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Problem No.6
Disappearing Ink

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Outline

- Question
- Chemical Formulation&Formula
- Parameter:
- **Theorical Research**
- **Experiment**
- Appear again
- Error Analysis
- Reference

Disappearing Ink

- Suggest a **chemical formulation** for the ink that would disappear after used to write a text. What **parameters** determine the time when the text becomes **invisible**? Is it possible to process the paper in such a manner that the text **appears again**?

Chemical Formulation

- I_2-starch solution(Blue)

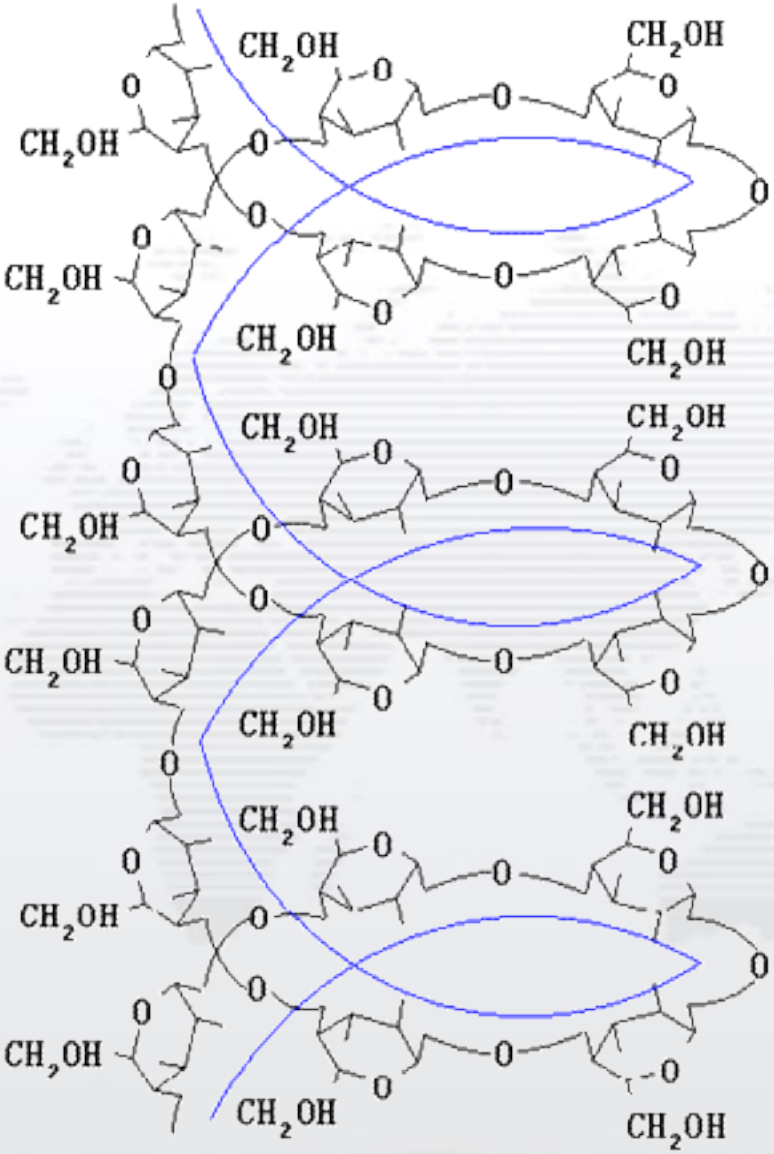
- Tip:All the starch I use is amylose.

Formulas

- $nI_2+(C_6H_{10}O_5)_{6n}$-->$(C_{18}H_{30}O_{15}I)_{2n}$ (clathrate)

(That's why I_2+ starch solution looks blue.)

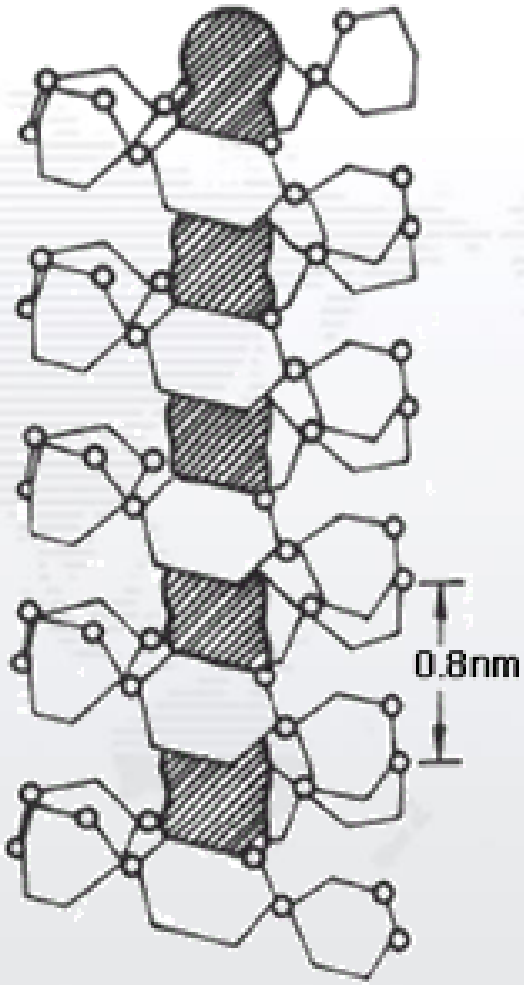
- $I_2+2NaOH==NaI+NaIO+H_2O$
- $3I_2+6NaOH=5NaI+NaIO_3+3H_2O$
- (It becomes invisible for the product is colorless and transparent)



Picture 1 Starch

直链淀粉的螺形结构

Another picture of starch and Iodine



直链淀粉与碘生成络合物

- **What parameters determine the time when the text becomes invisible?**

My Guess

- Temperature
- Concentration
- The size of the words

Theoretical research

- $I_2+2NaOH===NaI+NaIO+H_2O$
- $3I_2+6NaOH===5NaI+NaIO_3+3H_2O$
- NaOH:sodium hydrate [ˈsəʊdiːəm ˈhaɪˌdreɪt]
- Arrhenius equation: $K=Ae^{(-Ea/RT)}$ (1)
- $\ln K=\ln A-Ea/RT$ (2)
- So, when temperature is higher, K is higher.
- If K is higher, v is higher, so t is shorter.

- If the concentration of NaOH is higher, it will be quicker.
- If the concentration of Iodine is higher, it will be slower.

Theoretical research

- The rate is about the change of concentration, but not the mass. So, the size of the word won't influnce the time.
- For it is a reaction happened between NaOH and I_2, the concentration of starch will not influnce the time.

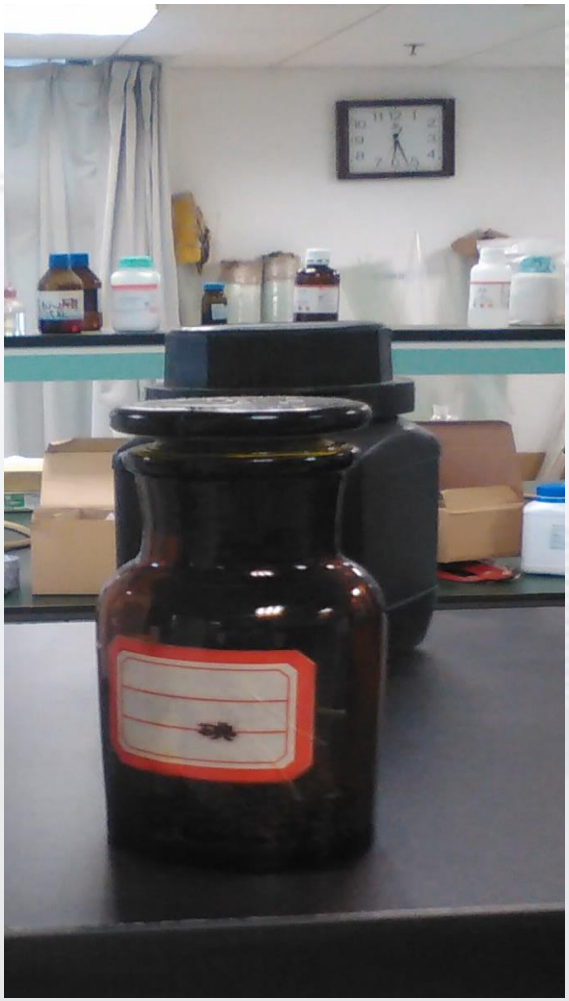
Experiment

Equipments:

- Some same pieces of paper
- I_2 -starch solution
- NaOH Solution

Equipments

Starch

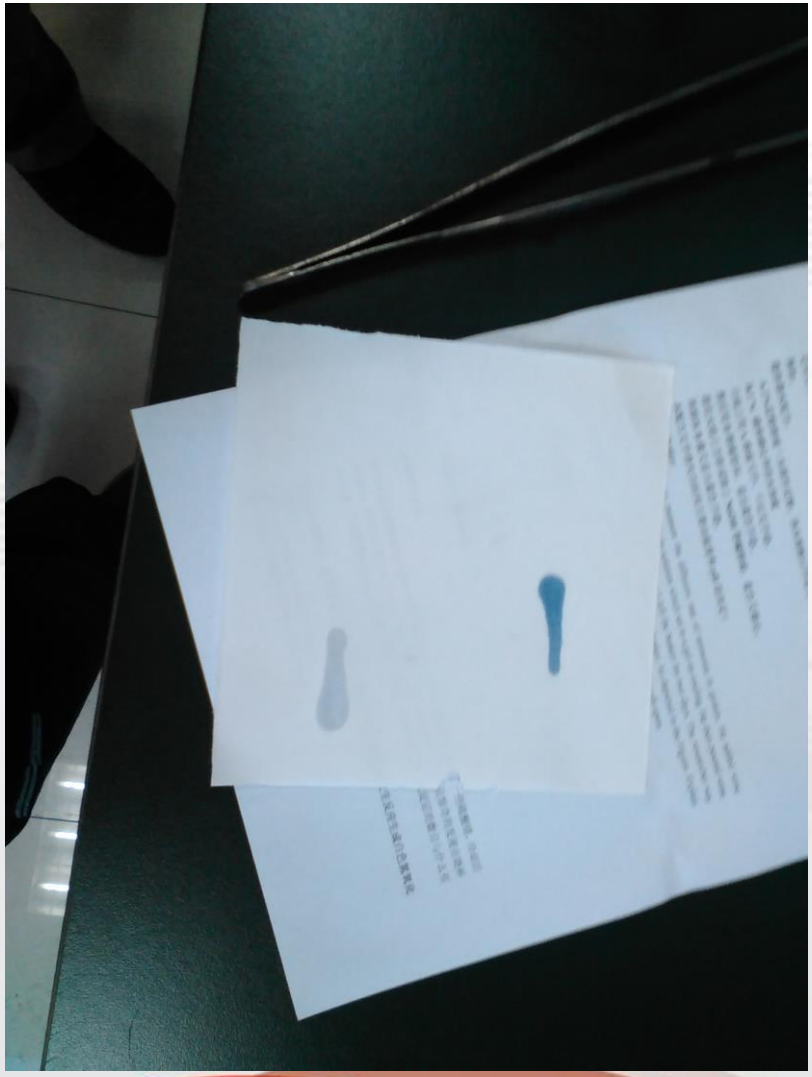


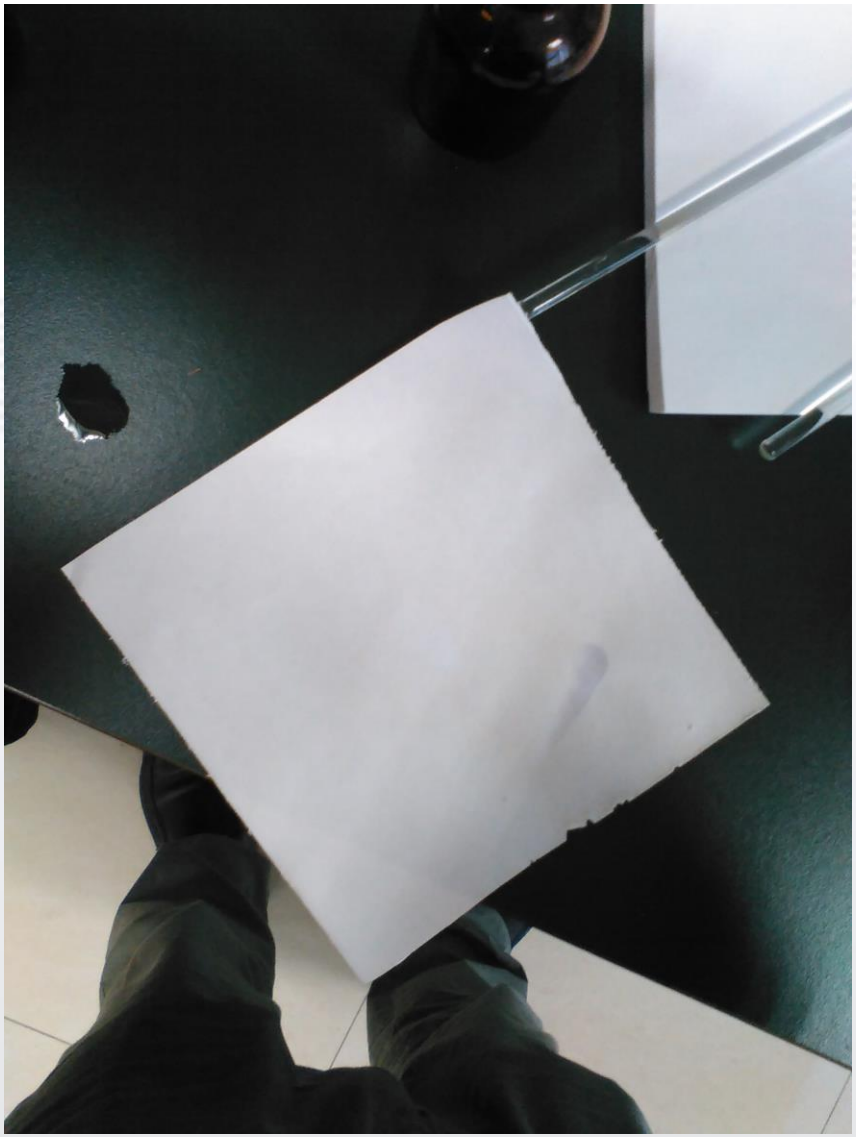
Iodine

Procedure

- 1. Write something on the paper with I_2- starch solution, it is blue.
- 2.Daub some NaOH Solution onto the paper. It disappers.

Some Photos





Video!

- 图片\1.mp4
- 图片\2.mp4
- 图片\3.mp4

Procedure

- 3.Keep Temperature:25℃, The size of the word: 2 square centimetres, Concentration of NaOH Solution:1%, concentration of I_2 in I_2-starch: 1%, change **the concentration of starch** in the solution. Time.
- Then keep the other parametres the same, keep the starch concentration 1%, change **the concentration of I_2** in the solution. Time.

Procedure

- 4.Keep the concentration of I_2-starch solution: 1% starch, 1% Iodine, Temperature:25℃, The size of the word: 2 square centimetres, change the concentration of NaOH Solution. Time.

Procedure

- 5.Keep the concentration of I_2-starch solution: 1%starch, 1% Iodine, The size of the word: 2 square centimetres, 1% NaOH Solution, change the temperature. Time.

Procedure

- 6. Keep the concentration of I_2-starch solution: 1%starch, 1% Iodine, 1% NaOH Solution, Temperature:25℃, change the size of the word. Time.

Temperature

- If the temperature of I_2-starch solution is too high(higher than 45℃), it won't become blue(or the color will disappear soon). But in most parts of the world, it won't be higher than 45℃.

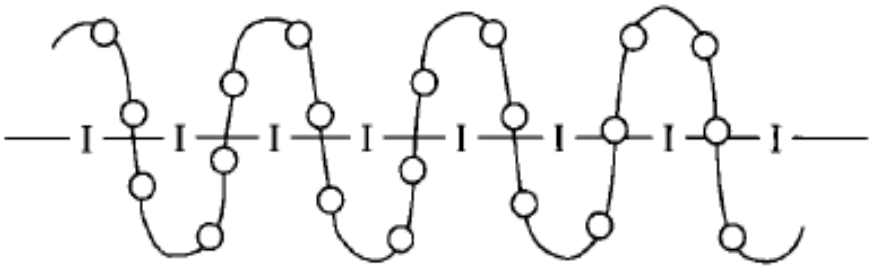
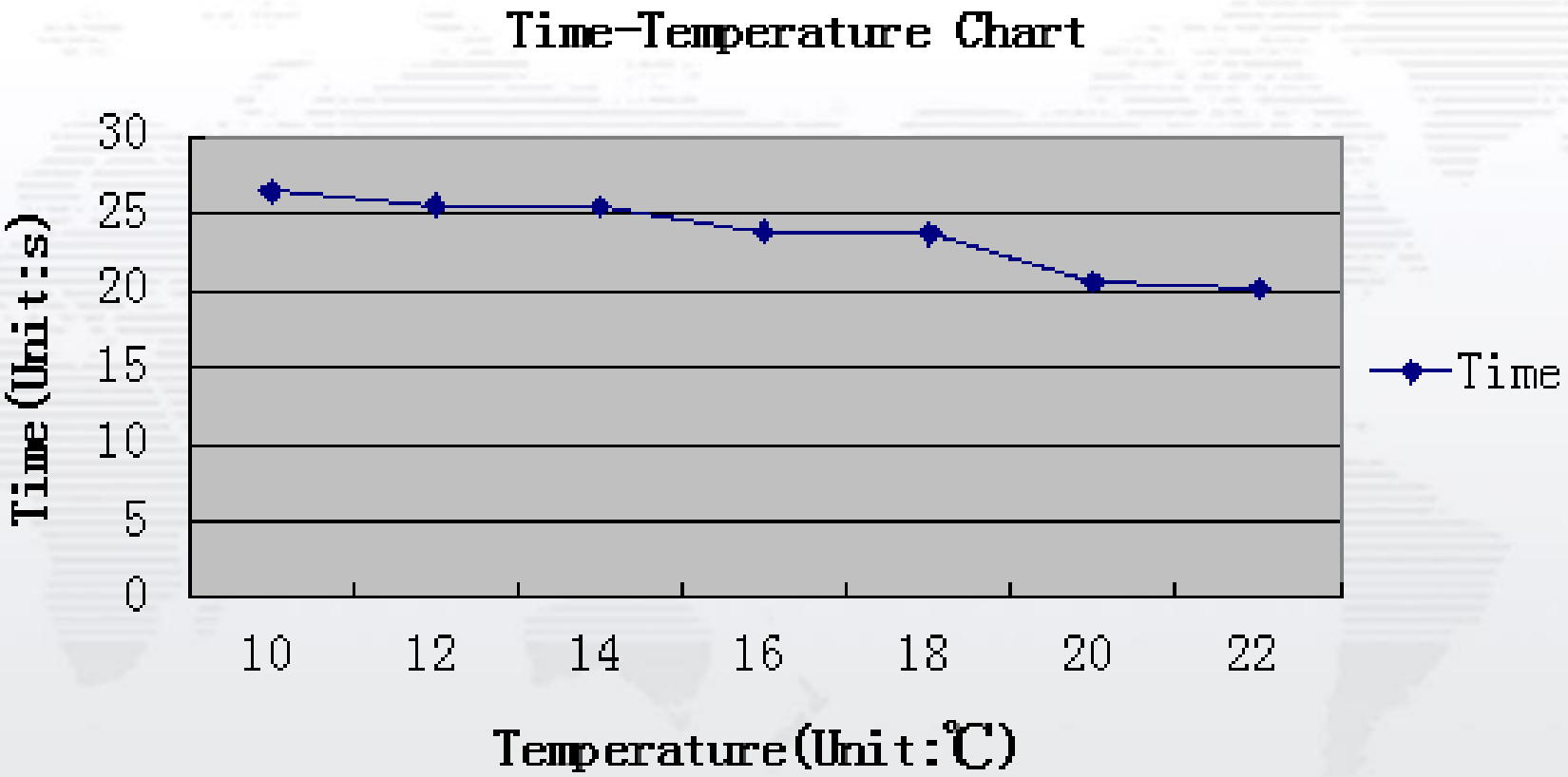
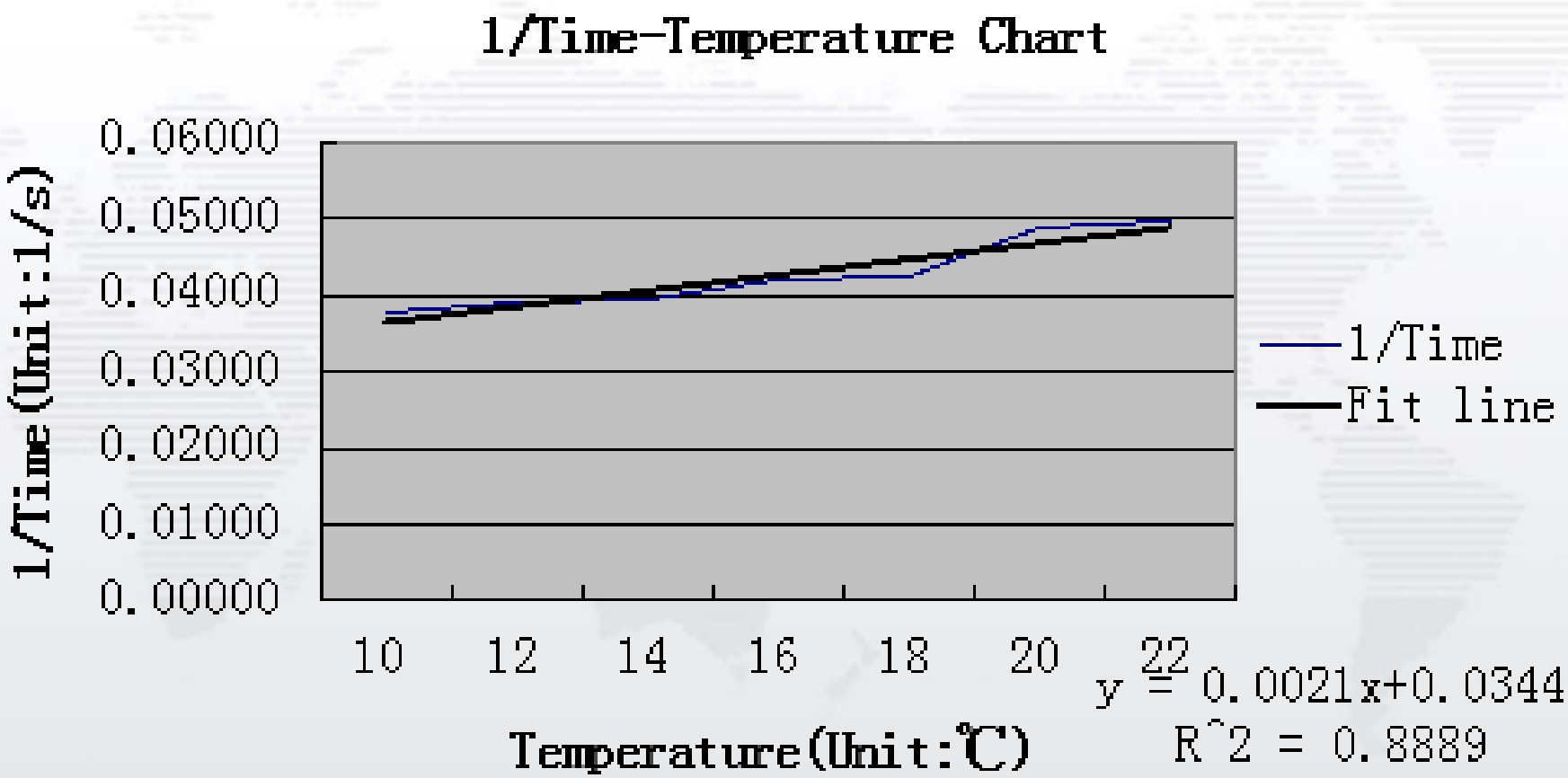
( is broken).

图 5 淀粉——碘包合物

Data


Time-Temperature Chart
30
25
20
15
10
5
0
Time(Unit:s)
10
12
14
16
18
20
22
Temperature(Unit:℃)
Time

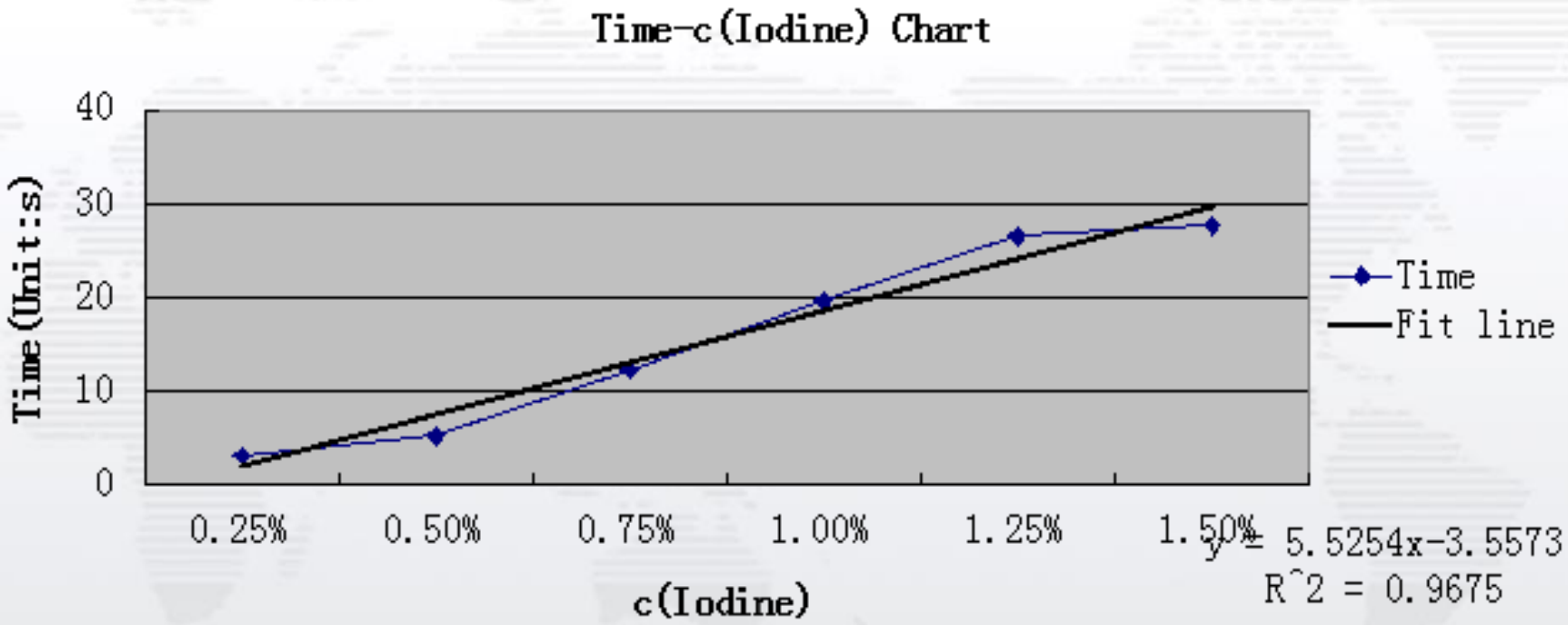
Data


1/Time-Temperature Chart
0.06000
0.05000
0.04000
0.03000
0.02000
0.01000
0.00000
1/Time(Unit:1/s)
10
12
14
16
18
20
22
Temperature(Unit:℃)
1/Time
Fit line
y = 0.0021x+0.0344
R^2 = 0.8889

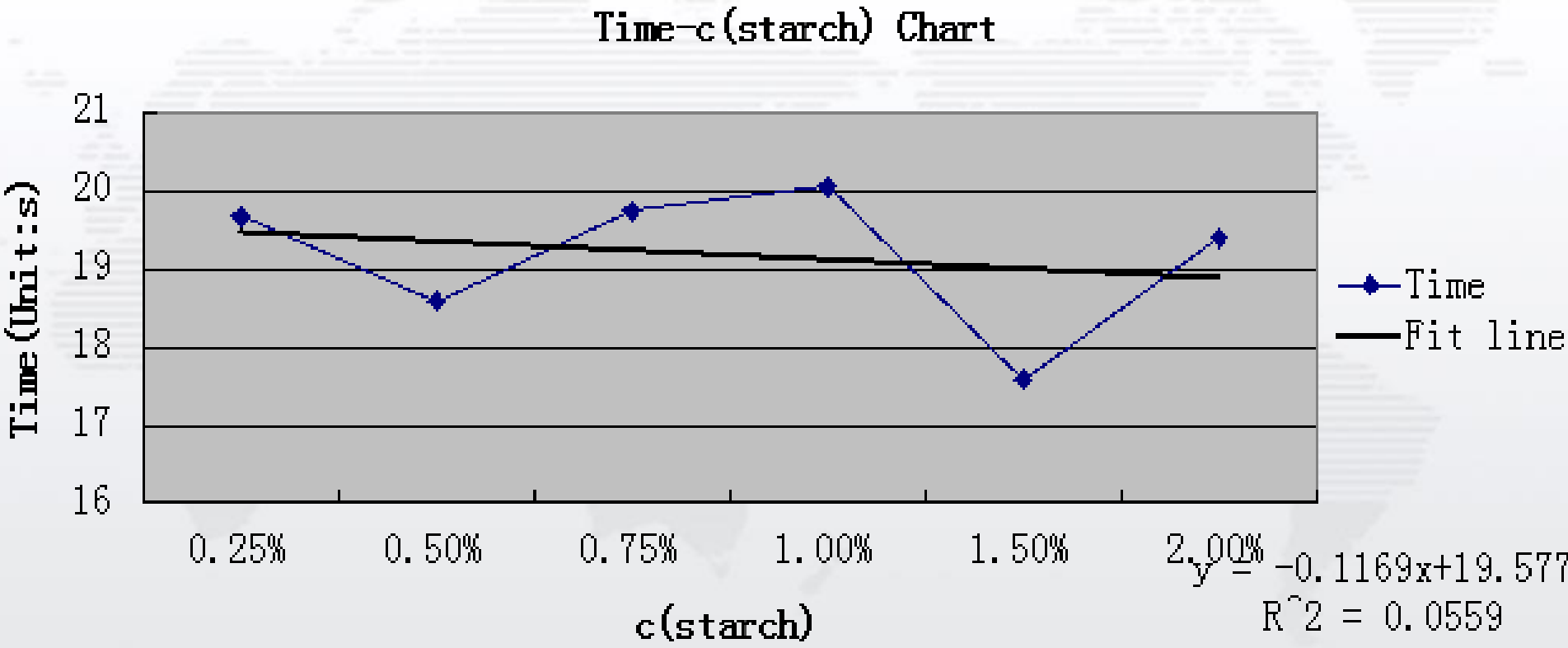
Temperature

- Under 45 ℃, temperature will influence the speed of this chemical reaction. If the temperature is higher, it will make the reaction more quickly.
- Second, when it is warmer, the iodine will evaporate more quickly.

Data


Time-c(Iodine) Chart
Time(Unit:s)
40
30
20
10
0
0.25%
0.50%
0.75%
1.00%
1.25%
1.50%
c(Iodine)
Time
Fit line
y = 5.5254x-3.5573
R^2 = 0.9675

Data


Time-c(starch) Chart
21
20
19
18
17
16
Time(Unit:s)
0.25%
0.50%
0.75%
1.00%
1.50%
2.00%
c(starch)
Time
Fit line
y = -0.1169x+19.577
R^2 = 0.0559

Concentration

If the I_2-starch solution has higher concentration of I_2, it will make the time longer.

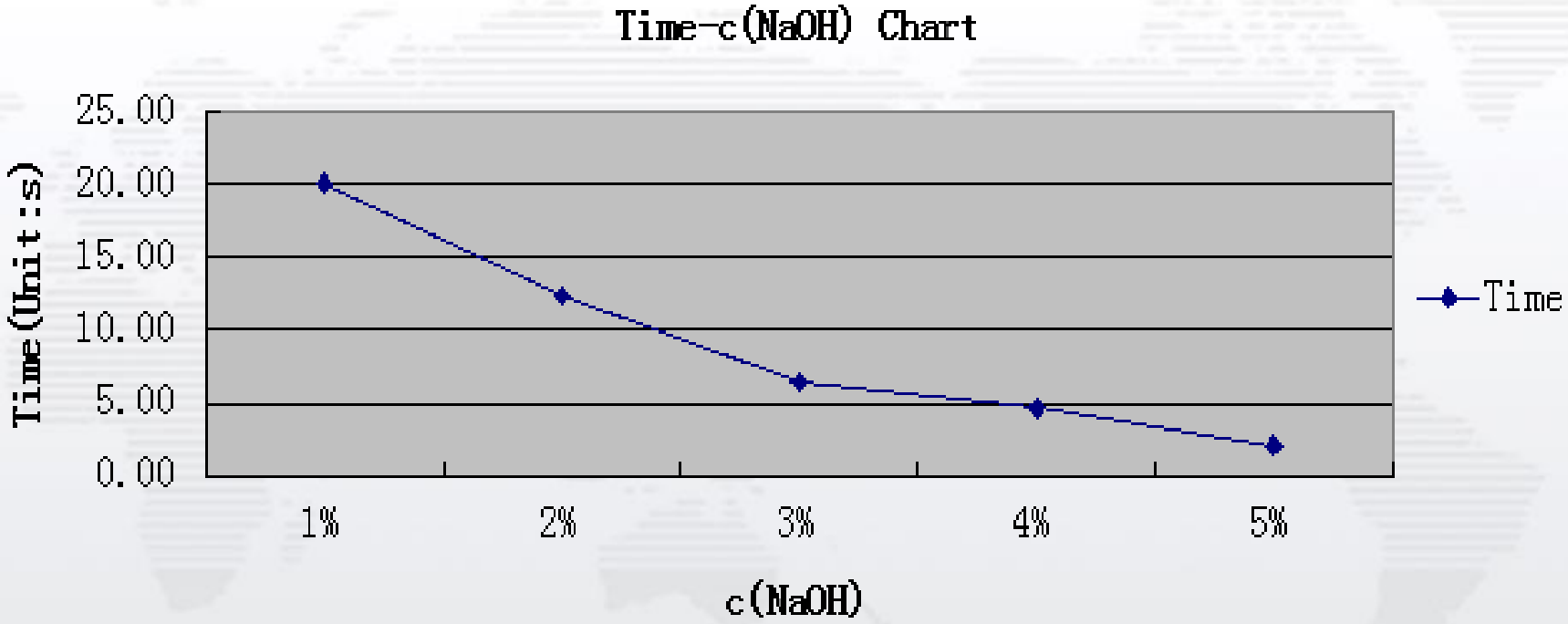
I_2 solution has its solubility, the concentration can't increase unlimitedly.

Tips:For Iodine's solubility is 0.029%, I added some KI in order to increase Iodine's solubility

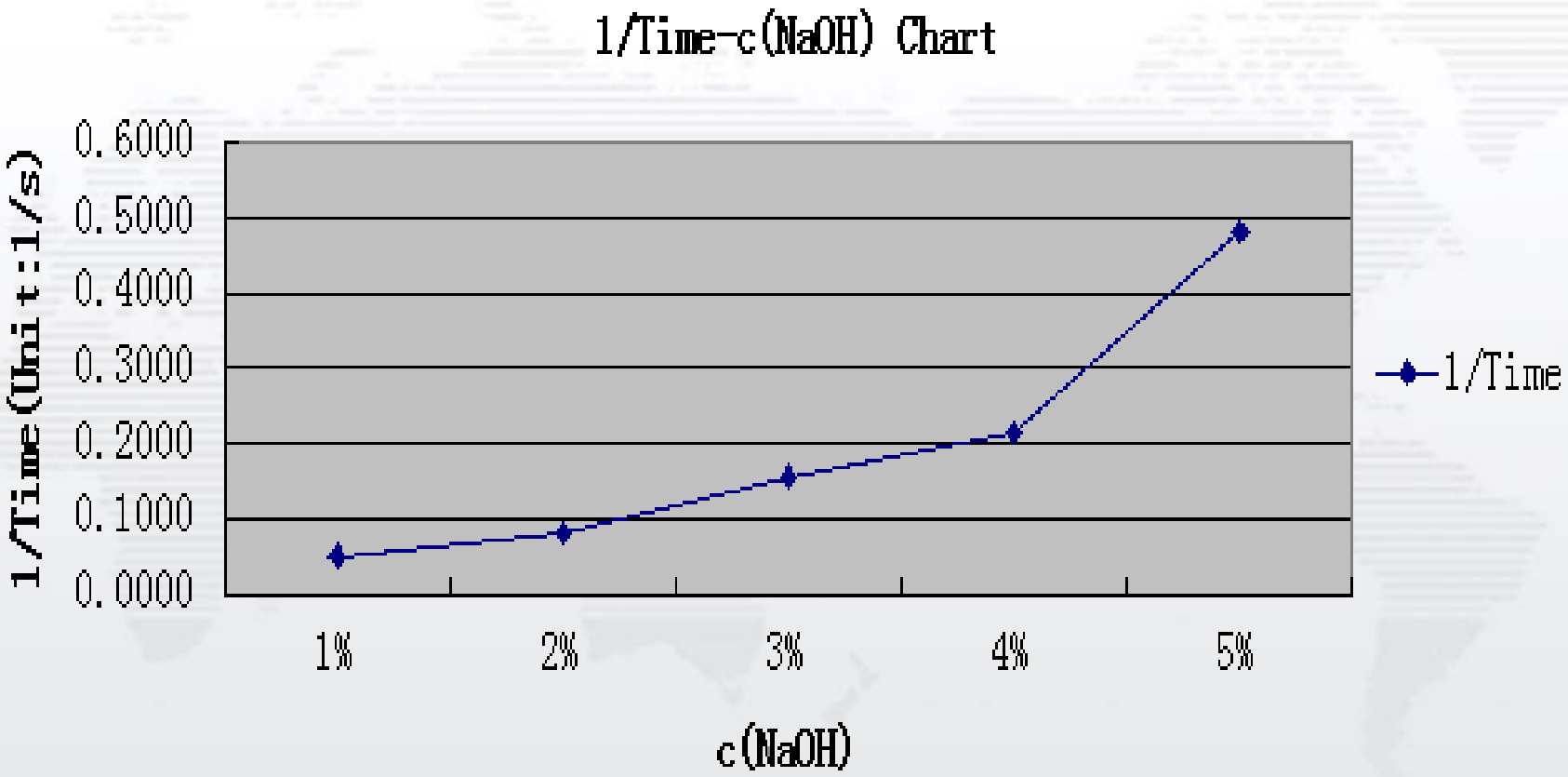
KI:potassium iodide [pəˈtæsiːəm ˈaiədaid]

But when it has higher concentration of starch, the time won't be longer or shorter.

Data


Time-c(NaOH) Chart
25.00
20.00
15.00
10.00
5.00
0.00
Time(Unit:s)
1%
2%
3%
4%
5%
c(NaOH)
Time

Data


1/Time-c(NaOH) Chart
1/Time(Unit:1/s)
0.6000
0.5000
0.4000
0.3000
0.2000
0.1000
0.0000
1%
2%
3%
4%
5%
c(NaOH)
1/Time

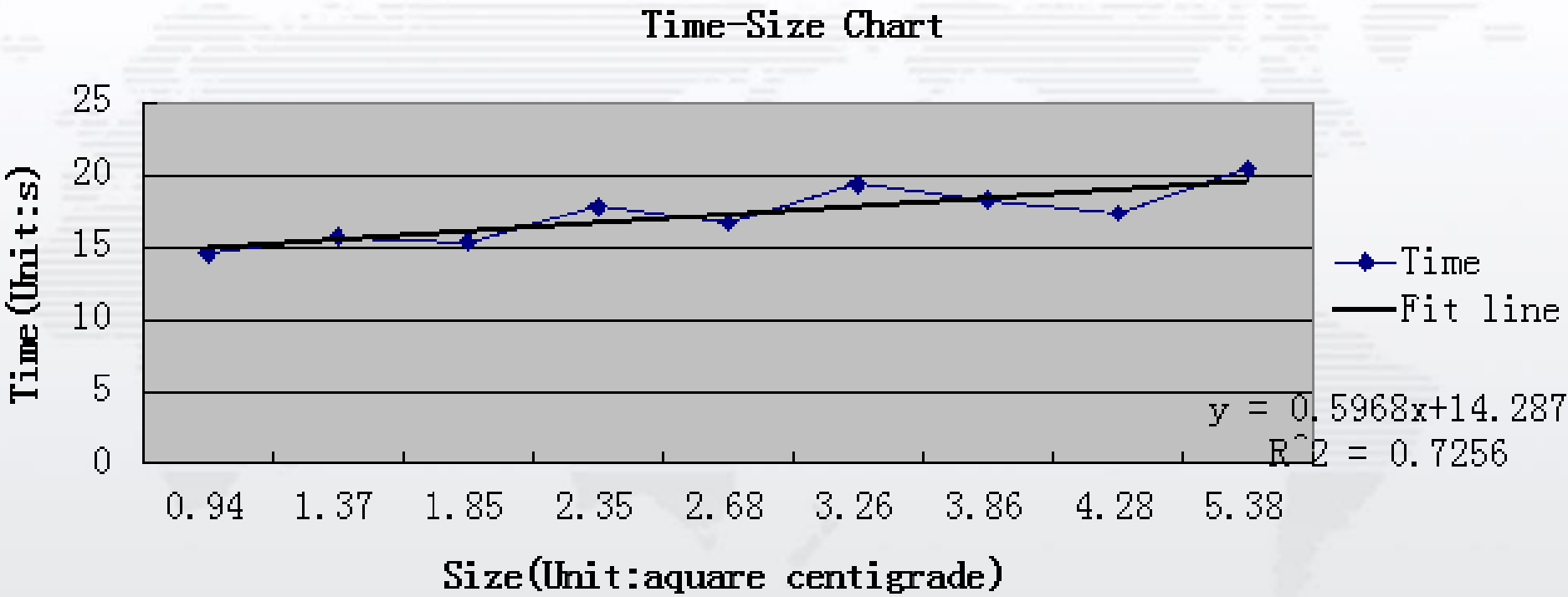
Concentration

- Within limit, when c(NaOH) is higher, the shorter time it will take.

Concentration

- If the N a O H solution has higher concentration, there will be some accidents.
- NaOH solution is caustic. So in my experiment, when 5% NaOH is used, the word disappeared but the paper broke.

Data


Time-Size Chart
25
20
15
10
5
0
Time(Unit:s)
0.94
1.37
1.85
2.35
2.68
3.26
3.86
4.28
5.38
Size(Unit:aquare centigrade)
Time
Fit line
y = 0.5968x+14.287
R^2 = 0.7256

Size

- When the size becomes larger, the time doesn't change a lot. The change of time may be related to the skill of daub.

Result

- My result:
- Concentration of I_2 and NaOH
- Temperature

Appear again?

- Is it possible to process the paper in such a manner that the text appears again?
- My answer: Yes.
- Daub I_2 solution(I used 0.25% I_2 Solution) on the word, it appears again.

Video and Photos

- 图片\4.mp4
- 图片\5.mp4

Error Analysis

- Main: Timing equipment.
- Some other:
- I have used analytical balance to weigh when making the solution. So there are only some tiny deviation in the concentration.
- When Daubing some NaOH Solution onto the paper, the control of my hands influnces the time.

How to improve

- Using more accurate equipments
- When reading the numbers, do it more carefully
- Using the same skill to daub

Reference

- 淀粉与碘反应的显色原理和反应条件《实验设计与技术》2006-12 P27-28
- Cotton, F. A.; Wilkinson, G. (1988). *Advanced Inorganic Chemistry* (5th ed.). John Wiley & Sons. ISBN 0-471-84997-9.
- http://netclass.csu.edu.cn/NCourse/hep016/n/html/n084.asp