Production and Kinetic Study of Acetylene Gas

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Abstract— Now a days due to energy crises it is very important to find a batter options which gives eco-friendly and efficient energy. The generation of acetylene from hydrolysis of calcium carbide was found as part of carbide-based fuel system. This reaction is highly exothermic and fastest. To batter rate control glycerin was used to coat the reactant particle to form a slurry prior to their reaction with water. The generation rate of reaction data with different amount of water and compare it's with and without adding glycerin as a part of kinetic study. With reference to the result, acetylene is strong contender to be used as alternative fuel in internal combustion engine after controlling the reaction rate by using glycerin.

Keywords: Calcium Carbide, Acetylene Gas, Water, Glycerin, Rate of Reaction

I. INTRODUCTION

Acetylene gas is highly exothermic and reactive gas.it is simplest alkyne form with formula c_2h_2.it is highly unstable and orderless in it's pure form and it is colureless gas. Acetylene is made from two process. 1)chemical reaction 2)thermal cracking. When acetylene burns it produces high amount of heat (11.8 kj/g) with 3330 °c, and it's eco-friendly and completely non-toxic gas. The major advantage of use acetylene gas as alternative fuel is, it's made from renewable sources.

II. ACETYLENE GAS PRODUCTION METHOD

There are two process available for production of acetylene gas. (a) chemical reaction process.(normal temperature. (b) thermal cracking process.(very high temperature).

A. Chemical Reaction Process

This process is widely used for acetylene gas generation, in this method methane react with air or oxygen and produce calcium carbide. The other processes is calcium carbide take as a main raw material for the generation of acetylene gas. When calcium carbide and water mixed with each other acetylene gas is formed and calcium hydroxide formed as residue. This process is done in two way 1) wet process. 2) dry process

Mostly wet process is used because of it is a simple and easily controllable.

1) Wet Process

In this process screw conveyor through calcium carbide added into a reaction chamber, which has been field with water at certain level. Gas flow rate is controlled by pressure switch. If too much gas is produced at one time, switch opens and cut the feeding of calcium carbide. For continues mixing reactor have a rotating paddles.

Then it is passed through spray chamber and cool down and passed from the scrubber for removing impurities and passed through dryer.

Chemical reaction:

$$CaC_{2(s)} + 2H_2O_{(l)} \longrightarrow C_2H_{2(g)} + Ca(OH)_{2(l)}$$

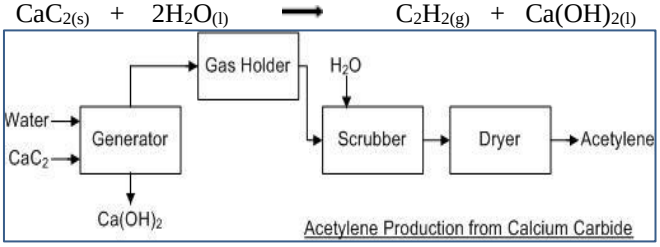

Fig. 1: Acetylene Gas Production
(Picture Courtesy: Acetylene Process.jpg)

2) Dry Process

In presences some industries like pvc and pharmaceutical use wet process for acetylene gas generation. But in the wet process uses 17 times water than theoretical value and also produces huge amount of carbide based slug slurry.

In this method mixing water with calcium carbide powder in proportion of 1.1-1.9:1, and spraying water on calcium carbide powders in acetylene generator and hydrolyzing to generate acetylene. Acetylene recovery rate reaches to 98.5 wt%, water content of calcium carbide slag is 4-12 wt%, reactive temperature is set between 87-93 °c and water content is 75%.the main purpose of using this method is increases acetylene gas yield, low energy consumption, and higher purity gas. the main advantage of use this method is lower pollution effect on the environment.

B. Thermal Cracking Process

In this process, acetylene gas is generated by raising the temperature of various hydrocarbons to the point where acetylene atomic bonds break. After the break, it rebounds to form different raw materials than the original. Acetylene gas is generated as a co-product of the steam cracking process in petroleum industries.

Natural gas is heated to about 650° c. The pre heated gas self-ignite when it is reach at burner and requires less oxygen for combustion. The heated gas passes through a venturi, where oxygen is injected and mixed with the hot gas. The mixture of gas and oxygen passes through a diffuser .then the gas mixture flows into the burner section, which contains more than 100 narrow channels. When the gas flows into this channel, it self-ignites and produces heat which raises the gas temperature to about 1,500° c

The burning gas flows into the reaction space which is beyond the burner where around one-third of the methane to be converted into acetylene, the flaming gas is quickly quenched with water sprays at the point where the acetylene gas produces more. The gas passes through a water scrubber, which removes much of the carbon particle the gas then passes through a second scrubber where it is sprayed with a solvent known as N-methyl pyrrolidinone which absorbs the acetylene, but not the other gases. The solvent is pumped into a separation tower where the acetylene is boiled out of the solvent and is drawn off at the

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top of the tower as gas and solvent is drawn out of the bottom.

III. EXPERIMENTATION 1

A. Acetylene gas production by chemical reaction method

The method used for the experiment is the hydrolysis of calcium carbide As show in Topic II (A). the aim of the experiment is to find a quantity of calcium carbide and water for maximum yield, measure volume of gas, a kinetic study on acetylene gas, control reaction rate by adding glycerin and survey and comparison from the graph.

Experimental apparatus are Measuring Cylinder, Conical Flask, Cork, Water, Calcium Carbide, Digital Weighing scale (with accuracy 0.01g), Flexible tube, Water Bathtub, Syringe (for accurate measurement of water), stopwatch, Gloves, Face masks and Protective glasses for safety.

Chemical reaction:

$$CaC_{2(s)} + 2H_2O_{(l)} \longrightarrow C_2H_{2(g)} + Ca(OH)_{2(l)} \quad \ldots(1)$$

1) Experimental setup

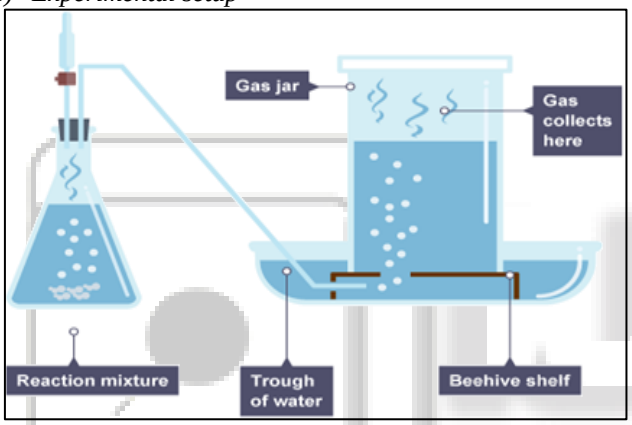

Fig. 2: Experimental setup for Acetylene Gas Generation (Picture Courtesy: askiitians.com)

Initially, a specified amount of calcium carbide(3g) is taken in a dry conical flask. A tube is filled with water(55 ml) .measuring cylinder(1000ml)is filled with water up to the brim and carefully reverse into a water bath without air leak into a measuring cylinder. Now the hole is drilled into a cork so that a flexible tube can fit without any clearance. The free end of the tube is placed inside the inverted measuring cylinder.

When the known amount of calcium carbide and water are mixed with each other acetylene gas is generated and it is passed through the flexible tube to inverted measuring cylinder and water displaced by the acetylene gas, And also measure the volume of gas by measuring cylinder marking.

Fig. 3: Flame of Acetylene Gas

2) Calcium Carbide and Water Reaction

Calcium carbide received from the manufacturer was in the form of stones ranging in size 1 cm to 5 cm. This size is not suitable for the experiment because of the lower surface area.

So first it crushed into roll crusher ranging in size 10 Mesh which is suitable for the experiment. When water is mixed with calcium carbide chemical reaction (1) occurs and acetylene gas generated. The gas flame of acetylene gas is shown in fig 3.

3) Materials issues

Calcium carbide is extremely reactive with water so extra care needed to keep it dry.it is also react with air and transfer into powder form. which decreases reactivity because of formation by air.

4) Observation

The first observed a volume of acetylene gas by adding different amounts of water.

Weight of CaC_2 (g)	Volume of Water (ml)	Volume of C_2H_2 (ml)
3	15	540
3	20	590
3	30	620
3	40	610
3	45	600
3	50	680
3	55	730
3	60	500

Table 1: Amount of Acetylene produced by varying volume of water.

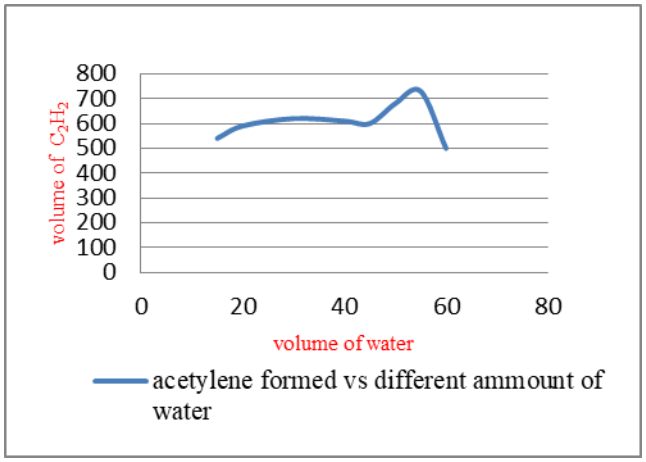

Fig. 4: Acetylene formed vs. different amount of water

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5) Calculation of rate of reaction and order of reaction

As per equation (1)

$CaC_{2(s)} + 2H_2O_{(l)} \longrightarrow C_2H_{2(g)} + Ca(OH)_2$ (l)

Takes 3g of calcium carbide and 55 ml water (Table 1)

So acetylene gas volume 625ml (Table.1)

Total volume of reactor used in experiment = 2.25 liter

The rate equation is,

$$r_A = (\frac{1}{V})(\frac{d\,nA}{dt}) \quad \ldots(2)$$

Where, r_A= reaction rate based on component A

V= Total Volume of Reacting system (reactor)

n_A= Number of moles of A at time t.

$\frac{d\,nA}{dt}$ = total concentration (mol/second)

Time (second)	Volume of C_2H_2 (measuring cylinder reading)(ml)	Concentration C_A (Mol/liter)
10	110	0.00042545
15	130	0.00036000
20	190	0.00024632
25	230	0.00020348
30	280	0.00016714
35	330	0.00014182
40	370	0.00012649
45	410	0.00011415
50	440	0.00010636
55	480	0.00009750
60	510	0.00009176
65	540	0.00008667
70	570	0.00008211
75	600	0.00007800
80	630	0.00007429
85	650	0.00007200
90	680	0.00006882
95	700	0.00006686
100	720	0.00006500
105	730	0.00006411
110	740	0.00006324
115	760	0.00006158
120	780	0.00006000
125	790	0.00005924
130	800	0.00005850
135	810	0.00005778
140	820	0.00005707
145	825	0.00005673
150	830	0.00005639
155	835	0.00005605
160	840	0.00005571
Total time =160 s	Total volume=730	Total concentration $=6.41 \times 10^{-5}$

Table 2: Concentration and volume(C2H2) data at 55 ml water.

The concentration is finding by below calculation

Total volume generated of C_2H_2 = 730 ml

So that total volume generate per unit time = $\frac{730}{160}$

= 4.56ml/second

= 4.56×10^{-3} liter/second

Now we know that, for the concentration

22.4 liter => 1 mol

4.56×10^{-3} => ?

$C_A = 2.03 \times 10^{-4}$mol/second

Now we can put C_A value in equation 2

Take total volume =2.25 liter

$\frac{d\,nA}{dt} = 2.03 \times 10^{-4} mol$/second

$r_{A1} = (\frac{1}{2.25})*(2.03 \times 10^{-4})$

$= 9.047 \times 10^{-5} \frac{mol}{liter*second}$

By this method we can find total reaction rate.

For The Total concentration .

Concentration =Total mole/total volume

Total mole of cac_2 = Given weight/molecular weight of cac_2

= 3/64.099

=0.04680 moles

Now put total mole value in concentration formula

= 0.04680/730

$C_A = 6.41 \times 10^{-5}$ mol/liter

As per this calculation we can find concentration at every point.

Now plot concentration vs. time graph.

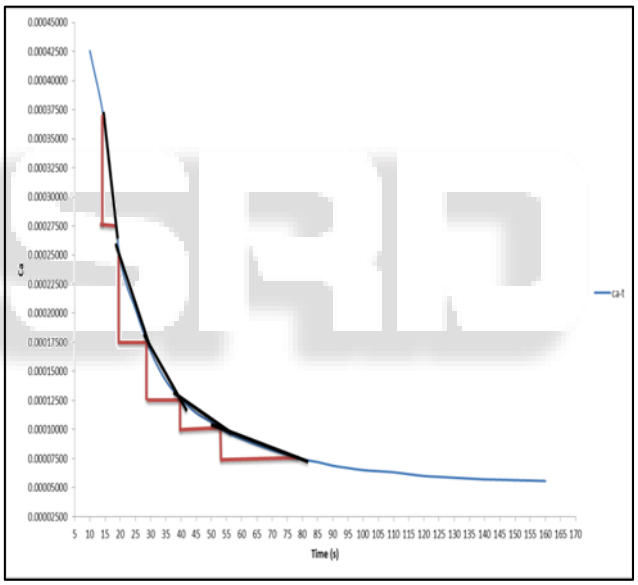

Fig. 5: concentration vs. Time

Now we can find order of reaction from this graph by using value of slope and run value of slope(c_A·)

C_A,	ln C_A,	dC_A/dt =slope value	ln (dC_A/dt)
1.20×10^{-5}	-8.198	1.9×10^{-5}	-10.87
8.06×10^{-5}	-8.651	7.5×10^{-5}	-9.50
9.36×10^{-5}	-8.987	5.0×10^{-5}	-9.90
1.08×10^{-5}	-9.210	1.92×10^{-5}	-13.16
1.34×10^{-5}	-9.498	1.04×10^{-5}	-13.78

Table 3: values from figure 5 (C_A –T)

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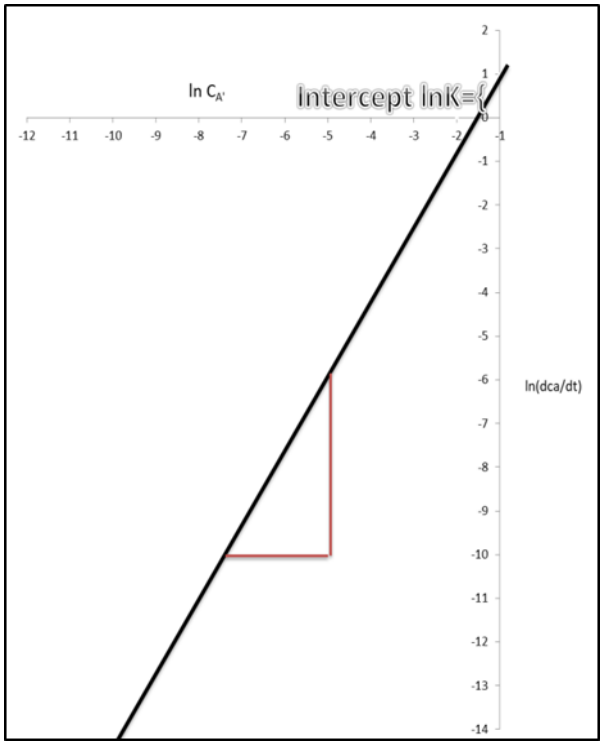

Fig. 6: ln C$_A$' vs. ln(dca/dt)

The value of slope =1.6
The value of intercept ln K= 0.9
Rate constant K=2.45
Order of reaction = 2nd order (slope > 1.6)

IV. EXPERIMENTATION 2

A. Acetylene gas production by chemical reaction method with Adding glycerin

It is a same method which uses in Experiment 1.A but the only difference is, in this experiment glycerin is added for coat the reactant particle.

So that we can control the reaction rate then it's become more applicable to use in Ic engine.

$CaC_{2(s)} + 2H_2O_{(l)} + \text{Glycerin} \longrightarrow C_2H_{2(g)} + Ca(OH)_{2(l)}$

Glycerin is not takes parts in reaction; it's only use for control the reaction.

Now as a same procedure we find a reaction rate and compare this data with experiment 1 data.

Take 55 ml water and 3g calcium carbide. Added around 7 to10ml glycerin. And for proper mixing with water give continues stirring .

After mixing with water added calcium carbide. Then note the volume.

B. Observations

Time (second)	Volume of C_2H_2 (measuring cylinder reading)(ml)	Concentration C_A (Mol/liter)
10	100	0.00046800
15	125	0.00037440
20	150	0.00031200
25	200	0.00023400
30	250	0.00018720
35	310	0.00015097
40	360	0.00013000
45	410	0.00011415
50	450	0.00010400
55	480	0.00009750
60	510	0.00009176
65	540	0.00008667
70	570	0.00008211
75	590	0.00007932
80	620	0.00007548
85	640	0.00007313
90	650	0.00007200
95	660	0.00007091
100	680	0.00006882
105	700	0.00006686
110	720	0.00006500
115	730	0.00006411
120	740	0.00006324
125	750	0.00006240
130	760	0.00006158
135	770	0.00006078
140	773	0.00006054
145	775	0.00006039
150	778	0.00006015
155	780	0.00006000
Total time =155 s	Total volume=680	Total concentration =6.88 x 10^{-5}

Table 2: Concentration and volume(c2H2) data at 55ml water with adding glycerin

The same calculation followed for finding C_A value
Then the values are ,
Take total volume =2.25 liter

$\frac{d\,nA}{dt}$ = 1.54 x 10^{-4} mol/second

$r_{A2} = (\frac{1}{2.25})*(1.54 \times 10^{-4})$

$= 6.84 \times 10^{-5} \frac{mol}{liter*second}$

Now comparing r_{A1} and r_{A2} value and find a result

C. Result

After performing both experiments the results shows that reaction rate is decrees after adding glycerin into the water.

r_{A1} value	r_{A2} value
9.047 x10^{-5} $\frac{mol}{liter*second}$	6.84 x 10^{-5} $\frac{mol}{liter*second}$

V. MAJOR APPLICATION OF ACETYLENE

Welding, Cutting, Heat-treating
Alternative fuel in IC engine.
Portable lighting.
Production of polyethylene plastic, PVC, polyethylene film.
Making semi-conductor.
Use as an acrylic acid derivatives.

VI. STORAGE AND HANDLING

Acetylene gas is highly exothermic so it's most important to handle with great care. When it is transported through the pipeline, the pressure keeps very low and pipeline length keeps short.

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For use in oxy-acetylene welding, cutting, and melting gas filled in a specialized storage cylinder with high pressure.

It filled with acetone absorber with pressure 300kpa, at this pressure, acetylene absorbed into acetone and it loses its explosive capability and making transport safe.

VII. FUTURE SCOPE

The search for an alternative fuel is one of the needs for sustainable development; many research activities were developed in order to study the Internal Combustion Engines with alternative fuels and it is tested and viable fuel for IC engines.

One other application which is most recently used the ethylene making by conversion of acetylene gas for use in making a polyethylene plastics.

VIII. CONCLUSION

It can be informed from the above observation at 55ml water and 3gm calcium carbide produces more volume than others by figure.4. means every mole of calcium carbide was consumed at 55ml water.

At every fraction of five-second volume measure in reverse measuring cylinder gives a concentration values which is used further for finding the rate of reaction.

Concentration vs. time curve gives a slope value (dC_A/dt) and $c_{A'}$ which uses in lncA' vs. ln (dC_A/dt) graph to find a reaction constant K and order of reaction.

And at end of all calculation, we got 2nd order of reaction. and rate of reaction is 9.47×10^{-5}. $\frac{mol}{liter*second}$

For controlling the reaction rate, added glycerin, and find a reaction rate, which is lower than without added glycerin reaction. i.e. $6.84 \times 10^{-5} \frac{mol}{liter*second}$

so acetylene gas is most suitable as an alternative fuel in the IC engine after solving a higher rate of reaction problems.

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