ChE331 Experimental Project

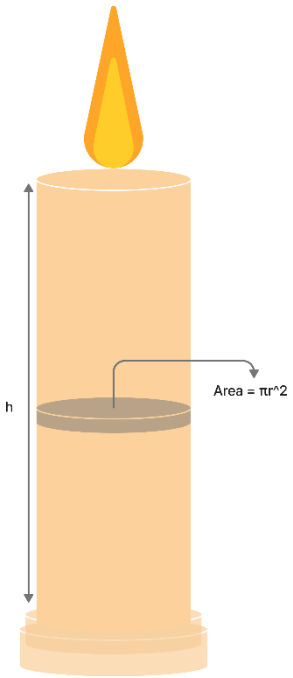
Rate Kinetics of Burning Candle

By: Tushar Verma (221147)
Under guidance of *Prof. Raj Ganesh S. Pala Sir*

Aim: To analyze & determine the rate kinetics of burning candle

Objective:

- Calculate & model the rate expression of candle burning.
- Calculate the overall order of reaction for complete combustion.
- Check does the rate of burning "depends" upon the 'concentration of candle wax' or 'height of candle' & if yes, then find out the relation.
- Optimize at which dimensions (or the ratio of height/area) does the candle last for the longest.

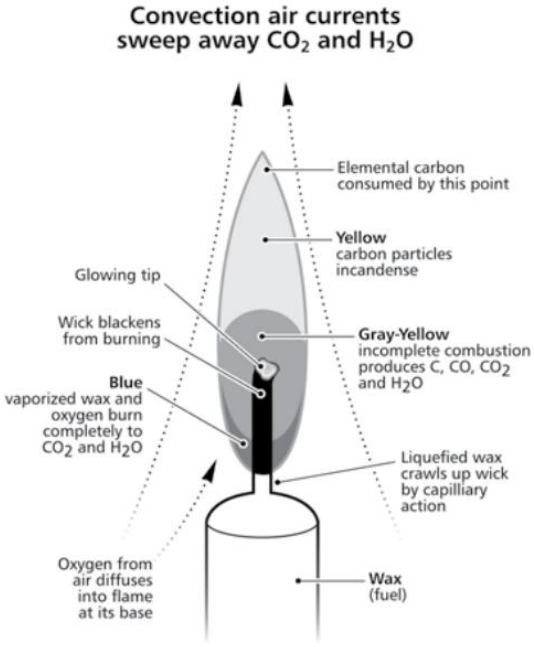


Procedure:

1) Take 5-6 candles of different size, with same volume of candle wax.
2) Observe the burning of candles & note down the "Xa" ('conversion') vs "time" data (at about interval of ~8 minutes).
3) $(1 - X_A) \approx \frac{vol\_left}{vol\_total}$; "Xa" can be approximated from height's ratio, because the cross-section area of candle is constant.
4) Perform this analysis for all 5-6 candles of different area & height such that volume of candle wax is constant.
5) Repeat the same observations for every candle.
6) Note down the total time taken by each candle to burn completely.

Chemical Reaction: In Burning of Candle

$$C_{25}H_{52} + 38O_2 \rightarrow 25CO_2 + 26H_2O$$



Materials Required:

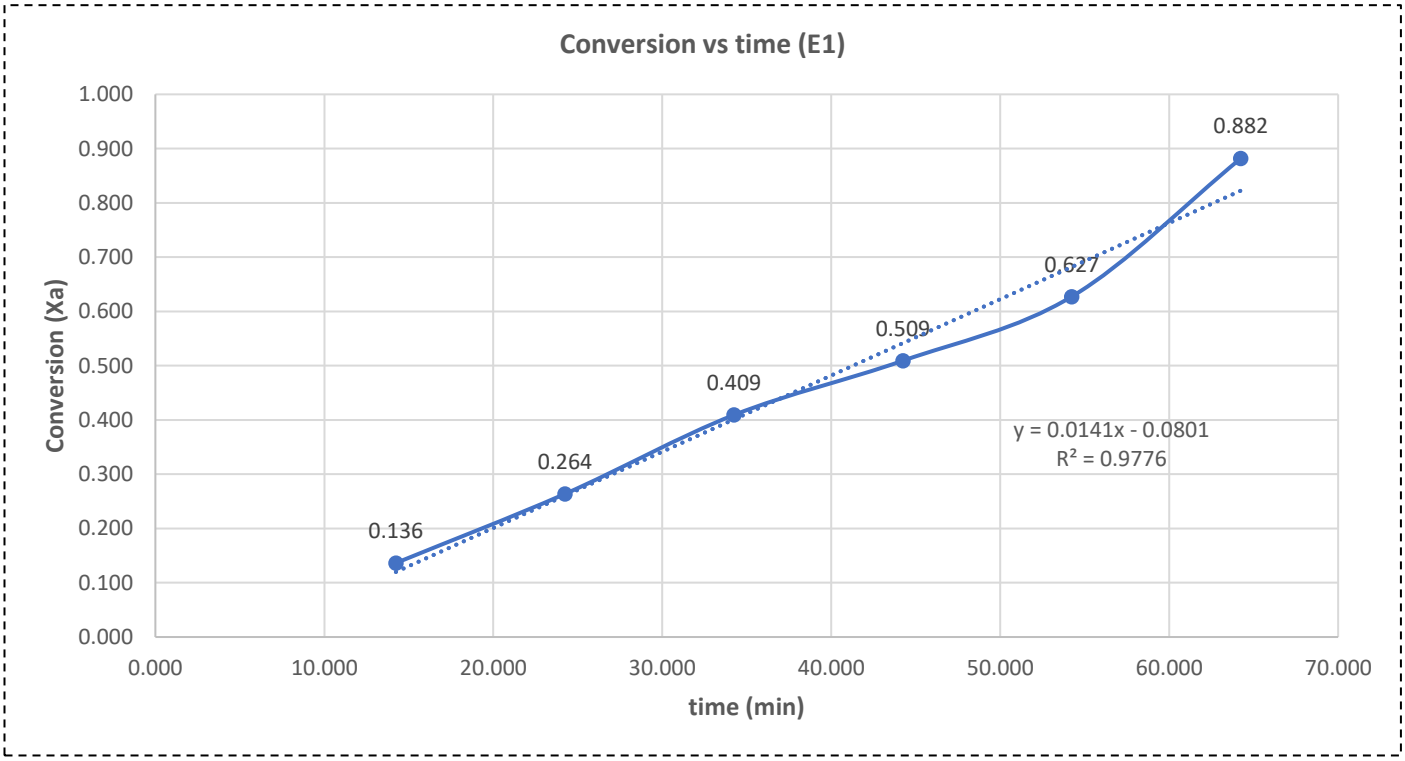
- 5-6 Candles of different sizes (if not available, then wax ~ 400gm; cotton wick; few beakers of different size; burner.)
- Temperature or Thermal sensor (if available) for measuring the variation of flame temperature with height of candle.

Observations:

***Experiment 1*:**

Exp 1	h_left	xa	t (sec)	t (min)	t (min)	vol_conv	vol_left
cone	11		254	4.233	00:04:14	0.619	14.601
cylinder	9.5	0.136	854	14.233	00:14:14	1.991	12.610
	8.1	0.264	1454	24.233	00:24:14	3.849	10.751
	6.5	0.409	2054	34.233	00:34:14	5.973	8.628
	5.4	0.509	2654	44.233	00:44:14	7.433	7.168
	4.1	0.627	3254	54.233	00:54:14	9.159	5.442
	1.3	0.882	3854	64.233	01:04:14	12.875	1.726

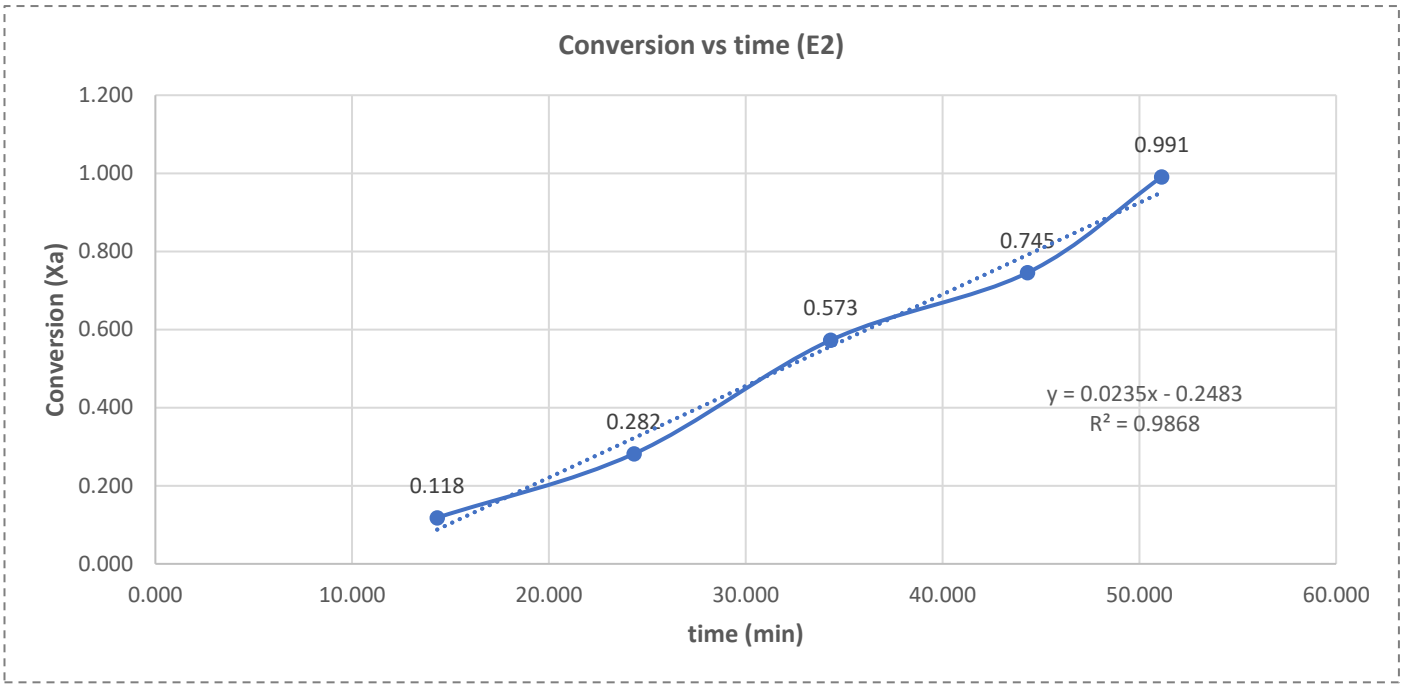
		units
h_cy	11	cm
h_cone	1.4	cm
dia	1.3	cm
rad	0.65	cm
vol_cy	14.60055	cm^3
vol_cn	0.619417	cm^3



***Experiment 2*:**

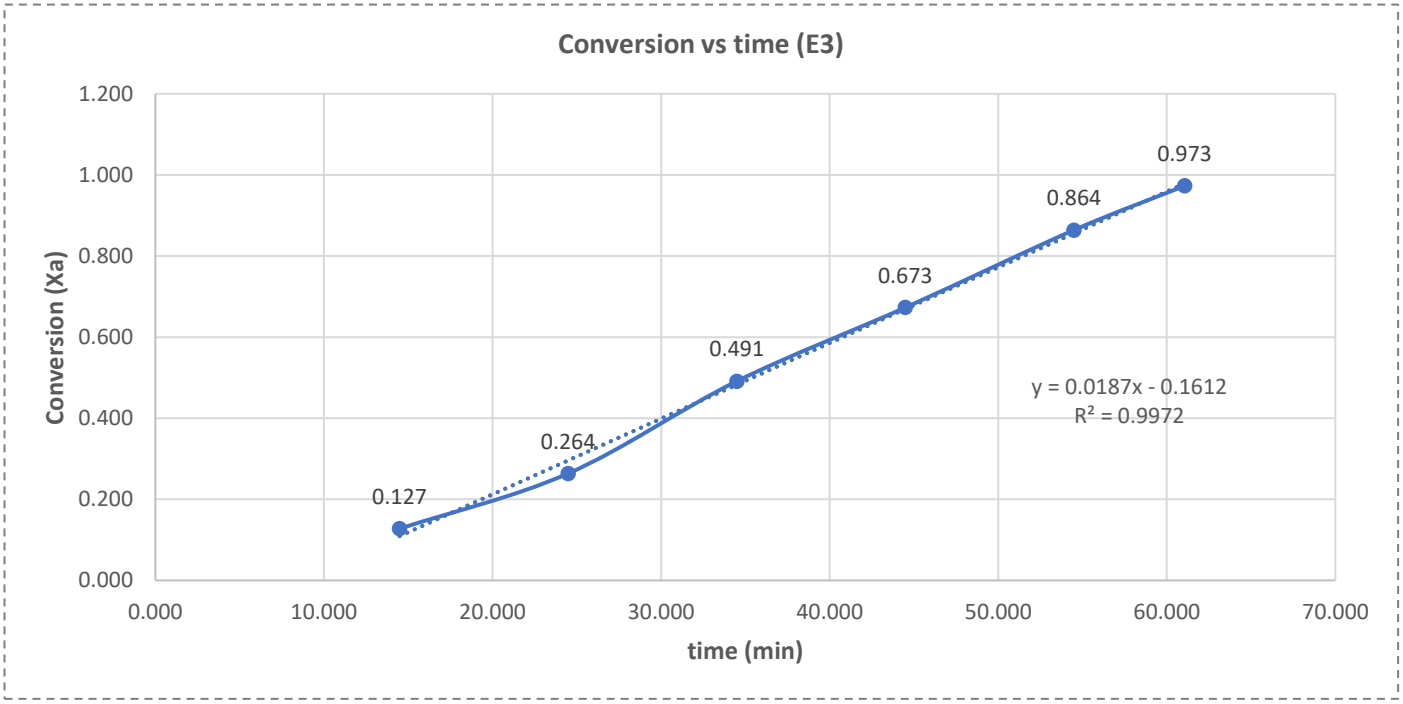
Exp 2	h_left	xa	t (sec)	t (min)	t (min)	vol_conv	vol_left
cone	11		259	4.317	00:04:19	0.619	14.601
cylinder	9.7	0.118	859	14.317	00:14:19	1.726	12.875
	7.9	0.282	1459	24.317	00:24:19	4.115	10.486
	4.7	0.573	2059	34.317	00:34:19	8.362	6.238
	2.8	0.745	2659	44.317	00:44:19	10.884	3.717
	0.1	0.991	3068	51.133	00:51:08	14.468	0.133

		units
h_cy	11	cm
h_cone	1.4	cm
dia	1.3	cm
rad	0.65	cm
vol_cy	14.60055	cm^3
vol_cn	0.619417	cm^3



Experiment 3:

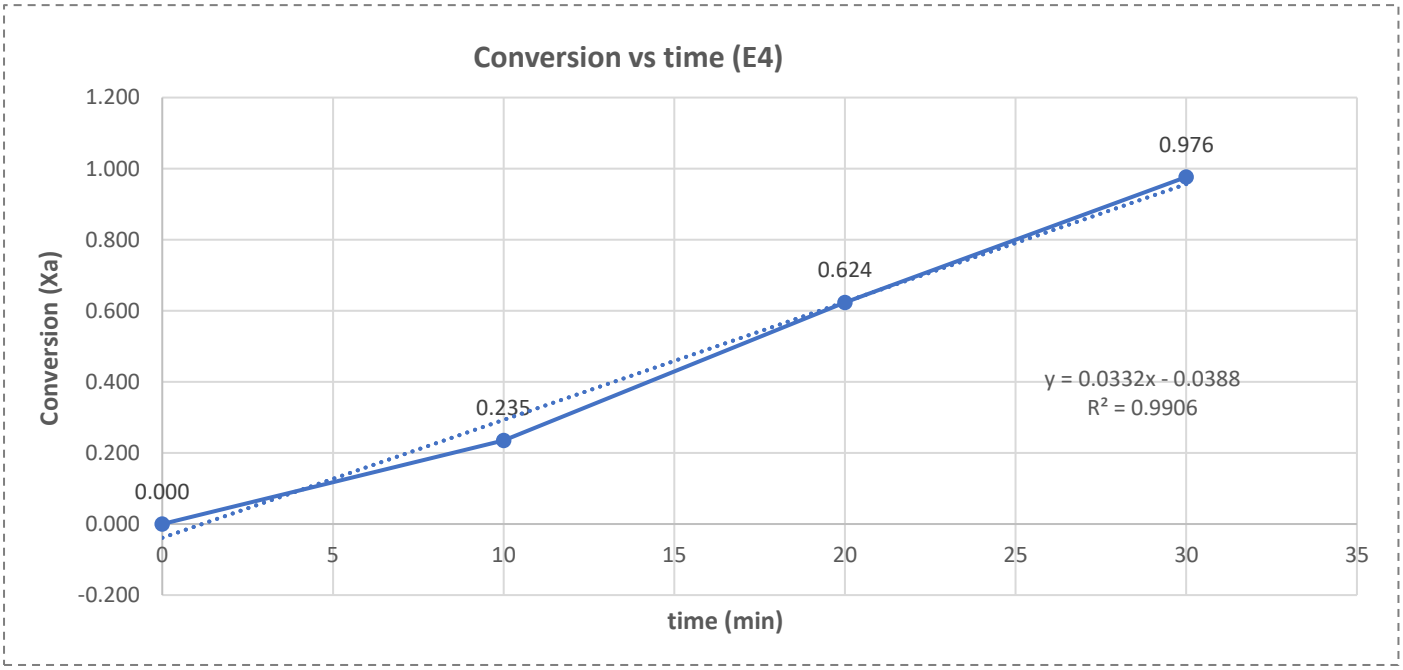
Exp 3	h_left	xa	t (sec)	t (min)	t (min)	vol_conv	vol_left				
cone	11		269	4.483	00:04:29	0.619	14.601				units
									h_cy	11	cm
cylinder	9.6	0.127	869	14.483	00:14:29	1.858	12.742		h_cone	1.4	cm
	8.1	0.264	1469	24.483	00:24:29	3.849	10.751		dia	1.3	cm
	5.6	0.491	2069	34.483	00:34:29	7.168	7.433		rad	0.65	cm
	3.6	0.673	2669	44.483	00:44:29	9.822	4.778		vol_cy	14.60055	cm^3
	1.5	0.864	3269	54.483	00:54:29	12.610	1.991		vol_cn	0.619417	cm^3
	0.3	0.973	3663	61.050	01:01:03	14.202	0.398				



Experiment 4:

Exp 4	h_left	xa	t (sec)	t (min)	t (min)	vol_conv	vol_left
cylinder	8.5	0.000	0	0	00:00:00	0.000	15.021
	6.5	0.235	600	10	00:10:00	3.534	11.486
	3.2	0.624	1200	20	00:20:00	9.366	5.655
	0.2	0.976	1800	30	00:30:00	14.667	0.353
Cup formed on the top got melted from one side, causing flickering & uneven melting.							

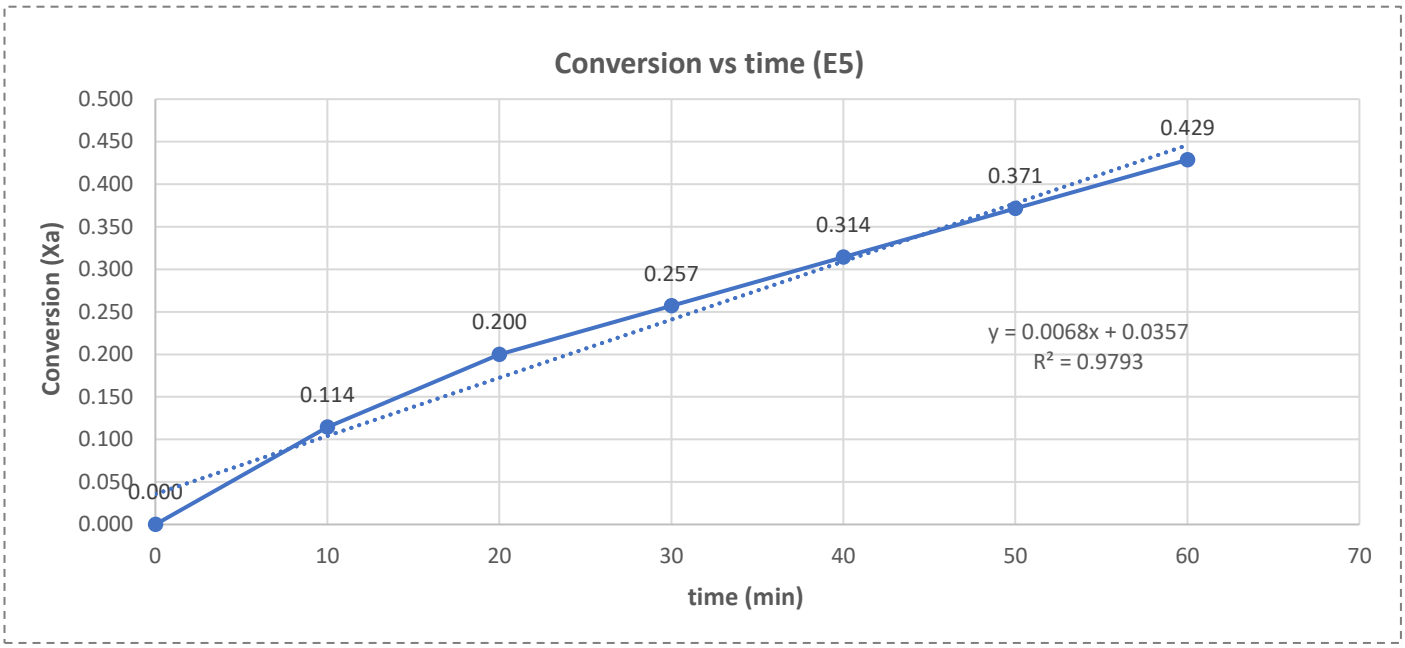
		units
h_cy	8.5	cm
dia	1.5	cm
rad	0.75	cm
vol_cy	15.02074	cm^3



Experiment 5:

Exp 5	h_left	xa	t (sec)	t (min)	t (min)	vol_conv	vol_left
cylinder	3.5	0.000	0	0	00:00:00	0.000	24.740
	3.1	0.114	600	10	00:10:00	2.827	21.913
	2.8	0.200	1200	20	00:20:00	4.948	19.792
	2.6	0.257	1800	30	00:30:00	6.362	18.378
	2.4	0.314	2400	40	00:40:00	7.775	16.965
	2.2	0.371	3000	50	00:50:00	9.189	15.551
	2	0.429	3600	60	01:00:00	10.603	14.137

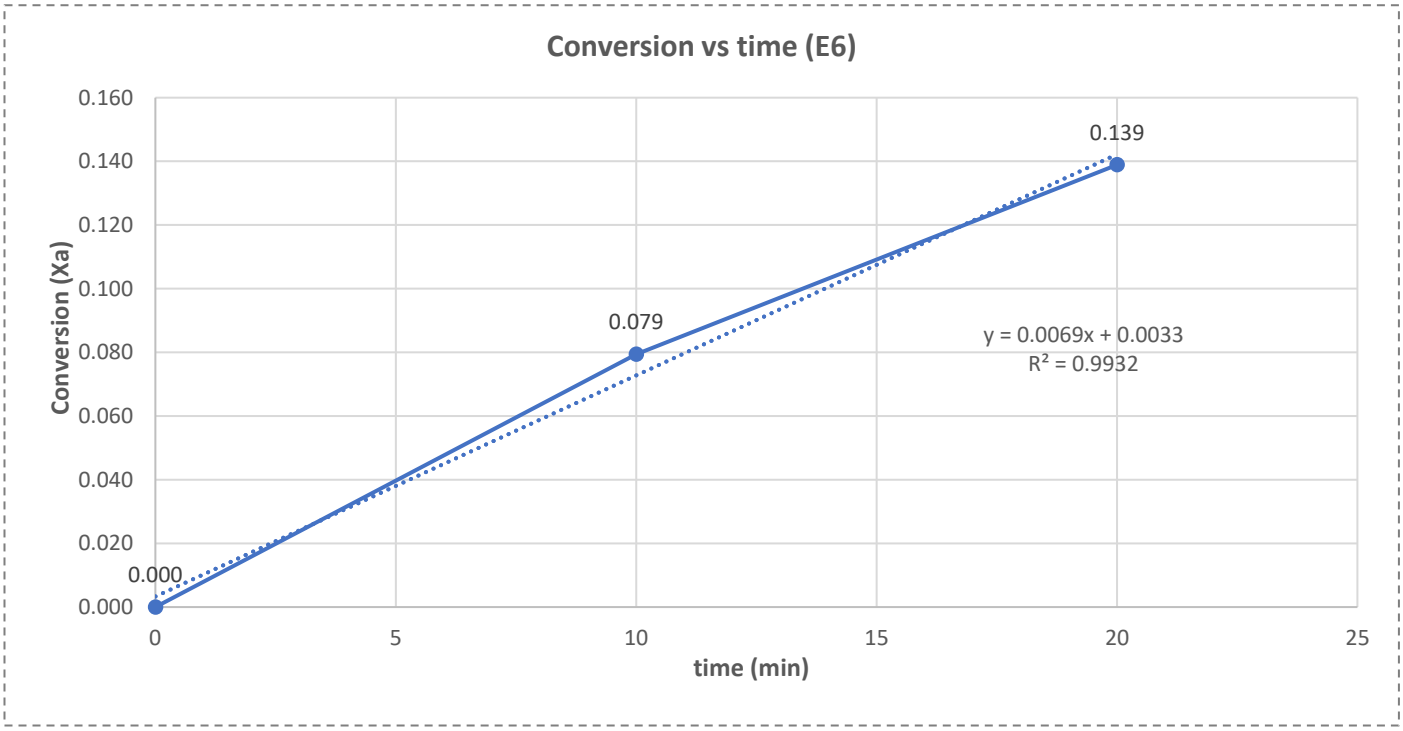
		units
h_cy	3.5	cm
dia	3	cm
rad	1.5	cm
vol_cy	24.74004	cm^3



Experiment 6:

Exp 6	h_left	xa	t (sec)	t (min)	t (min)	vol_conv	vol_left
cylinder	3	0.000	0	0	00:00:00	0.000	14.726
	2.6	0.079	600	10	00:10:00	1.963	12.763
	2.3	0.139	1200	20	00:20:00	3.436	11.290
Candle's cover was made of cardboard, which caught fire after these readings.							

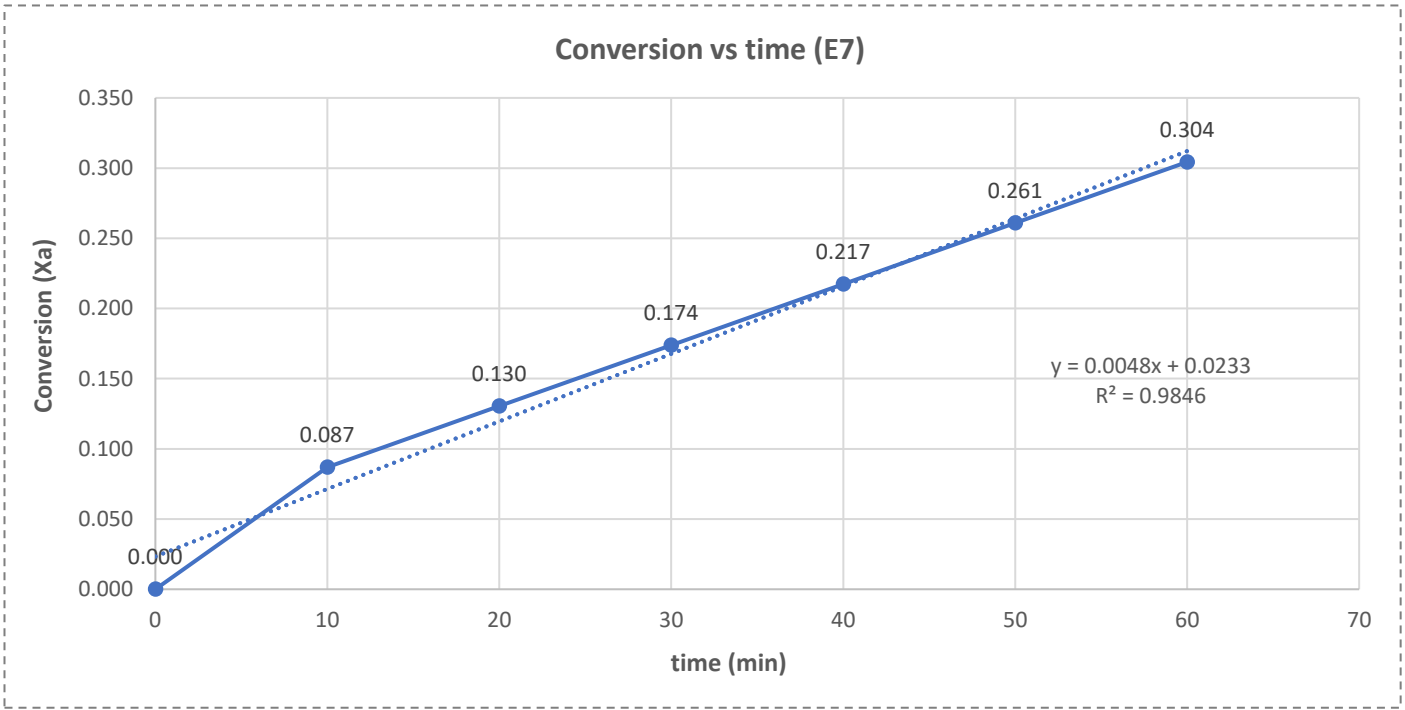
		units
h_cy	3	cm
dia	2.5	cm
rad	1.25	cm
vol_cy	14.72622	cm^3



***Experiment 7*:**

Exp 7	h_left	xa	t (sec)	t (min)	t (min)	vol_conv	vol_left
cylinder	2.3	0.000	0	0	00:00:00	0.000	7.226
	2.1	0.087	600	10	00:10:00	0.628	6.597
	2	0.130	1200	20	00:20:00	0.942	6.283
	1.9	0.174	1800	30	00:30:00	1.257	5.969
	1.8	0.217	2400	40	00:40:00	1.571	5.655
	1.7	0.261	3000	50	00:50:00	1.885	5.341
	1.6	0.304	3600	60	01:00:00	2.199	5.027

		units
h_cy	2.3	cm
dia	2	cm
rad	1	cm
vol_cy	7.225663	cm^3



Analysis & Conclusion:

- Change of volume or Conversion is linearly proportional to time i.e. Equal volume decreases in equal amount of time, independent of the shape of candle.
- Rate kinetics for candle wax is following zero-order kinetics as dXa/dt = constant (~0.01).
- Volume conversion data obtained from experiments follows a linear curve as $R^2 \sim 1$.
- Hence, we can say that chemical reaction in burning of candle follows zero-order kinetics & is independent of shape chosen. Flame luminosity depends on O_2 (oxygen) available near the flame (where wick is burning).
- During candle burning a beautiful cup is formed where solid wax is melted to liquid & this liquid is transferred to top of wick through capillary action. There the wax is vaporized & this vaporized wax undergoes chemical reaction to form carbon-dioxide & water vapor. If this cup is somehow broken or leaked, the melted wax flows down causing uneven burning of candle. Flame width & conversion rate will increase of sudden, as occurred in during Experiment 4.
- Ratio of radius/height does not effect the change of volume per unit time. So for optimization we should choose a candle in which the cup formed at top is stable.

Possible sources of errors during experiment:

- When candle is burned in open atmosphere, blowing of wind can cause uneven burning of flame & making the cup of liquid wax broken from one side, leading to increased rate of combustion & error in data. (As shown in figure ->)
- Candle burned in ceramic beaker was having a limited source of O_2 (from top only), therefore it's luminosity was less as compared to candle burned in open. Rate of change of volume with time was also less. (As seen in Experiment 5,6,7)
- In experiment 6, melted wax was stored in cardboard container & allowed to freeze it. Due to some unwanted air which caused flickering of candle flame & led to burn the carboard container, so further data couldn't be obtained.
- Flame width was dependent on the oxygen available for combustion, which was different in Experiment 5,6,7 because of different dimensions & shapes of containers. It led to difference in luminosity.