Finding the Boltzmann Constant through the Evaporation of Ethanol and the Formaldehyde Clock Reaction.

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The Formaldehyde Clock Reaction – Theory.

- Solution A →

5 g of Anhydrous Sodium diSulfite +

1 g of Anhydrous Sodium Sulfite +

1 L of Distilled Water.

- Solution B →

10 cm cubed of 37% Formaldehyde Solution +

1 L of Distilled Water + (after 24 hours)

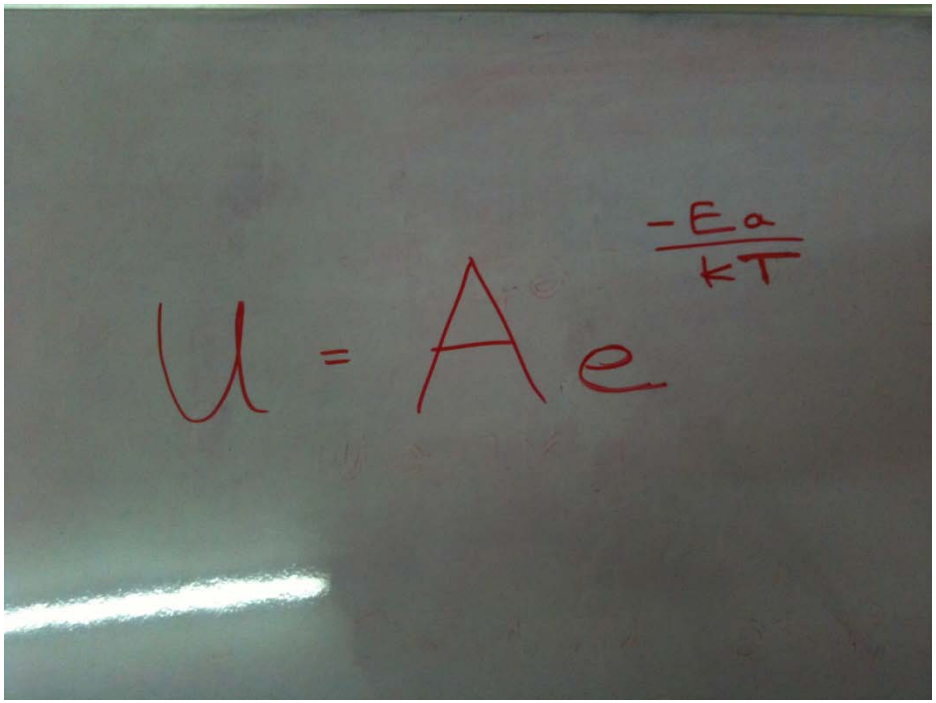
1 g of Phenolphthalein.

Theory – Continued.

- Mix equal volumes of both solutions.
- After some time, ‘delta T’, the solution turns pink.

The Equations and the Math.

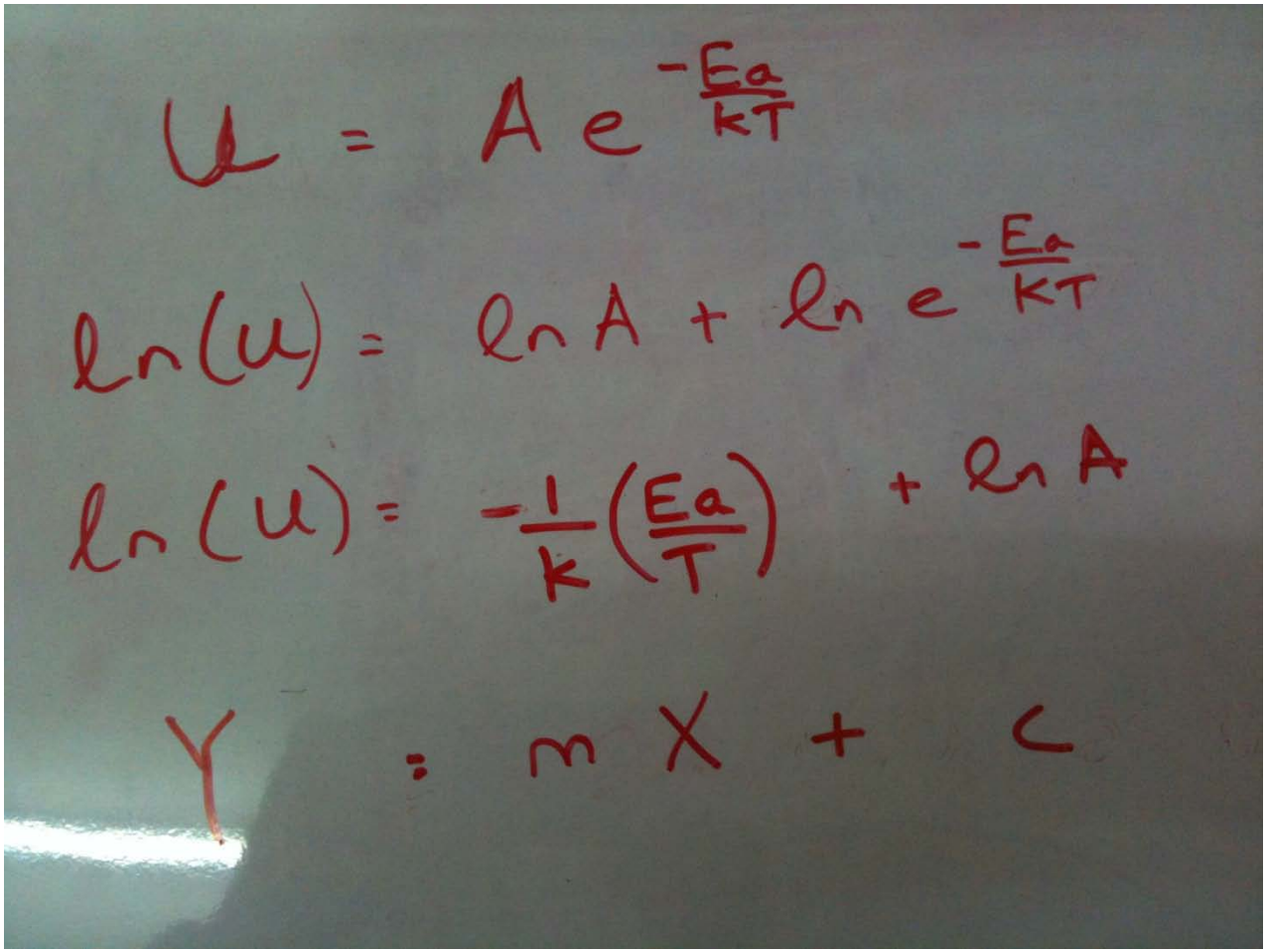
- The rate of the reaction is governed by the Arrhenius Equation.



The Equation and the Math.

- u → the reaction speed.
- A → a constant.
- Ea → energy of activation.
- K → the Boltzmann Constant.
- T → the temperature (in Kelvin) at which the reaction occurred.

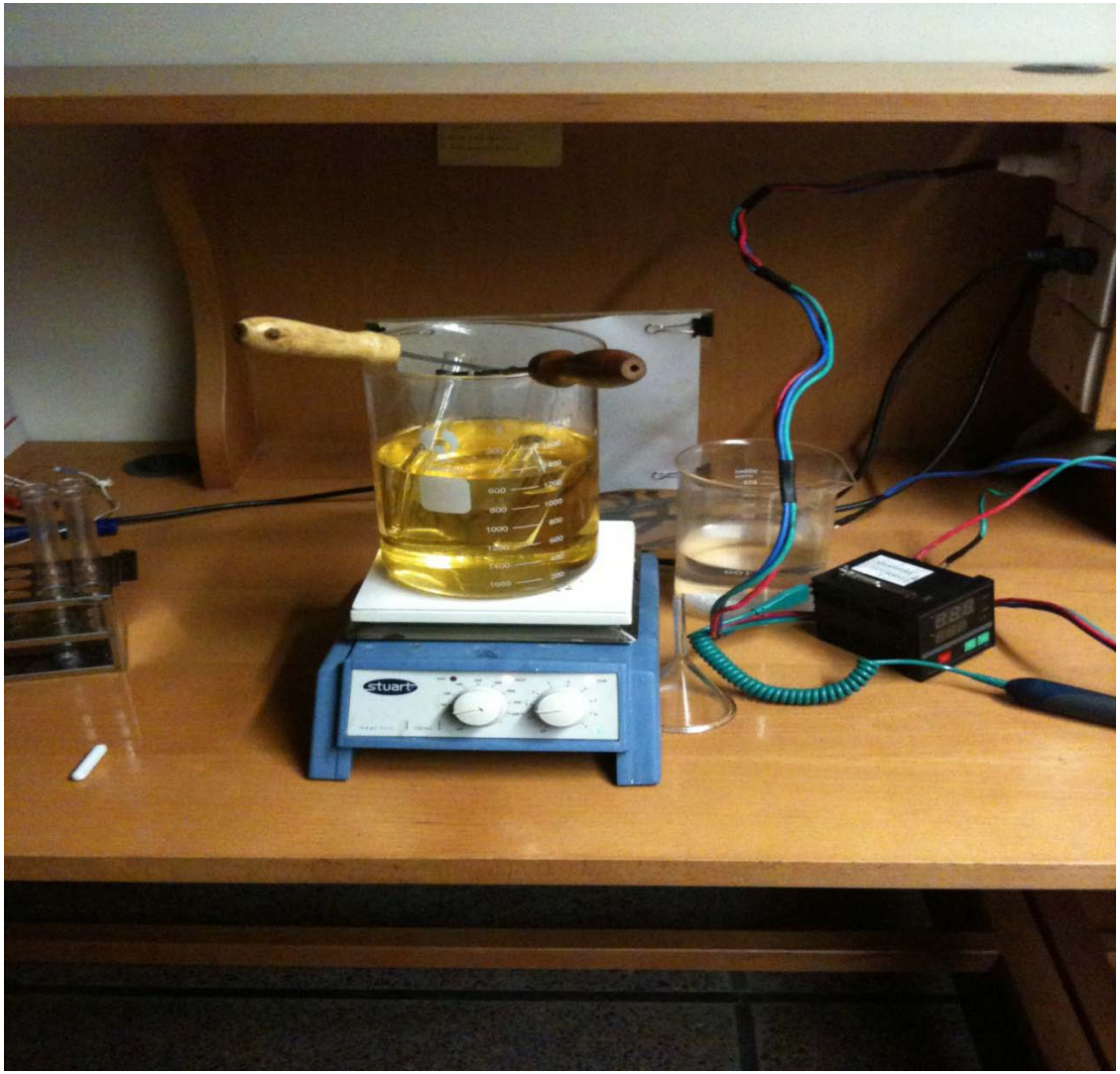
The Equation and the Math – The Linear Form.



The Experimental Setup – Equipment

- A hot plate.
- Magnetic Stirrer to distribute heat uniformly.
- A Temperature Probe.
- Oil Bath.
- Test Tubes.
- Stop Watch.
- Funnel.

The Experimental Setup – A Snapshot.



The Experiment.

- 5 cm cubed of each solution was placed in separate test tubes. The test tubes were half immersed in the oil bath the temperature of which was monitored constantly.
- After 5 minutes the two solutions were mixed and the stopwatch was started simultaneously.

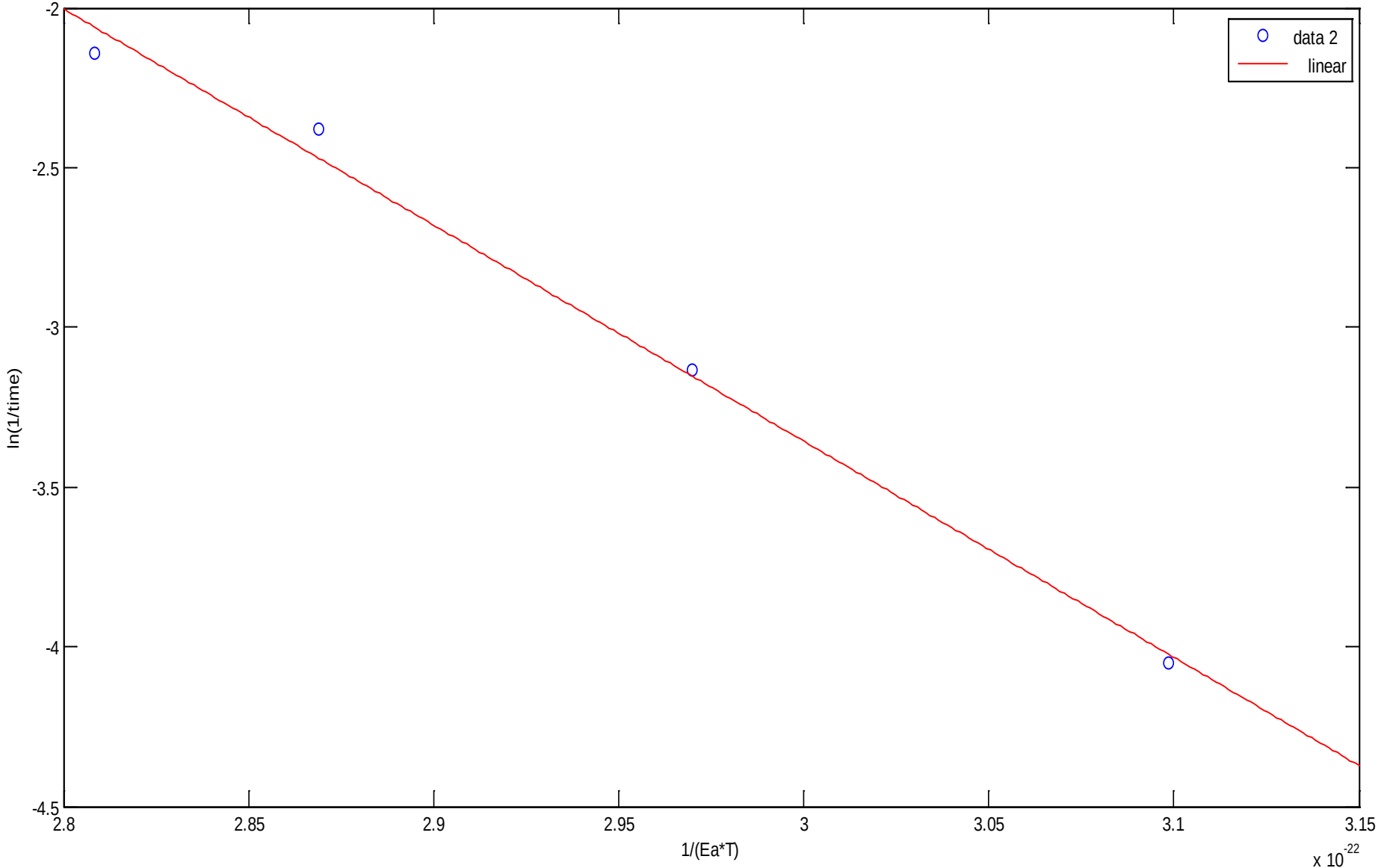
The Experiment – Continued.

- The stopwatch was stopped the instant the pink color appeared.
- The experiment was repeated three times at the same temperature.
- The entire procedure was repeated at 27, 40, 51 and 58 degrees Celsius.

Results

- The value of the Activation Energy was taken from literature.
- Ea = 9.30 x (10^22) J.
- A graph of ln(1/time) against Ea/Temperature was plotted.

Results – The Graph.



The Boltzmann Constant.

Gradient = -6.7659 x (10)^22

(-1/k) = -6.7659 x (10)^22

k = 1.478 x (10)^ -23 J/K

Error.

- The percentage error comes to about 9.8% when compared to the literature values.

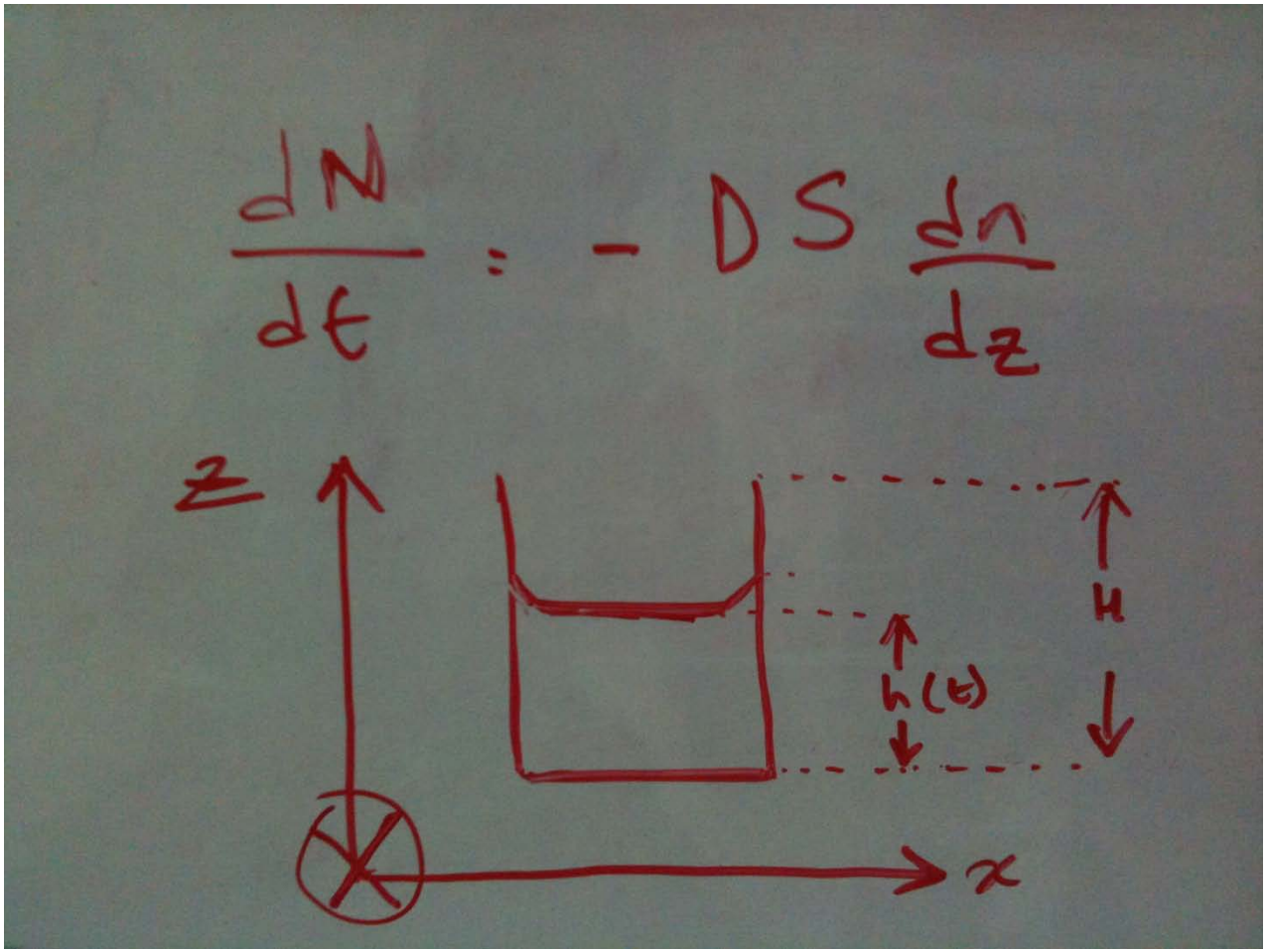
- Reasonable estimation of the Boltzmann Constant.

The Evaporation of Ethanol – Theory.

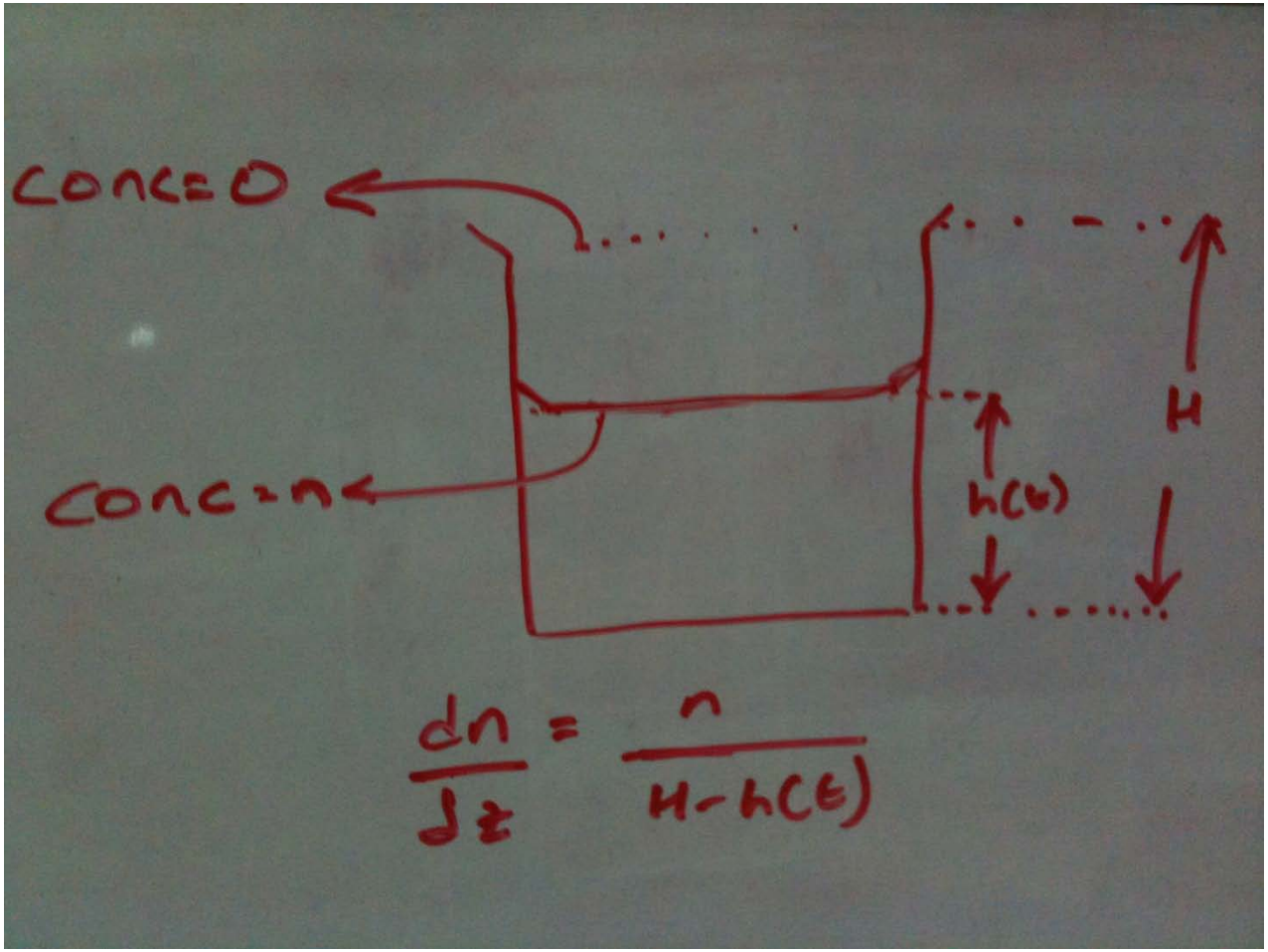
- The 4 Assumptions:

1. The concentration of Ethanol outside the container is zero.
2. There exists no temperature gradient within the bulk of the liquid.
3. There exists a steady flow of air outside the container.
4. Above the surface of the Ethanol there exist saturated vapors of Ethanol.

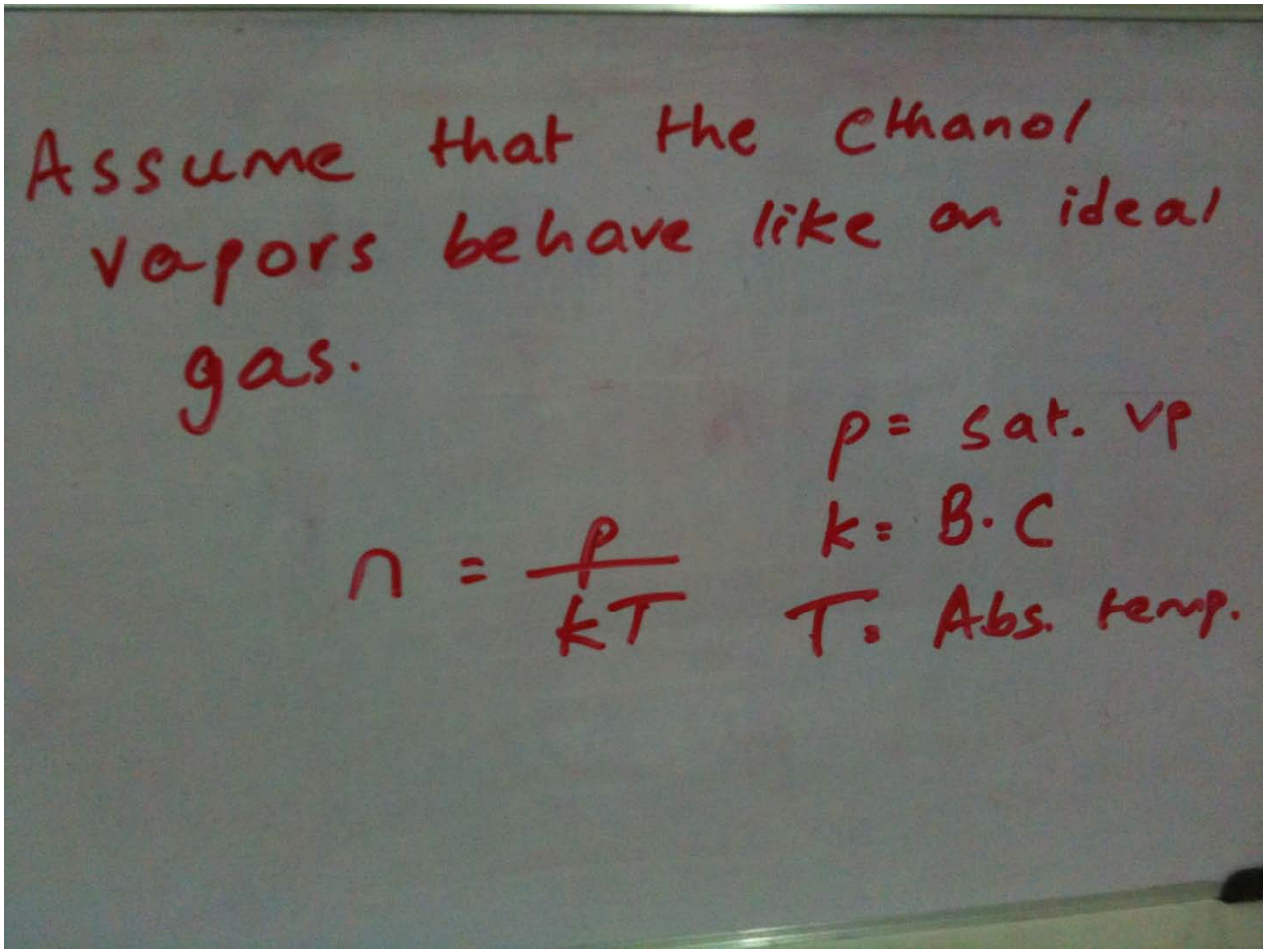
Theory – Fick's Diffusion Law.



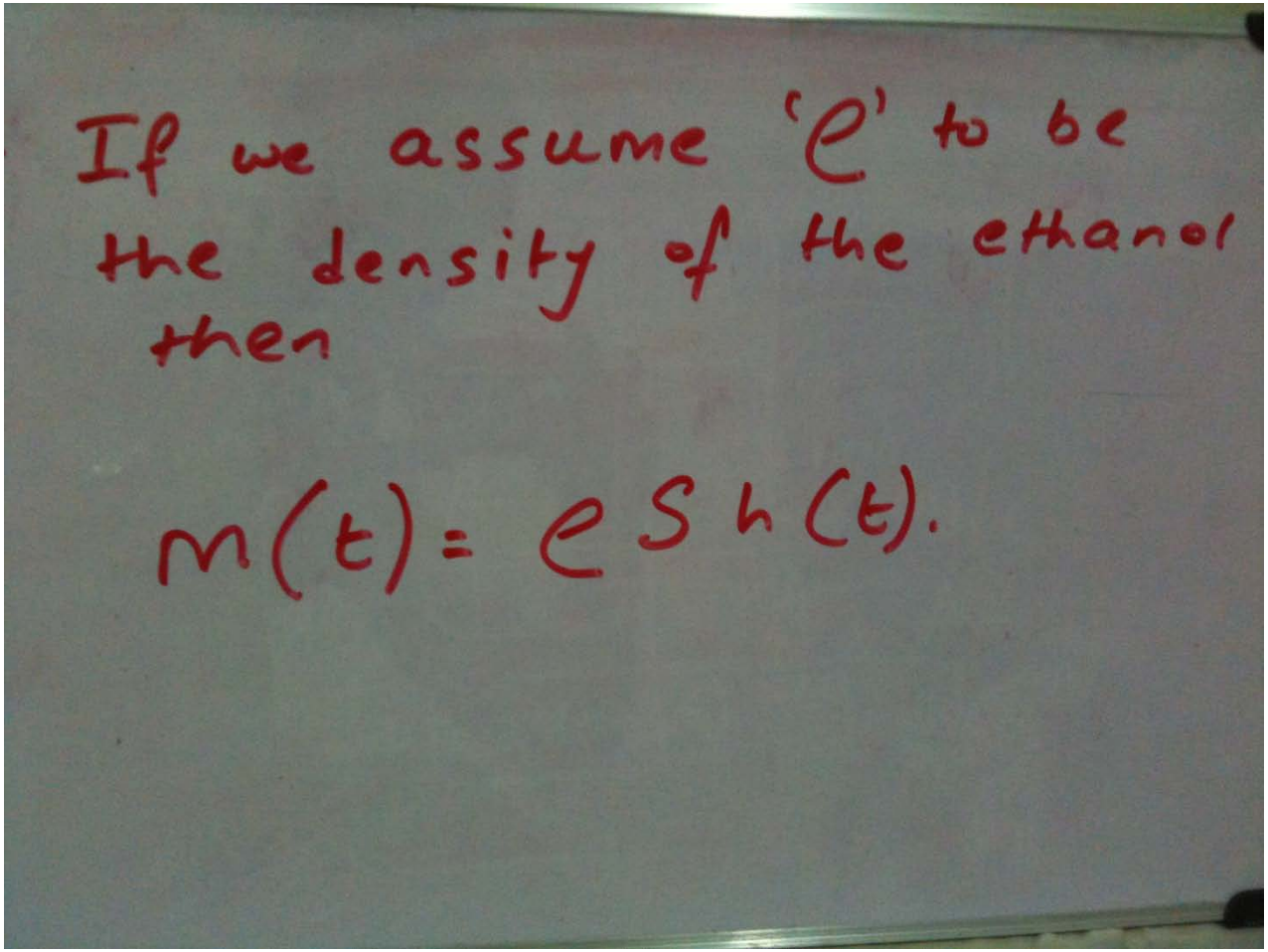
Theory – Assumption # 1



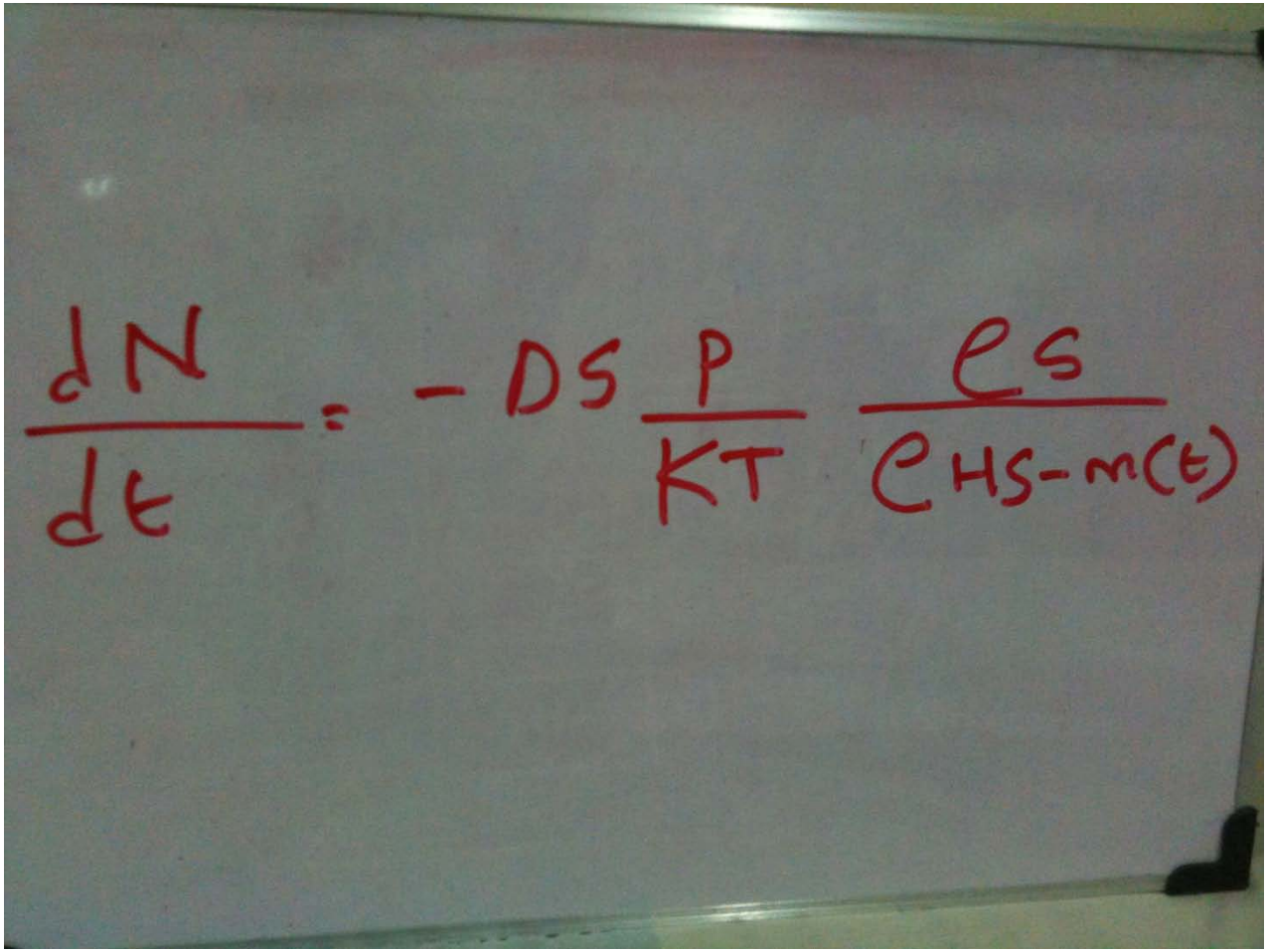
Theory – Another Assumption.



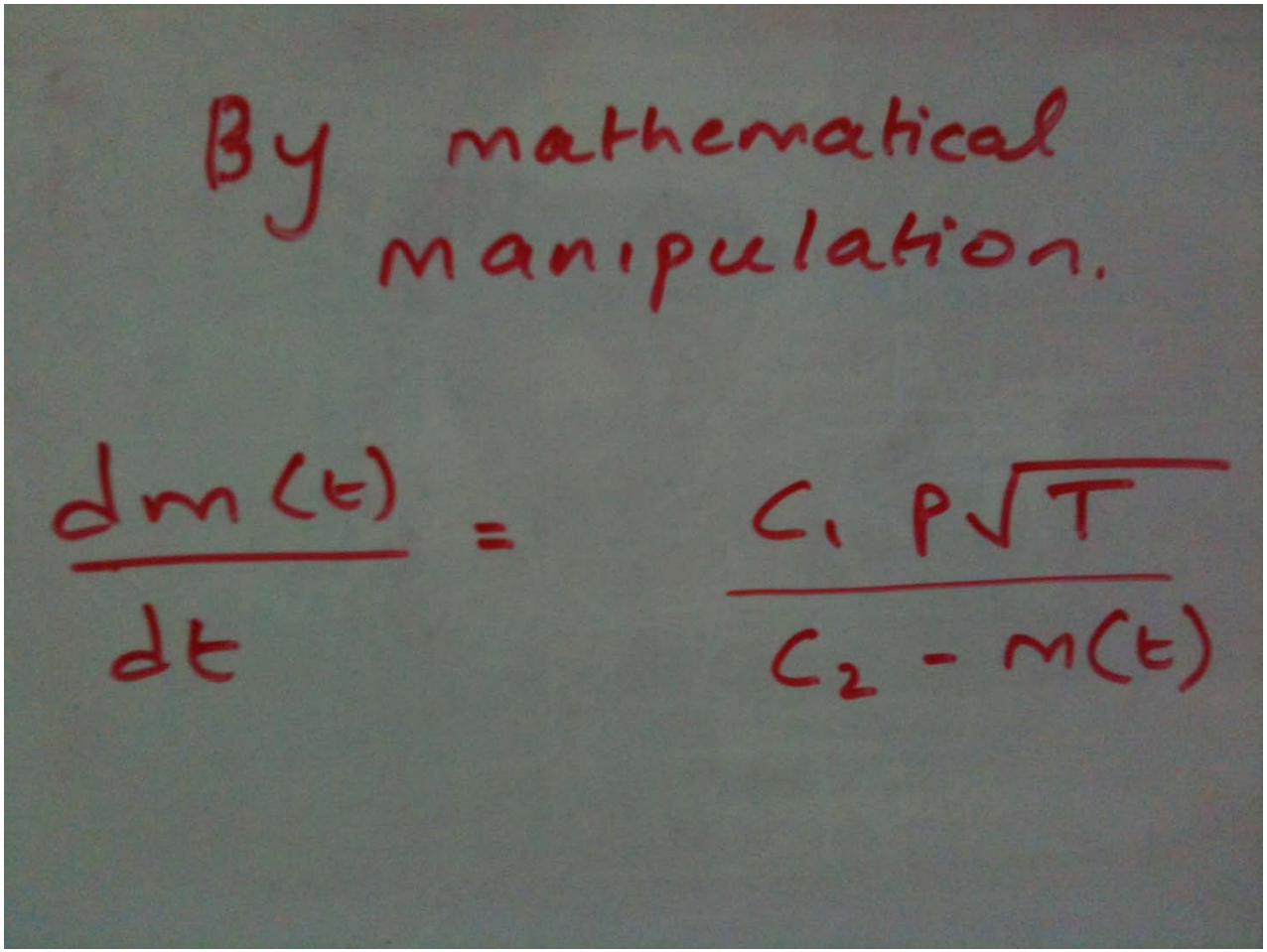
Theory – Yet Another Assumption.



Fick's Law after Assumption # 5, 6 & 7



After a Lot of Math.

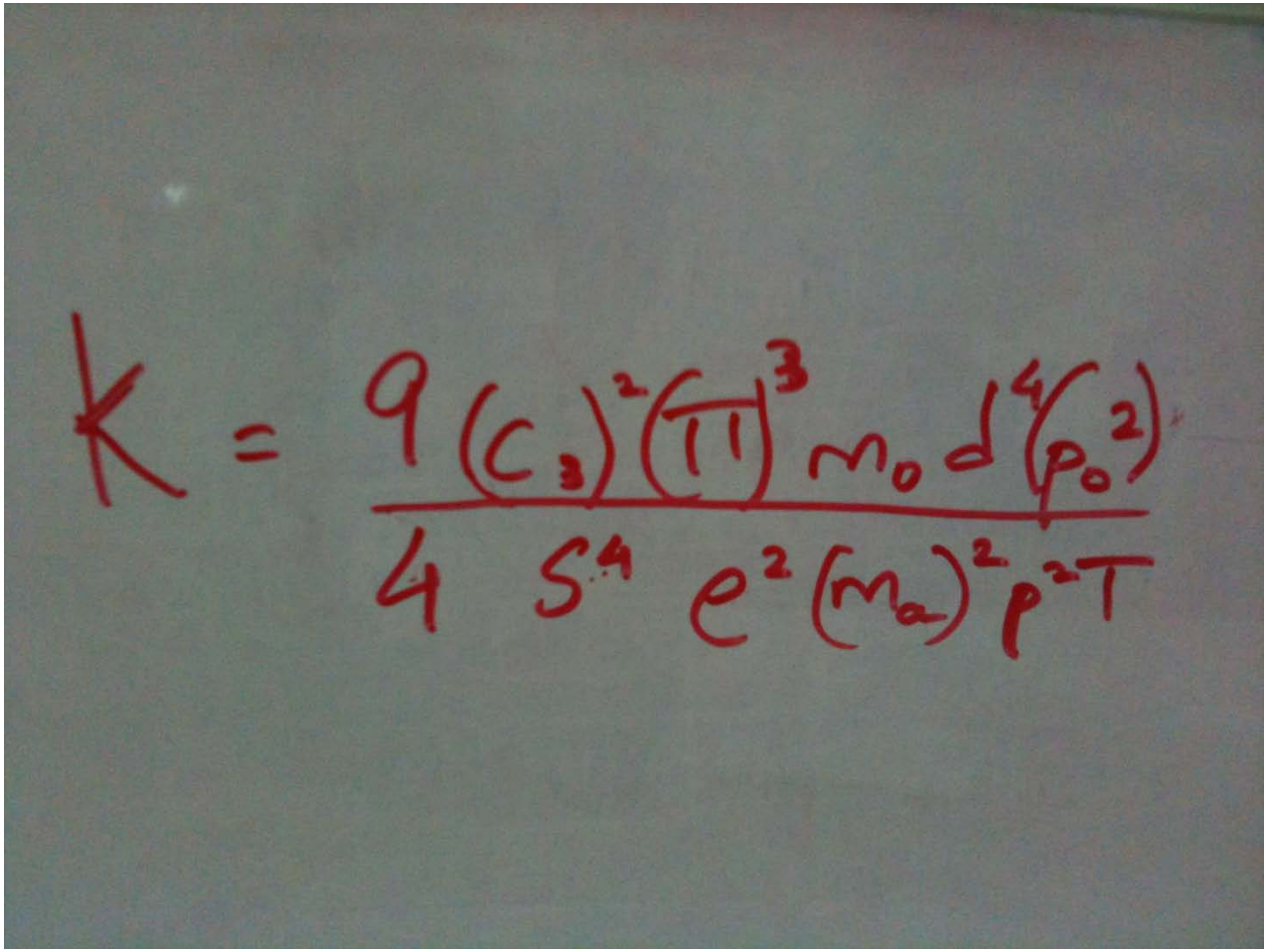


Yet Another Assumption.

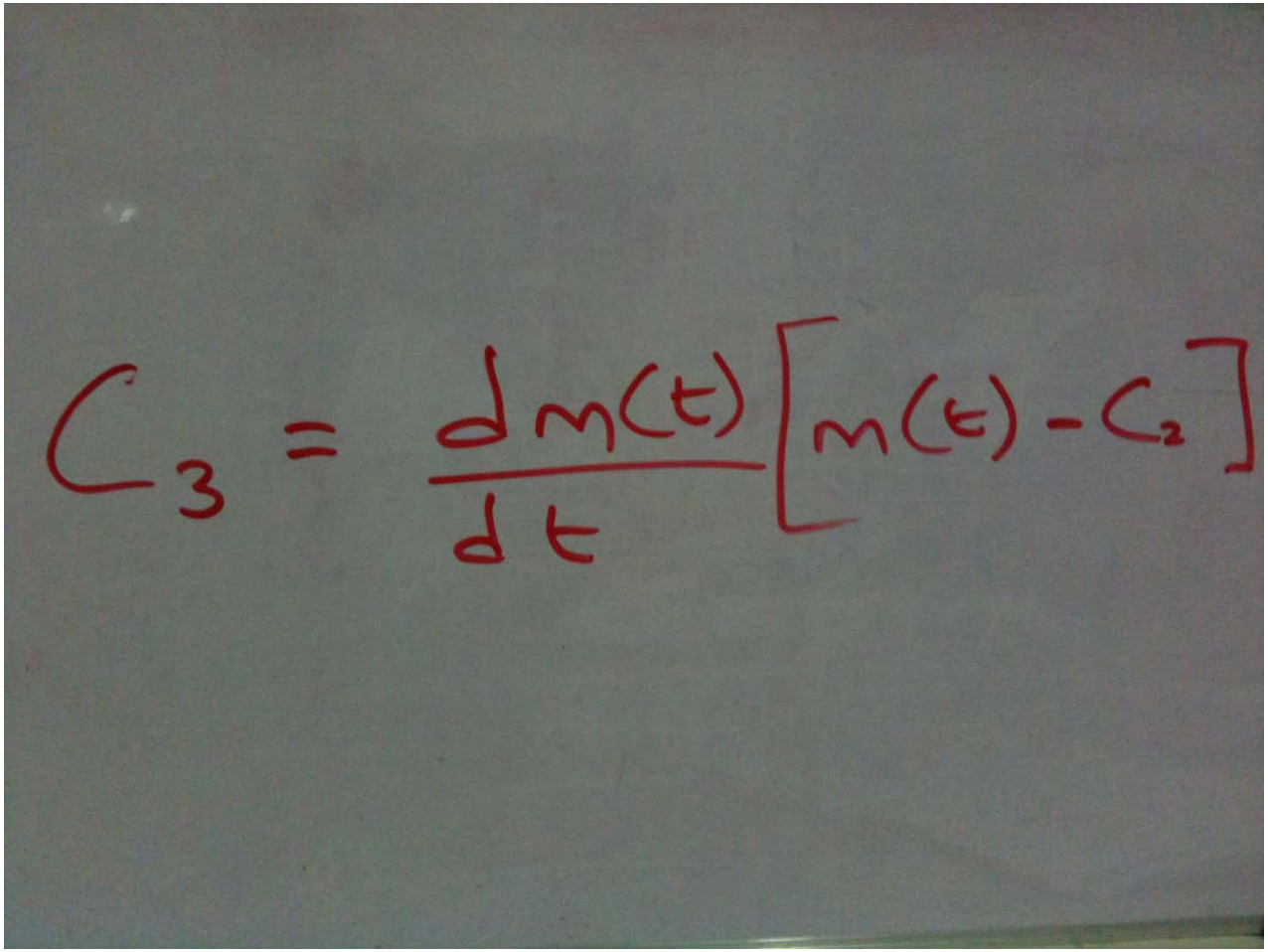
$$\frac{dm}{dt} = c_3 \frac{1}{c_2 - m(t)}$$

$$c_3 = p\sqrt{T}\, c_1$$

After some more Math.



C3



The Experimental Setup – A Snapshot.

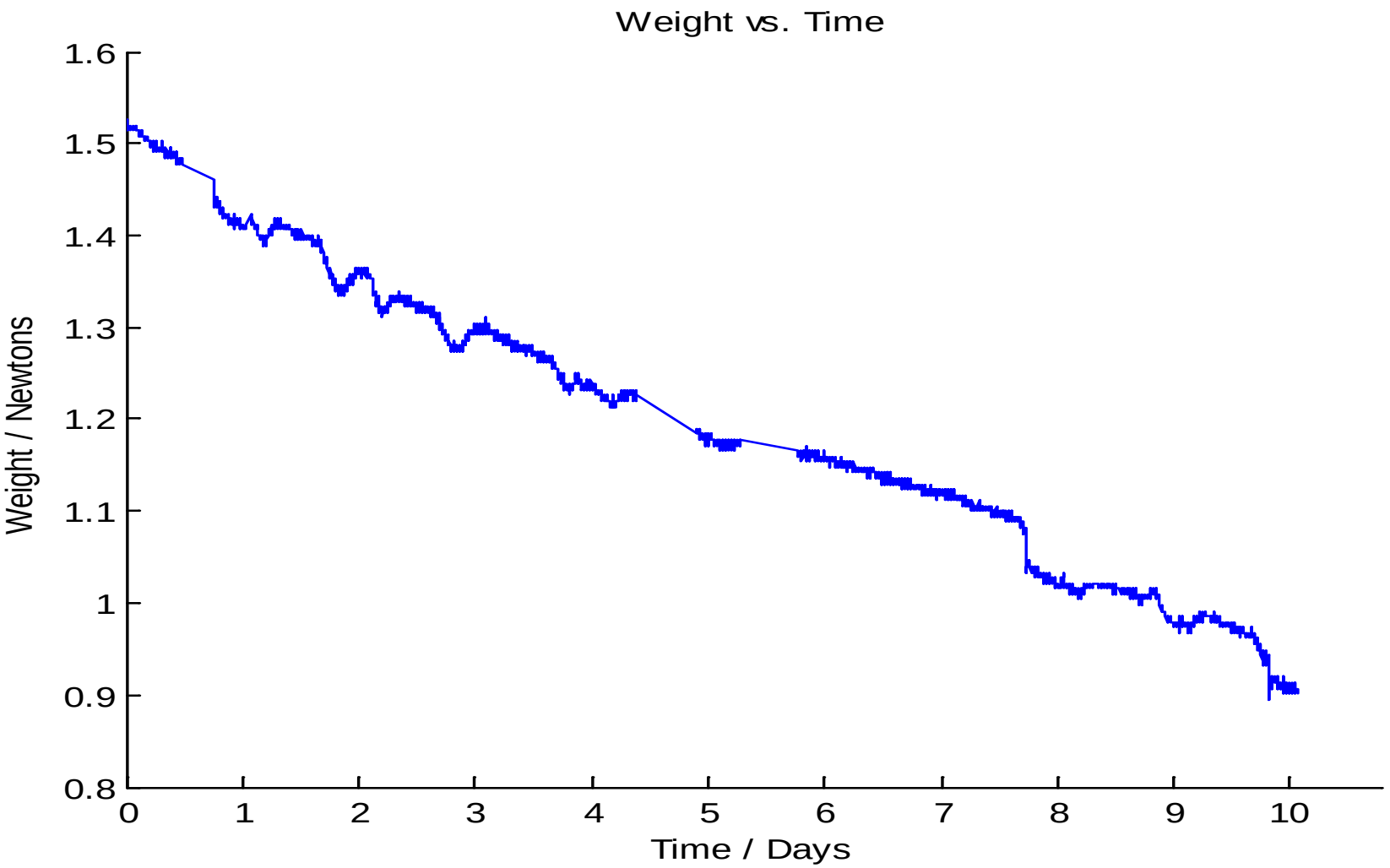
The Experiment – Software Used.

- Labview → To check the temperature variations. It was determined that they were not significant.
- Logger Pro → Interfaces Lab Pro with the computer. Lab Pro gathered information from the…
- Force Sensor (devise)→ Measured the weight of the alcohol after every 100 seconds.

The Disaster.

- On the 12th of June, the experiment was started. On the 6th day, three consecutive power failures caused the data collected to crash.
- A re-run was immediately started.
- The experiment which was scheduled to finish on the 22nd now finished on the 27th.

The Results on the 27th.



Some Problems.

- On Monday morning, 5 grams of the Ethanol were unaccounted for.
- On Wednesday, 1 gram of Ethanol was unaccounted for.
- Restricted to two parts of the graph and not the entire graph as a whole.
- The evaporation procedure was not yet complete.

What to do now?

1. Evaluate the Boltzmann constant for the two separate parts.
2. Theoretically account for the mass loss.

Apologies.

- I have not yet been able to calculate the Boltzmann constant through the evaporation of ethanol. However considering the nice trend of the graph and the good behavior of temperature I can be confident of a highly accurate answer.

Thank you !