How Does the Viscosity of a Liquid Change with Temperature

Theory

Viscosity is a measure of a fluid's resistance to flow when acted upon by an external force such as a pressure differential or gravity. Viscosity is a general property of all fluids, which includes both liquids and gases. It describes the internal friction of a moving fluid. A fluid with large viscosity resists motion because its molecular makeup gives it a lot of internal friction. A fluid with low viscosity flows easily because its molecular makeup results in very little friction when it is in motion. The viscosity affects the size of liquid particles, increasing the viscosity tends to increase the size of liquid particles, which then increases their gravitational settling rates.

The viscosity of a liquid changes with temperature, as the temperature increases the viscosity decreases as the intermolecular forces weaken. Energy added to the system in the form of heat increases the kinetic energy of the molecules, with higher kinetic energy, the molecules are able to overcome the intermolecular attraction resulting in a less viscous liquid. If a ball bearing is dropped through liquid it very quickly reaches its terminal velocity, when it reaches terminal velocity it should then be going at a constant speed.

Stokes Law can be used to calculate the viscosity of a liquid. The formula for Stokes Law is:-

$$v_t = \frac{2r\ \rho - \delta\ g}{9\mu}$$

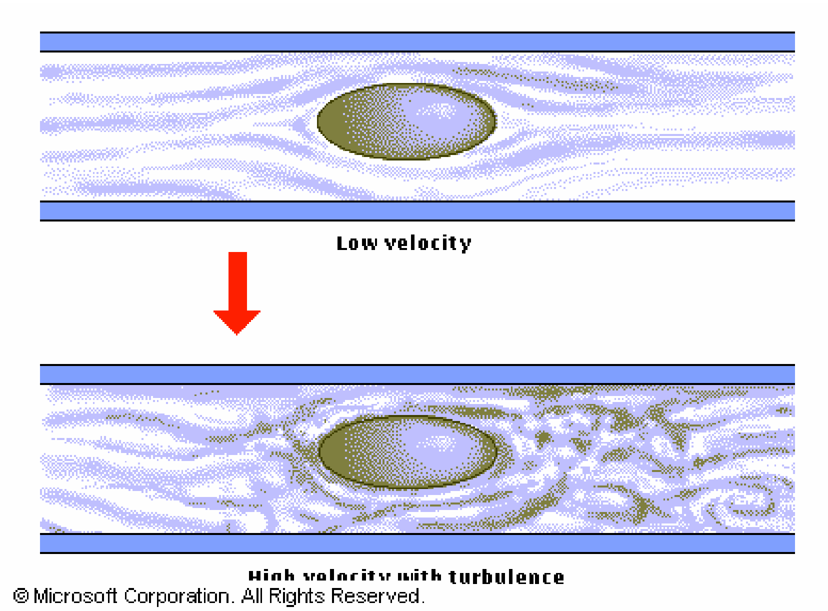
v_t = Terminal Velocity
r = Radius
⑧ = Density of the ball bearing
δ = Density of the liquid
μ = Viscosity

Density of the ball bearing- $\delta = \frac{Mass}{Volume}$

Density of Liquid $\rho = \frac{Mass}{Volume}$

Volume = 4/3⑥r^3

Depending on the velocity of the ball bearing, the motion of the liquid is different. These diagrams show the liquid molecules movement around the ball bearing when it is dropped.



At low velocities the liquid flows in a streamlined pattern, which is called laminar motion, as shown in the top diagram. When the velocity is high the liquid flows in a much more complicated way called turbulent motion. When a liquid is travelling in a pipe as in our experiment, the transition from laminar to turbulent motion depends on the diameter of the pipe and ball bearing in comparison to each other, and the velocity, density and viscosity of the liquid. It is more likely to be turbulent when the diameter of the pipe is larger, and the velocity and density of the liquid is higher, and therefore has a lower viscosity.

Prediction

I predict that as the temperature increases the viscosity decreases due to the intermolecular forces weakening as a result of the temperature increase. This is because the kinetic energy of the molecules is increasing as the heat energy is transferred. The higher the kinetic energy, the more molecules are able to weaken the intermolecular attraction and so this results in a less viscous liquid.

Apparatus

100ml measuring cylinder, 125ml of honey, a steel ball, a magnet, 2 decimal scale, micrometer screw gauge, thermometer

Plan

Before starting the constants will be taken, which are-

Terminal velocity, v_t, $= \frac{Distance}{Time}$

Gravity, g, = 9.81 seconds

Radius of the ball bearing, r, = 0.284 x 10 -2

Distance travelled, d, = 0.226 m

Density of the ball bearing- $\rho = \frac{Mass}{Volume}$

Density of the liquid- $\delta = \frac{Mass}{Volume}$

The radius of the ball bearing will be measured using a micrometer screw gage. A stop clock will be used to measure the time so the terminal velocity can be calculated. A balance to two decimal places will be used to measure the mass of the ball bearing so the density can be calculated. A measuring cylinder will be used to find the volume of the liquid so the density of it can be found. A thermometer will be used to find the temperature of the liquid and of the water bath.

Then a tube will be put onto a tray, glycerine at a temperature of 20 ° C will then be poured into it. Two marks will be made a fixed distance from each other to represent *d*. A ball bearing will then be dropped down it and the time taken to fall between the two points will be taken. If possible a light gate will be used to measure the time so that inaccuracies will be minimised when making the calculations. A range of temperatures up to 80 ° C will be done with each one being repeated three times for accuracy. The liquid will be heated in a water bath so the temperature can be as exact as possible.

Results

Distance the ball bearing drops- 0.22m

Gravity- 9.81 m/s^2
Radius of Ball Bearing- 0.284 x 10^{-2} m
Mass of Ball Bearing- 0.105 x 10^{-2} kg
Diameter of Ball Bearing- 0.568 x 10^{-1} m
Mass of Liquid- 0.25kg
Volume of Liquid- 0.2 x 10^{-3} m^3

Volume of Ball Bearing- 4/3⑥ x (0.284 x 10^{-2})^3 = 9.59 x 10^{-8}m³

Density of Ball Bearing- $\frac{0.105 \times 10^{-2}}{9.59 \times 10^{-8}} = 10.95 \times 10^{3}$ kg/m³

Density of Liquid- $\frac{0.25}{0.2 \times 10^{-3}} = 1.250 \times 10^{3}$

Rearranging Stokes Law we obtain-

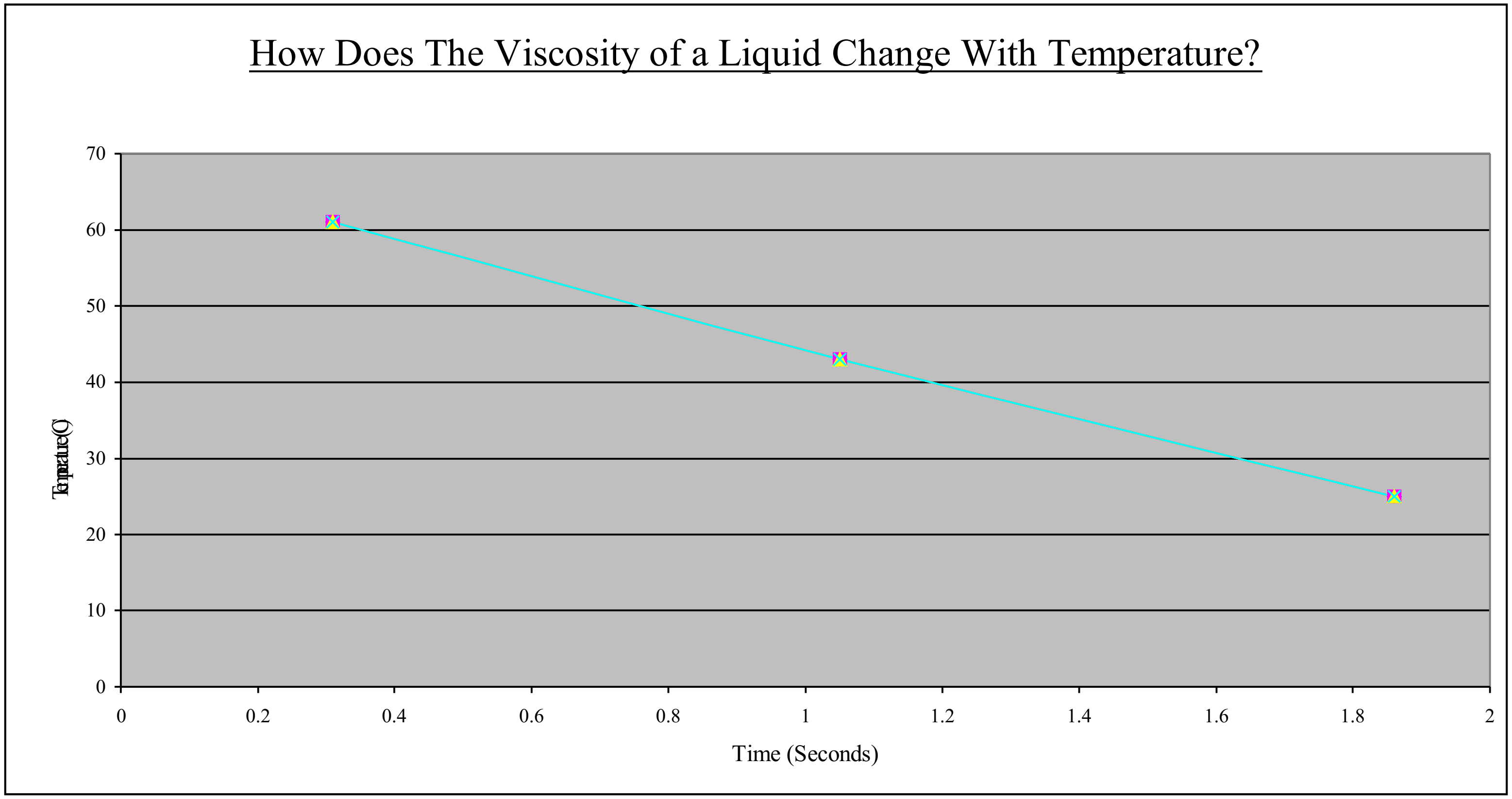
$$\eta = \frac{2r^2 (\rho - \delta) g}{9v_t}$$

$$\eta = \frac{2(0.0284)^2 (10.95 \times 10^{3} - 1.25 \times 10^{3}) \times 9.81}{9v_t}$$

$$\eta = \frac{17.06}{v_t}$$ kg/m/s

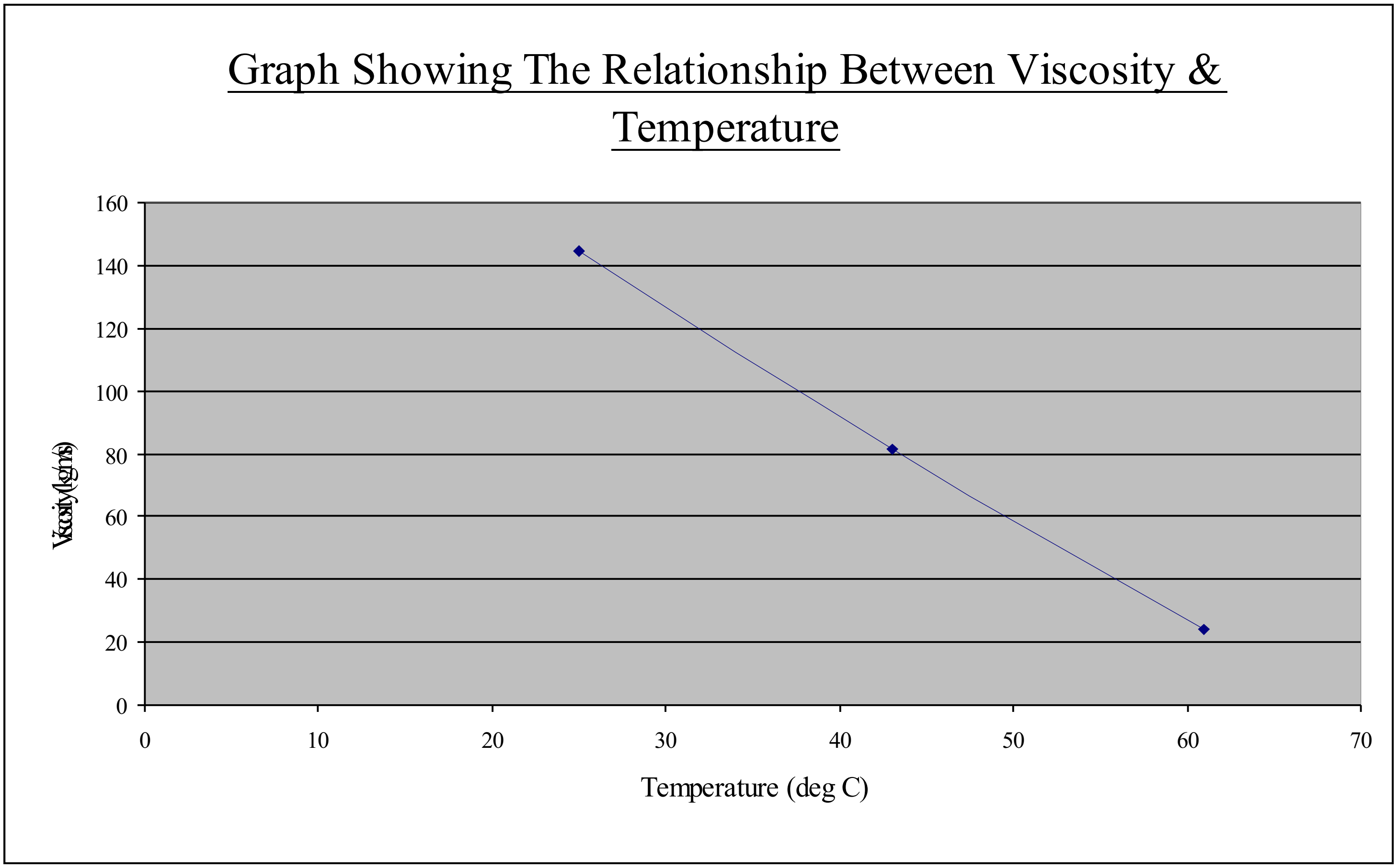
Temperature (° C)	Time Taken (secs)	Average time taken (secs)	Average Velocity m/s	Viscosity kg/m/s
25	1.82	1.86	0.118	144.6
	1.88			
	1.88			
43	1.11	1.05	0.210	81.2
	1.01			
	1.04			
61	0.29	0.31	0.710	24.0
	0.23			
	0.41			

Graph



How Does The Viscosity of a Liquid Change With Temperature?
70
60
50
40
30
20
10
0
Temperature (C)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Time (Seconds)

<u>Conclusion</u>



As the temperature got higher the ball bearing fell through the liquid faster. This is because as the temperature increases the intermolecular forces get weaker so there is less friction against the ball bearing. The results comply with my theory and prediction that as the temperature increases the intermolecular forces weaken, because the kinetic energy of the molecules increases and so the viscosity decreases. Both of the graphs are straight lines with no anomalous results, which suggests that the experiment was conducted consistently. Any errors present are most likely to have been systematic and not detectable in this experiment.

<u>Evaluation</u>

The graphs show that the experiment was reasonably successful, as there are no anomalous results and they are both straight lines. The method worked well, though when timing there would have been some error because a person was timing, if the experiment was to be made more accurate a light gate could be used so the accuracy of timing would be greatly improved and less prone to human error. Also it was not easy to keep the temperature of the water constant and so it decreased in the middle of doing some of the experiment so some accuracy would have been lost there. Another source of error is the acceleration that occurs between the ball being dropped and it hitting the liquid. If the experiment was to be extended, the size of the ball bearing could be varied and the temperature kept constant, this could eliminate the problem of it accelerating before it hit the liquid, to see how it affects the time it takes for the ball to fall down. The diameter of the tube could be varied to and the size of the ball bearing and temperature could be kept constant instead