**AIM**

To investigate how the rate of reaction varies using the Iodine Clock experiment with changes in temperature, different concentrations of substrates and the use of transition metals.

BACKGROUND THEORY

The iodine clock reaction was first studied by Augustus Harcourt and William Esson. They studied the reaction between iodide and hydrogen peroxide [1]

In the experiment Potassium Peroxodisulphate ($K_2S_2O_8$) is used instead of Hydrogen Peroxide, in which the Peroxodisulphate ions react with the iodide ions from the Potassium Iodide solution to form Sulphate ions and iodine. It can be represented by this half equation

$$S_2O_8^{2-}{}_{(aq)} + 2I^-{}_{(aq)} \Longrightarrow 2SO_4^{2-}{}_{(aq)} + I_{2(aq)}$$
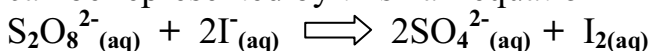
The reaction involves the oxidation of the iodide ions to iodine molecules.

Sodium thiosulphate increases the time taken for the iodide ions to turn to iodine. All the Sodium thiosulphate has to be used up before the colour of the starch to change. Sodium thiosulphate changes the iodine to iodide ions, without sodium thiosulphate the reaction would be too fast for getting reliable results. The reaction between the Sodium thiosulphate and the iodine can be shown as:

$$2S_2O_3{}^{2-}{}_{(aq)} + I_{2(aq)} \Longrightarrow S_4O_6{}^{2-}{}_{(aq)} + 2I^-{}_{(aq)}$$
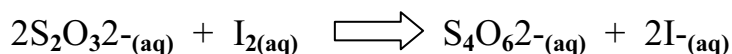
Rates of reaction
The rate of reaction is a measure of how fast a reaction occurs. If the reaction fast then the rate of reaction is high but if the reaction is slow then the rate of reaction is low. For a reaction to occur the particles must collide with sufficient energy to overcome the activation energy.

Activation Energy
The activation energy is the minimum energy needed to for a reaction to arise between to colliding molecules. In fast reactions the number of molecules moving fast enough to overcome the activation energy is high so more reactions take place easily; in slow reactions the quantity of molecules that move fast enough to overcome the activation energy is low so the rate of successful collisions will be low therefore the rate of reaction will be low.

All chemicals have different rates of reaction. The rate of a chemical reaction can be changed if [2]:
- The pressure of the gas is changed
  Increase in pressure means that the molecules (mainly in gases) have less space to move around in so have a greater chance to collide with other molecules and react.

- The temperature of the reactants is increased
  Increasing the temperature of the system will increase the chances of successful collision because the molecules will have more kinetic energy and will collide with other molecules with more power increasing the chance of a reaction.

- Increasing surface area of the solid
  Large lump of solid substrate will have a smaller surface area for other reactants to react on so the rate of reaction will be slow. If the solid substrate was smaller e.g. powder the surface area would be

much bigger and the reactants would easily react thus increasing the rate of reaction.

- Concentration of reactants increased
  Increase in the concentration of reactants will result in more molecules of reactants in the same volume. More molecules in the same volume will increase the chances of successful collisions. The more the concentration of the reactants is increased the faster the rate of reaction.

- A catalyst is present
  Catalysts are used to speed up biological and chemical reactions. Catalysts speed up reactions by lowering the activation energy needed to a reaction to take place.

By doubling one of the above for example the temperature doesn't necessarily mean that the rate of the reaction will double as most would expect. The rate of reaction can stay the same, it can double and the rate of reaction can also quadruple. The rate of reaction staying the same, doubling or quadrupling is called the order of reaction.

Zero Order Reaction
In a zero order reaction if the concentration of a reactant is doubled then the rate will not be affected, e.g. if reactants A and reactant B react in 30 seconds, even if concentration of reactant A is doubled the amount of time will still be the same.

First Order Reaction
In a first order reaction if the concentration of a reactant is doubled the rate of the reaction will double, e.g. if reactants A and reactant B react in 30 seconds, if concentration of reactant A is doubled the rate of reaction will also double so the time taken will drop by half. This is what you would expect from every reaction but isn't always the case.

Second Order Reaction
In a second order reaction if the concentration of a reactant is doubled the rate of the reaction will quadruple, e.g. if reactants A and reactant B react in

30 seconds, if concentration of reactant A is doubled the rate of reaction will go up by 4 times, so the time taken will drop by a quarter.

Rate Equation

$$\text{Rate} = k\,[\text{reactant A}]^m\,[\text{reactant B}]^n$$

Where:
- [A] and [B] are the initial concentrations of reactants A and B
- k is the rate constant
- m is the order of reaction with respect to reactant A
- n is the order of reaction with respect to reactant B
- (n + m) is the overall order of the reaction [3]

To find out the order of reaction of substrate A, experiments need to be conducted where the concentration of substrate A need to stay the same. By keeping the concentration the same of substrate A and getting enough results to plot a graph we can see what order of reaction it is.

For the zero order reaction the graphs should look something like this:-

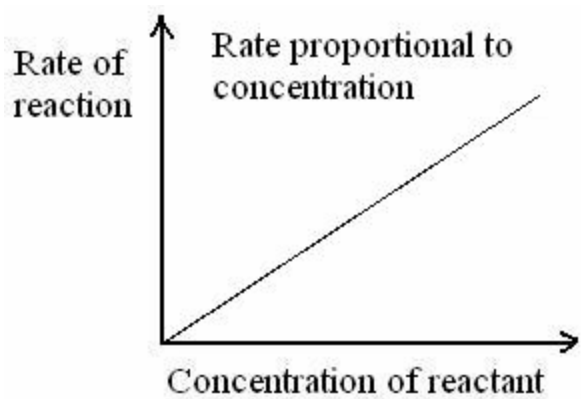Rate of Reaction against Concentration of Reactant
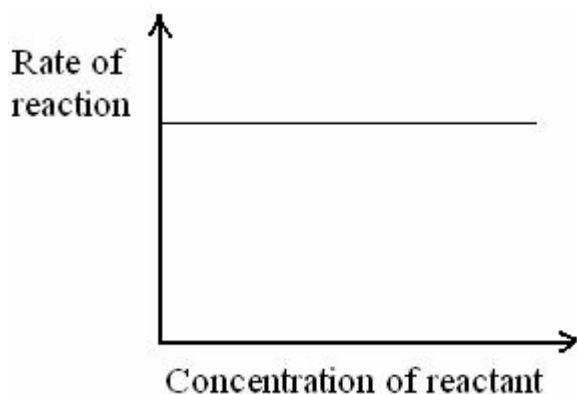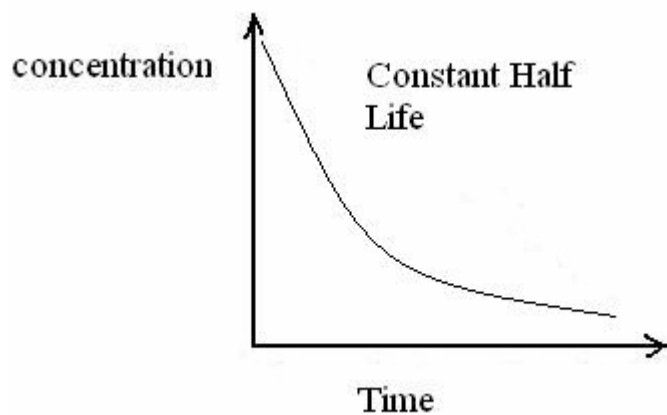
Concentration against Time
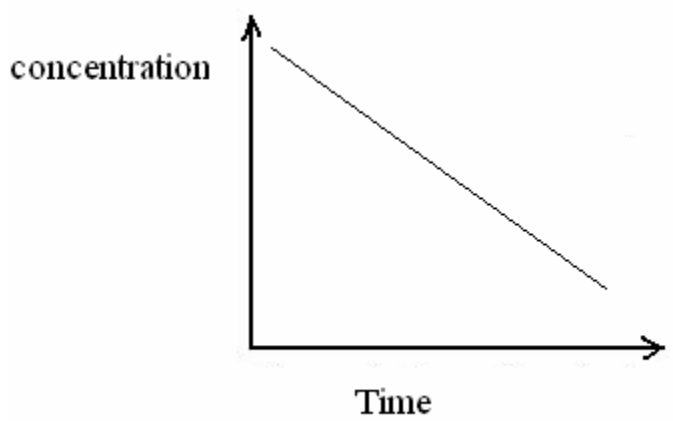
The graphs for the first order should look something like this:

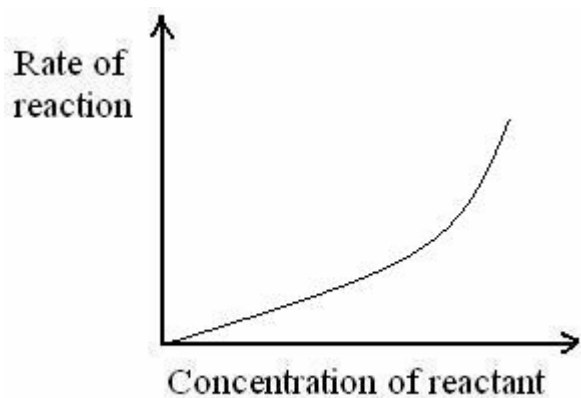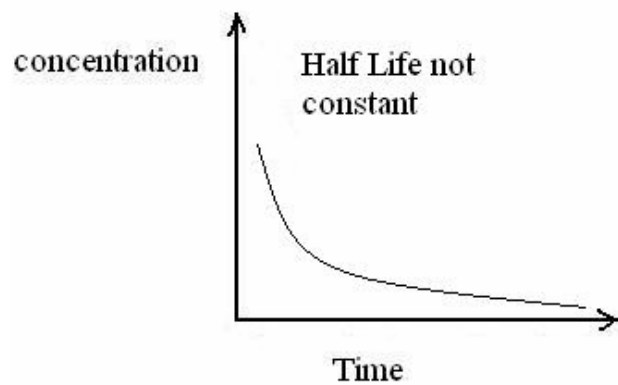Rate of reaction against Concentration

Concentration against time

The graphs for the second order reaction should look like this:

Rate of reaction against concentration

Concentration against time

Plan

Making a standard solution
A standard solution is a solution of known concentration which is mostly measured in mol dm^{-3}

Standard solution of Sodium thiosulphate
We need to calculate how many moles we need. This can be worked out by this equation:

Number of moles = concentration x volume

We will be using 0.010 mol dm^{-3} of Sodium thiosulphate ($Na_2S_2O_3$) and making 250cm^3 of solution. The 250cm^3 needs to be converted in decimetres cubed (dm^3) so we need to divide 250cm^3 by 1000 to get 0.25dm^3

Number of moles = 0.010 x 0.25
                         = 0.0025 moles

Now that we have worked out the number of moles we can work out the mass of Sodium thiosulphate needed by the following equation:

Mass (measured in grams) = Mr (molecular mass) x Moles

We need to work out the molecular mass of Sodium thiosulphate $Na_2S_2O_3$

Element	Mr		
Sodium (Na)	22.989 x 2	=	45.978
Sulphur (S)	32.065 x 2	=	64.130
Oxygen (O)	15.999 x 3	=	47.997
	Total Mr	=	158.105

We have the molecular mass now we can work out the mass needed.
Mass = 158.105 x 0.0025
       = 0.3953g

Instruction to make standard solution of Sodium thiosulphate

1- Take lab safety to consideration i.e. wear lab coat, goggles and gloves if needed

2- Measure the solid on an accurate balance, Tare the balance so it shows zero (use a balance that measures to at least 2 decimal places to make it more accurate)

3- Put the solid in a clean beaker (clean beaker with distilled water just to be sure)

4- Dissolve the solid with distilled water; use a clean glass rod to stir if necessary.

5- Once dissolved transfer the solution to a 250cm^3 volumetric flask

6- Rinse the beaker out with distilled water (and glass rod if used); do this at least twice so less chance of any solution left in beaker (or on glass rod)

7- Add more distilled water to the volumetric flask if needed to get the level just under the mark.

8- Using a pipette add drop by drop on distilled water into the flask until the bottom of the meniscus is on the line. Make sure your eyes are in level with the line to ensure you don't add more distilled water than needed.

9- Insert the lid on the top and shake the solution to homogenise it. This ensures that the solution is mixed properly.

10- Write on the flask the name of solution, that way you won't get mixed up when you make other solutions.

Standard solution of Potassium Iodide

We need to calculate how many moles we need. This can be worked out by this equation:

Number of moles = concentration x volume

We will be using 1.00 mol dm^{-3} of Potassium Iodide and making 250cm^3 of solution. The 250cm^3 needs to be converted in decimetres cubed (dm^3) so we need to divide 250cm^3 by 1000 to get 0.25dm^3

Number of moles = 1.00 x 0.25
                 = 0.25 moles

Now that we have worked out the number of moles we can work out the mass of Potassium Iodide needed by the following equation:

Mass (measured in grams) =   Mr (molecular mass)   x   Moles

We need to work out the molecular mass of Potassium Iodide (KI)

Element	Mr
Potassium (K)	39.098
Iodine (I)	126.904
Total Mr =	166.002

We have the molecular mass now we can work out the mass needed.
Mass = 166.002 x 0.25
     = 41.501g

To make the solution follow instructions on page 8

Standard solution of Potassium Peroxodisulphate (VI) ($K_2S_2O_8$)

We need to calculate how many moles we need. This can be worked out by this equation:

Number of moles = concentration x volume

We will be using 0.040 mol dm^{-3} of Potassium Peroxodisulphate ($K_2S_2O_8$) and making $250cm^3$ of solution. The $250cm^3$ needs to be converted in decimetres cubed (dm^3) so we need to divide $250cm^3$ by 1000 to get $0.25dm^3$

Number of moles = 0.040 x 0.25
= 0.01 moles

Now that we have worked out the number of moles we can work out the mass of Potassium Peroxodisulphate ($K_2S_2O_8$) needed by the following equation:

Mass (measured in grams) = Mr (molecular mass)   x   Moles

We need to work out the molecular mass of Potassium Peroxodisulphate ($K_2S_2O_8$)

Element	Mr
Potassium (K)	39.098 x 2 = 78.196
Sulphur(S)	32.065 x 2 = 64.130
Oxygen (O)	15.999 x 8 = 127.992
Total Mr	= 270.318

We have the molecular mass now we can work out the mass needed.
Mass = 270.318 x 0.25
= 67.580g

To make the solution follow instructions on page 8

Once all the standard solutions were made I set the apparatus listed below as shown in Diagram 1

Equipment needed for experiment:
Burettes x4
Pipettes x1
Funnels x4
Test tubes x5
Boiling tubes x5
Test tube holder
Clamps x4
Beakers x4
Stop clock
Starch (freshly made)
Potassium Peroxodisulphate solution
Potassium Iodide solution
Sodium Thiosulphate solution
Distilled water

Diagram 1:

Each Burette with Different standard solutions

Distilled Water

Stop Clock

Freshly made starch
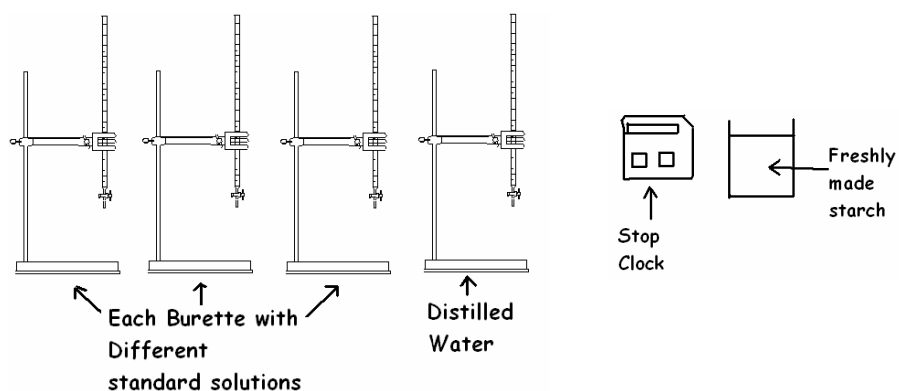
This experiment is to see how fast the starch changes colour. These are the amounts of each solution I will be using.

In this experiment the independent variable will be Potassium Iodide, the amount of distilled water will vary to keep the overall volume the same; the amount of Sodium thiosulphate, Starch and Potassium Peroxodisulphate will be controlled.

Mixture	Volume of $KI_{(aq)}$ /cm^3	Volume of water /cm^3	Volume of $Na_2S_2O_{3(aq)}$	Volume of Starch /cm^3	Volume of $K_2S_2O_{8(aq)}$ /cm^3
1	5	0	2	1	2
2	4	1	2	1	2
3	3	2	2	1	2
4	2	3	2	1	2
5	1	4	2	1	2

Method to do Preliminary experiment
   1- Put safety equipment on i.e. lab coat, goggle and gloves

   2- Set the clamp and the burette as shown:

Each Burette with Different standard solutions

Distilled Water

3- Rinse a burette with Potassium Iodide (KI), do this at least 3 times to make sure that the burette has no other solution in it.

4- Repeat step 3 with the other solutions.

5- Take a test tube and accurately measure and add the amount shown of Potassium Peroxodisulphate in mixture 1

6- Take a boiling tube and put all solutions of quantity from mixture 1 apart from Potassium Peroxodisulphate

7- Pour the Potassium Peroxodisulphate into the test tube and immediately start the stop clock.

8- Record the time taken for the starch to change colour into a table. (see table below)

9- Repeat steps 5 to 8 so you get at least 3 separate results.

10- Repeat steps 5 to 9 but with quantities from different mixtures

Mixture	Test 1/ Time taken (s)	Test 2/ Time taken (s)	Test 3/ Time taken (s)	Average time (s)
1				
2				
3				
4				
5				

Method to do Experiment- Change of concentration of Potassium Peroxodisulphate

1. Put safety equipment on i.e. lab coat, goggle and gloves

2. Set the clamp and the burette.

3. Rinse a burette with Potassium Iodide (KI), do this at least 3 times to ensure that the burette has no other solution in it.

4. Repeat step 3 with the other solutions.

5. Take a test tube and accurately measure and add the amount shown of Potassium Peroxodisulphate in mixture 1

6. Take a boiling tube and put all solutions of quantity from mixture 1 apart from Potassium Peroxodisulphate

7. Pour the Potassium Peroxodisulphate into the test tube and immediately start the stop clock.

8. Record the time taken for the starch to change colour into a table. (see table below)

9. Repeat steps 5 to 8 so you get at least 3 separate results.

10. Repeat steps 5 to 9 but with quantities from different mixtures

Experiment-Change in Temperature

In this experiment the independent variable will be the temperature. The solutions will be controlled. In my experiment I chose mixture 3.

Mixture	Volume of $KI_{(aq)}$ /cm^3	Volume of water /cm^3	Volume of $Na_2S_2O_{3(aq)}$	Volume of Starch /cm^3	Volume of $K_2S_2O_{8(aq)}$ /cm^3
3	3	2	2	1	2

Apparatus:
Thermometer x3
Burettes x4
Pipette x1
Funnels x4
Test tubes x5
Boiling tubes x5
Test tube holder
Clamps x4
Beakers x4
Stop clock
Starch (freshly made)
Potassium Peroxodisulphate solution
Potassium Iodide solution
Sodium Thiosulphate solution
Distilled water
Water bath (which can vary the temperature)

Method
1. Put safety equipment on i.e. lab coat, goggle and gloves

2. Set the clamp and the burette.

3. Rinse a burettes with the solutions, do this at least 3 times to make sure that the burette has no other solution in it.

4. Take a test tube and accurately measure and add the amount shown of Potassium Peroxodisulphate in mixture 3

5. Take a boiling tube and put all solutions of quantity from mixture 3 apart from Potassium Peroxodisulphate

6. Set the water bath temperature to 30°C

7. Using the thermometer ensure that the temperature is at 30°C

8. Put the boiling tube and the test tube from steps 4 and 5 into the water bath

9. Take two thermometers and put one into the boiling tube and the other into the test tube so see if the temperature is 30°C.

10. Add the $K_2S_2O_8$ into the boiling and immediately start the stop clock

11. When reaction is finished record the result into a table.

12. Repeat the experiment with same temperature so you have at least 3 results.

13. Repeat steps 4 to 12 but with different temperatures e.g. 40°C, 50°C (see table below)

Temperature (°C)	Temperature (K)	Test 1/ time (s)	Test 2/ time (s)	Test 3/ time (s)	Average time (s)
30	303.15				
40	313.15				
50	323.15				
60	333.15				
70	343.15				

Increasing the temperature will increase the chances of successful collisions between reactants. This is because the molecules have more kinetic energy so can collide with more power making the chance of collision to be higher.

The rate of temperature change can be calculated by using the Arrhenius equation. The equation is shown below. The symbols are explained in the diagram.

The Arrhenius equation
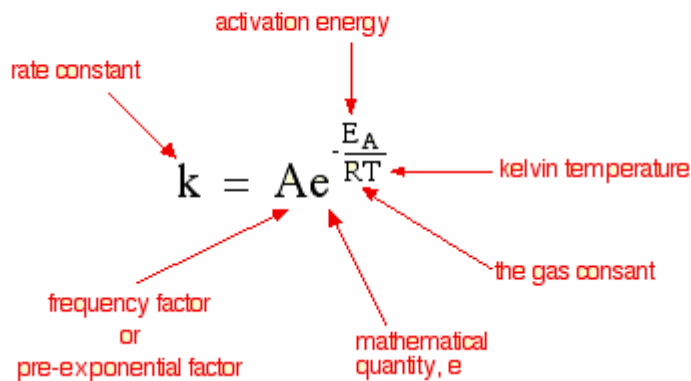
Values for the symbols

R has the value of 8.314×10^{-3} kJ mol^{-1}K^{-1}
e has the value of 2.71828 (natural log)
T has the value of ^{0}C + 273.15 (measured in Kelvin)

Experiment- Using Transition metal solutions

This experiment will show if the transition metal solutions affect the rate of reaction.
For this experiment I have chosen Mixture 3:

Mixture	Volume of $KI_{(aq)}$ /cm^3	Volume of water /cm^3	Volume of $Na_2S_2O_{3(aq)}$	Volume of Starch /cm^3	Volume of $K_2S_2O_{8(aq)}$ /cm^3
3	3	2	2	1	2

The transition metal solutions used (1cm^3 of 0.1mol):
Copper Sulphate
Nickel Sulphate
Ferrous Sulphate
Zinc sulphate

Apparatus needed:
Transition metal solutions
Burettes x4
Pipette x1
Funnels x4
Test tubes x3for each transition metal solution
Boiling tubes x3 for each transition metal solution
Test tube holder
Clamps x4
Beakers x4
Stop clock
Starch (freshly made)
Potassium Peroxodisulphate solution
Potassium Iodide solution
Sodium Thiosulphate solution
Distilled water

Method

1. Put safety equipment on i.e. lab coat, goggle and gloves

2. Set the clamp and the burette as shown in diagram 1

3. Rinse the burettes with the solutions, do this at least 3 times to ensure that the burette has no other solution in it.

4. Take a test tube and accurately measure and add the amount shown of Potassium Peroxodisulphate in mixture 3

5. Take a boiling tube and put all solutions of quantity from mixture 3 apart from Potassium Peroxodisulphate

6. Use a measuring cylinder and measure out $1cm^3$ of the transition metal solution

7. Add the solution to the boiling tube from step 5

8. Add the $K_2S_2O_8$ into the boiling and immediately start the stop clock

9. When reaction is finished record the result into a table.

10. Repeat the experiment with same transition metal solution so you have at least 3 results. (see table below)

11. Repeat steps 4 to 10 but with different transition metal solutions.

Transition Metal $1cm^3$	Test 1/ time (s)	Test 2/ time (s)	Test 3/ time (s)	Average time (s)

Analysis of Preliminary Experiment 1

In the preliminary experiment I followed the table below.

Mixture	Volume of KI$_{(aq)}$ /cm^3	Volume of water /cm^3	Volume of Na$_2$S$_2$O$_{3(aq)}$ /cm^3	Volume of Starch /cm^3	Volume of K$_2$S$_2$O$_{8(aq)}$ /cm^3
1	5	0	2	1	2
2	4	1	2	1	2
3	3	2	2	1	2
4	2	3	2	1	2
5	1	4	2	1	2

The results I received from doing this experiment are:

Mixture	Test 1/ Time taken (s)	Test 2/ Time taken (s)	Test 3/ Time taken (s)	Average time (s)
1	33.47	31.93	32.43	32.61
2	45.47	43.91	54.69	42.02
3	80.50	76.72	69.09	75.44
4	149.44	131.28	145.18	141.97
5	374.56	355.81	437.28	389.22

Analysis of Experiment 2- changing the temperature

From getting the results from the 1st experiment I decided to choose Mixture 3 as the mixture. Talk about temp increase etc why u chose mixture 3

Mixture	Volume of $KI_{(aq)}$ /cm^3	Volume of water /cm^3	Volume of $Na_2S_2O_{3(aq)}$	Volume of Starch /cm^3	Volume of $K_2S_2O_{8(aq)}$ /cm^3
3	3	2	2	1	2

The results are as follows:

Temperature (°C)	Temperature (K)	Test 1/ time (s)	Test 2/ time (s)	Test 3/ time (s)	Average time (s)
30	303.15	95.53	95.62	89.62	93.59
40	313.15	47.66	55.32	48.78	50.59
50	323.15	28.31	27.60	30.25	28.72
60	333.15	17.38	16.00	17.56	16.98
70	343.15	7.41	8.15	7.79	7.78

Experiment- Using Transition Metal solutions

The results I recorded for the transition metal ion solutions are:
1cm^3 of 0.1mol of each transition metal was used

Transition Metal ion solution	Test 1/ time (s)	Test 2/ time (s)	Test 3/ time (s)	Average time (s)
Nickel Sulphate	96.50	102.12	89.47	96.02
Ferrous Sulphate	11.50	11.47	11.49	11.49
Zinc Sulphate	96.09	95.90	98.22	96.74

Experiment- Using Transition Metal Solids

Transition Metal	Test 1/ time (s)	Test 1 mass (g)	Test 2/ time (s)	Test 2 mass (g)	Test 3/ time (s)	Test 3 Mass (g)	Average mass (g)	Average time (s)
Nickel	48.15	0.501	46.18	0.507	51.43	0.508	0.505	48.57
Iron II	7.44	0.508	8.91	0.504	7.59	0.506	0.506	7.98
Zinc	73.88	0.502	73.56	0.507	72.71	0.507	0.505	73.38
Coboltous Nitrate	62.81	0.502	58.61	0.506	58.24	0.508	0.505	59.89
Manganese Sulphate	65.75	0.504	67.23	0.502	69.04	0.504	0.505	67.34

References

1- http://en.wikipedia.org/wiki/Augustus_George_Vernon_Harcourt
   Tuesday 1st April 2008   3:11pm
2- http://www.4college.co.uk/a/index.php
   ENGINEERING PROTEIN $\Longrightarrow$ RATES OF CHEMICAL REACTIONS
   Wednesday 2nd April 2008
3- Revise A2 Chemistry Salters OCR ISBN 0-435-58347-6
   Page 26
4- http://www.chemguide.co.uk/physical/basicrates/arrhenius.html
   Visited Monday 7th April 2008