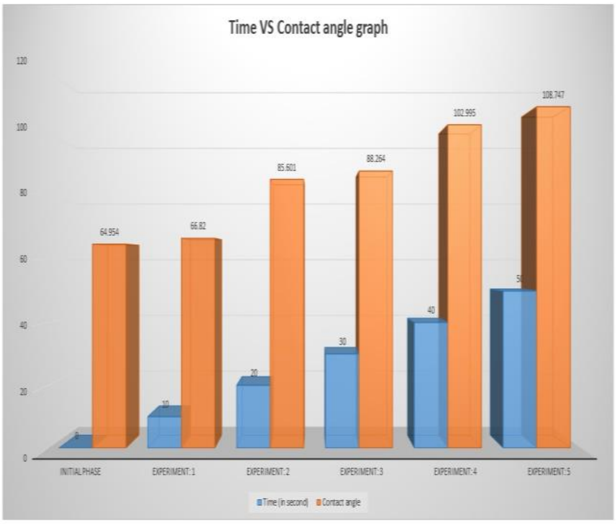

Fig 9: Graph of time vs contact angle

Now on combining both equations... (i) and (ii), we get:
$\cos\theta c \propto (\Delta t)S$
$\Rightarrow \cos\theta c = \Psi(\Delta t)S$ [where, 'Ψ' is the constant of proportionality, reflecting the quality of the material with which the vessel is being built of].

Now, Q= mc (Δt) (According, to the principle of Calorimetry) [where 'm' is the mass of the liquid poured in the vessel, 'c' being the specific heat capacity of the liquid, 'Q' is the amount of heat energy supplied to the system externally and '(Δt)' the change in temperature of the system].

$\Rightarrow (\Delta t) = (\Delta Q)/mc$
$\Rightarrow \cos\theta c = \Psi(\Delta Q)S/mc$ [where 'Ψ' is the constant of proportionality, '(ΔQ)' is the change in heat energy supplied to the system, 'S' is time, 'm' is the mass of the liquid poured in the vessel and 'c' is the specific heat capacity of the liquid] ... (iv)

Unit of the constant 'Ψ'-

$\cos\theta c = \Psi(\Delta Q)S/mc$
$\cos\theta c \times mc/(\Delta Q)S = \Psi$
Now, Cosθc is a unit less quantity, S.I. unit of mass (m) is Kilogram 'Kg', S.I. unit of specific heat capacity of the liquid (c) is Joule per kilogram per kelvin 'J/Kg K'
S.I. unit of time (S) is second 's'

And the S.I. unit of change in heat energy (ΔQ) is joule 'J'
Therefore, Kg × J/Kg × K × J × s = Ψ
Or, Ψ = 1/ K × s
Or, Ψ = K-1 × s-1 [Kelvin inverse multiplied by Second inverse]

Modification of the 'Young's Equation':

$\cos\theta c = (\gamma sg - \gamma sl)/\gamma lg$ ...(iii) (4) [where 'γsg' is the solid - vapour interfacial energy, 'γsl' is the solid–liquid and 'γlg' is the liquid–vapour interfacial energy (Figure 10)].

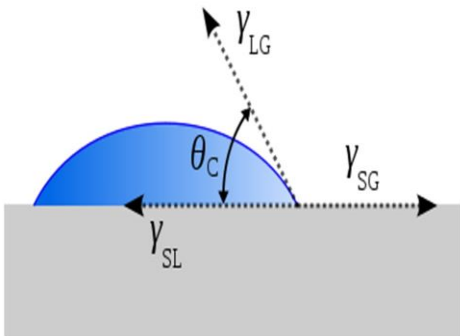

Fig 10: Contact angle of a liquid showing all the interfacial energies between the different states of matter namely solid, liquid and gas

Also, $\cos\theta c = \Psi(\Delta Q)S/mc$ [From ...(iv)]
On adding both the equations... (iii) and (iv), we get-
$2\cos\theta c = (\gamma sg - \gamma sl)/\gamma lg + \Psi(\Delta Q)S/mc$
$\Rightarrow \cos\theta c = (\gamma sg - \gamma sl)/2\ \gamma lg + \Psi(\Delta Q)S/2mc$, which is the required modified equation.

V. Conclusion and Future Scope

From, the above experiments we can draw a conclusion that water at 130°C having contact angle equal to '102.995' (θ>90°) behaves like a substance having a low wettability rate like that of mercury, although at a room temperature 20° C it has a contact angle of 64.954° (θ<90°) behaves like a substance having a high wettability rate (5). Therefore, we can also say that contact angle is relative, and it is not constant with time and temperature. On having a close review to all the inferences driven from the experiments one could conclude that 130 Degree Celsius may be considered as a point when water drops changes its adhesive force to that of the cohesive force. Although, this conclusions also derive to the conclusion that the surface in which the experiments were done in this case the hard glass beaker tube becomes hydrophobic in nature at this temperature. Limitations to this research study includes areas like more appropriate measurements to this study and using more analytical approach to this experiments which can prove this hypothesis to be more experimentally true.

References

[1] A. Azoulay, P. Garzon, M.J. Eisenberg, "Comparison of the mineral content of tap water and bottled waters,". Journal of General Internal Medicine, **Vol.16, Issue.3, pp. 168–175, 2001.**

[2] E. Dinelli, A. Lima, S. Albanese, M. Birke, D. Cicchella, L. Giaccio, P. Valera, B. De Vivo, "Comparative study between bottled mineral and tap water in Italy," Journal of Geochemical Exploration, **Vol.112, Issue.1, pp. 368–389, 2012.**

[3] Gugliotti, Marcos. "Tears of Wine." Journal of Chemical Education 81.1 (2004): **67-68. Web. 9 Mar. 2010.**

[4] Aparup Roy, "Thermal Conversion of Water`s Adhesive Force to Cohesive Force," International Journal of Scientific Research in Chemical Sciences, **Vol.8, Issue.4, pp.19-22, 2021**

[5] Worley JL, Hamm RC, von Fraunhofer JA. Effects of cement on crown retention. The Journal of Prosthetic Dentistry. 1982; 48(3):289–291.

[6] H. I. Mukhtar, M. A. Yaro, M. Suleiman, N. Mai Unguwa, "Physicochemical Analysis of Rainwater Harvested From Different Rooftop along Zaria Road, In Kano Metropolitan," *Journal of Physics and Chemistry of Materials,* **Vol.6, Issue.1, pp.1-4, 2019.**

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Mr. APARUP ROY has been doing research in Physical & Bio-Chemistry in St. Peter's School. He had published two books namely "Problems in General Chemistry and Master ICSE Chemistry Semesters (I & II) [Class - X]". He had also been awarded with the "India Book Of Records in 2021". He is also doing research with some of the MIT Harvard Scientist since 2020. The author also have published two research paper in the "International Journal Of Science and Research and International Journal Of Scientific Research In Chemical Sciences" named "Development of Cow Dung using Herbal Ingredients Based Mosquito Repellent" and "Thermal Conversion of Water's Adhesive Force to Cohesive Force, respectively".

