OBSERVATIONS SHEET - EXPERIMENT M

Effect Of Temperature On Rate Of Reaction

Chemical	KI	$(NH_4)_2S_2O_8$
Mass of beaker	59.078 g	55.229 g
Mass of beaker + reagent	60.795 g	58.577 g
Mass of reagent	1.717 g	3.348 g

Calculate the molarity of I^- in the 250.0 mL volumetric flask in units of M (0.5 mark):

Molar mass of KI: 166.00 g/mol

$$1.717\,\cancel{g} \cdot \frac{1\ \text{mol}}{166.00\ \cancel{g}} \cdot \frac{1}{0.250\ \text{L}} \cdot \frac{1}{1} = 0.04137\ \text{M} \qquad \boxed{[I^-] = 0.04137\ \text{M}}$$

Calculate the molarity of $S_2O_8^{2-}$ in the 250.0 mL volumetric flask in units of M (0.5 mark):

Molar mass of $(NH_4)_2S_2O_8$: 228.18 g/mol

$$3.348\,\cancel{g} \cdot \frac{1\ \text{mol}}{228.18\ \cancel{g}} \cdot \frac{1}{0.250\ \text{L}} \cdot \frac{1}{1} = 0.05869\ \text{M} \qquad \boxed{[S_2O_8^{2-}] = 0.05869\ \text{M}}$$

molarity of $S_2O_3^{2-}$ (from the bottle label): 7.0×10^{-4} M

	KI buret			$(NH_4)_2S_2O_8$ buret			$S_2O_3^{2-}$	Time Δt	Temp
Run	final	initial	vol.	final	initial	vol.	mL	sec	°C
1	29.70	9.62	20.08	26.48	6.43	20.05	10.00	84	22.7
2	49.69	29.70	19.99	28.84	8.82	20.02	10.00	402	2.50
3	26.45	6.49	19.96	48.84	28.82	20.02	10.00	52	30.3
4	46.46	26.45	20.01	48.85	28.84	20.01	10.00	27	41.0
with $CuSO_4$	41.58	21.67	19.91	43.24	23.22	20.02	10.00	7	22.5

Signature of Lab Instructor

Sam Leader

Name of StudentLab

Z01

Period

Name of Lab Partner

Experiment M: EFFECT OF TEMPERATURE ON RATE OF REACTION

PRELAB ASSIGNMENT

Name Sam Leader Z01

TA

Read the **attendance** policy on p. 19 and the **Code of Student Behaviour** on p. M-5. You are required to **follow the appropriate course schedule** at the front part of this manual.

Read the section

STANDARD SAFETY PROCEDURES FOR CHEMISTRY UNDERGRADUATE LABS

inside the front cover of this Lab Manual.

Hint - If you do the prelab assignments on ordinary paper **first** and then copy your solutions onto this form, it will be neater **and** you will be able to refer to the rough copy when doing the Postlab assignment.

Submit this prelab assignment (done in ink) at the **start** of the lab period. **No marks** are awarded **for late prelabs. No marks** are awarded for an experiment **unless you do the experiment**; i.e. if you are absent from an experiment, you cannot get credit for the prelab assignment. **No marks will be given if supporting work is not shown.**

1. For a reaction with $E_a = 75.0$ kJ/mol

(a) Calculate the fraction of the collisions at 298 K having energies greater than or equal to E_a. (1 mark)

$T = 298\ K$

$E_a = 75.0\ kJ/mol = 7.50 \cdot 10^4\ J/mol$

$R = 8.3145\ J/mol \cdot K$

$f = e^{-E_a/RT}$

$f = e^{-(7.50 \cdot 10^4\ J/mol / 8.3145\ J/mol \cdot K \cdot 298 K)}$

$f = 7.15 \cdot 10^{-14}$ ∴ the fraction of collision is $7.16 \cdot 10^{-14}$ greater than the activation energy.

(b) Calculate the ratio

k (at 308 K) / k (at 298 K)

i.e. the factor by which the rate constant changes on increasing the temperature by 10 degrees from 298K to 308K. (1 mark)

$$= \frac{k_1}{k_2} = \frac{\cancel{A}e^{-E_a/RT_1}}{\cancel{A}e^{-E_a/RT_2}} = \frac{e^{-7.50 \cdot 10^4/308 \cdot 8.3145}}{e^{-7.50 \cdot 10^4/298 \cdot 8.3145}} = 2.67$$

∴ the ratio between the rate constant at ~~298~~ 308 K and the rate constant at 298 K is 2.67.

(Problems continue on the next page).

EXPERIMENT M: EFFECT OF TEMPERATURE ON RATE OF REACTION
PRELAB ASSIGNMENT (CONTINUED)

2. Assume that you mixed 20.00 mL of 0.040 M KI with 20.00 mL of 0.060 M $(NH_4)_2S_2O_8$, 10.00 mL of 0.00070M $Na_2S_2O_3$, and a few drops of starch. The point of mixing sets time = 0.

   (a) Calculate the concentrations of the three species KI, $(NH_4)_2S_2O_8$, and $Na_2S_2O_3$ after mixing but before any reaction has occurred. (1 mark)

   Hint: your calculated [KI] should equal 0.016 M.

$V_T = 0.02\,L + 0.02\,L + 0.01\,L = 0.05\,L$ $\qquad VM = n$

KI: $VM = n \Rightarrow (0.02\,L)\cdot(0.04\,M) = 0.0008\ mol$

$\Rightarrow \frac{0.0008\ mol}{0.05\,L} = 0.016\,M = [KI]$

$(NH_4)_2S_2O_8$: $VM = n \Rightarrow (0.02\,L)(0.06\,M) = 0.0012\ mol$

$\Rightarrow [(NH_4)_2S_2O_8] = \frac{0.0012\ mol}{0.05\,L} = 0.024\,M$

$Na_2S_2O_3$: $VM = n \Rightarrow (0.01\,L)(0.0007\,M) = 7.0\cdot10^{-6}\ mol$

$\Rightarrow [Na_2S_2O_3] = \frac{7.0\cdot10^{-6}\ mol}{0.05\,L} = 0.00014\,M$

   (b) The basis of the "Method of Initial Rates" used in this experiment, is that the concentrations of reagents are essentially unchanged during the measurement time period. Calculate the % of the initial $(NH_4)_2S_2O_8$ that has reacted when the blue colour appears. (1 mark)

(Questions continue on the next page)

EXPERIMENT M: EFFECT OF TEMPERATURE ON RATE OF REACTION
PRELAB ASSIGNMENT (CONTINUED)

3. In the ozonation of 1-pentene the following results were measured at 27.0°C:

$$O_3 + C_5H_{10} \rightarrow C_5H_{10}O_3$$

$[C_5H_{10}]$ in M	$[O_3]$ in M	$-\frac{\Delta[C_5H_{10}]}{\Delta t}$ mol L^{-1} s^{-1}
2x(0.010	0.0028	2.19) 2x
0.005	0.0028	1.11
0.005	0.0056) 2x	4.40) 4x

Using these results, calculate the order of reaction. (Hint - Silberberg 2nd ed. p. 566-568)

(a) with respect to C_5H_{10} (1 mark)

$$\frac{r_1}{r_2} = \frac{k[O_3]^x[C_5H_{10}]_1^y}{k[O_3]^x[C_5H_{10}]_2^y}$$

$$\frac{2.19}{1.11} = \frac{\cancel{k[0.0028]^x}[0.010]^y}{\cancel{k[0.0028]^x}[0.005]^y}$$

$$2 = \frac{[0.010]^y}{[0.005]^y}$$

$$2 = 2^y$$

$$\therefore y = 1$$

$$\boxed{\therefore [C_5H_{10}]^1}$$

(b) with respect to O_3. (1 mark)

$$\frac{r_1}{r_2} = \frac{k[O_3]_1^x\cancel{[C_5H_{10}]^1}}{k[O_3]_2^x\cancel{[C_5H_{10}]^1}}$$

$$\frac{1.11}{4.40} = \frac{k[0.0028]^x[0.005]^1}{k[0.0056]^x[0.005]^1}$$

$$\frac{1}{4} = \left(\frac{1}{2}\right)^y$$

$$4 = 2^y$$

$$y = 2$$

$$\boxed{\therefore [O_3]^2}$$

$$\boxed{\text{rate law: } k[C_5H_{10}]^1[O_3]^2}$$

4.(a) What is the effect of a catalyst on the reaction rate? (0.5 mark)

A catalyst increases the rate of a reaction

(b) How does the catalyst effect such a change? (0.5 mark)

The catalyst provides an alternate pathway for the reaction, one with a lower E_a

5. On the observations sheet, you will have to calculate the concentrations of your solutions. You might want to calculate the molar mass of KI and the molar mass of $(NH_4)_2S_2O_8$ and write these on the Observations Sheet before your lab period. (No marks)

In k vs 1

EXPERIMENT M - EFFECT OF TEMPERATURE ON RATE OF REACTION

POSTLAB ASSIGNMENT

Name Sam Leader

Lab Period Z01 Lab Room ________

TA ________

Show your work - answers without supporting work will get zero marks. Give units and use the correct number of significant figure.

1. Complete Table I (page M-21) and include it with this Postlab assignment. (2 marks)

2. Show your calculations for Run 1 below. Include units. (1 mark)

$[I^-] = [KI]$

$[KI] = 0.04137\ M$

$(0.04137\ M)(0.02008\ L) = 8.307 \cdot 10^{-4}\ mol$

$V_T = 20.08\ mL + 10.00\ mL + 20.05\ mL$

$[KI] = \frac{8.307 \cdot 10^{-4}\ mol}{0.05013\ L}$

$[KI] = 1.657 \cdot 10^{-2}\ M$

$[S_2O_8^{-2}] = [(NH_4)_2S_2O_8]$

$[S_2O_8^{-2}] = 0.05869\ M$

$(0.05869\ M)(0.02006\ L) = 1.177 \cdot 10^{-3}\ mol$

$[S_2O_8^{-2}] = \frac{1.177 \cdot 10^{-3}\ mol}{0.05013\ L}$

$[S_2O_8^{-2}] = 2.347 \cdot 10^{-2}$

$\Delta[I_2] = \frac{1}{2}[S_2O_8^{-2}]$

$\therefore \Delta[I_2] = 1.174 \cdot 10^{-2}\ M$

$k = \left(\frac{\Delta[I_2]}{\Delta t}\right) \cdot \frac{1}{[I^-][S_2O_8^{-2}]}$

$k = \frac{1.174 \cdot 10^{-2}\ M}{84\ sec} \cdot \frac{1}{(1.657 \cdot 10^{-2}\ M) \cdot (2.347 \cdot 10^{-2}\ M)}$

$k = 0.3594\ s^{-1} M^{-1}$

3. Complete the following table relating the temperature to reaction rate. (1 mark)

Temperature		$\frac{1}{T(K)}$	k (from Table I)	ln k
T(°C)	T(K)		$0.3594\ s^{-1}M^{-1}$	−1.023
22.7	295.85	$3.380 \cdot 10^{-3}$	~~[illegible]~~	~~[illegible]~~
2.50	275.65	$3.628 \cdot 10^{-3}$	0.07520	−2.588
30.3	303.45	$3.295 \cdot 10^{-3}$	0.5820	−0.5412
41.0	314.15	$3.183 \cdot 10^{-3}$	1.119	0.1124
22.5	295.65	$3.382 \cdot 10^{-3}$	4.329	1.465

(a) **Use the graph paper is given** at the back of this Lab Manual. Plot ln k against 1/T with T in degrees K on a **suitable** scale and submit it with this Postlab assignment (see Guidelines on Graphing, p. 39 and 40 of this Manual). Alternatibely an Excel plot may be used provided the plot is expanded to the same size of the graphing paper. Draw a straight line best-fit curve through the noncatalyzed data points. (2 marks)

(b) Show **on your graph** your calculation (in **ink**) of

(i) the slope of the line (1 mark)

(ii) E_a. (1 mark)

(Questions continue on the next page)

4. Draw a diagram of the potential energy *versus* reaction coordinate (progress) similar to the one in Fig. 1 for the reaction studied. (1 mark)

$$2I^- + S_2O_8^{2-} \rightarrow I_2 + 2SO_4^{2-} \qquad \Delta H = -322 \text{ kJ/mole}$$

Sketch below the reaction profile for the uncatalyzed reaction with E_a and ΔH drawn approximately **to scale**. Superimpose on this sketch the reaction profile of the catalyzed reaction. Clearly label the activation energy, the enthalpy change, the catalyzed and uncatalyzed reaction, the reaction coordinates, etc.

5. (a) What happens to k as the temperature is raised? (0.5 mark)

The rate constant will increase and decrease with temperature, they are proportional

(b) What happens to E_a as the temperature is raised? (0.5 mark)

Activation energy is independant of temperature, so it isn't effected.

(c) Explain *how* raising the temperature affects the rate of reaction (see Figure 14.16 in Silberberg/Amateis). (1.5 marks)

Raising the temperature leads to a larger fraction of collisions, meaning more molecules will be able to overcome the activation energy. In turn, this increases the rate of the reaction.

6. In the Arrhenius model, at what temperature does k = A ? (0.5 mark)

As $T \rightarrow \infty$, $e^{-E_a/RT} \rightarrow 1$, making $k = A$

ASSESSMENT

Prelab assignment (max. of 7 marks):

Observations sheet (max. of 1 mark):

Postlab assignment (max. of 12 marks):

Deductions (if any):

TOTAL (max. of 20 marks):

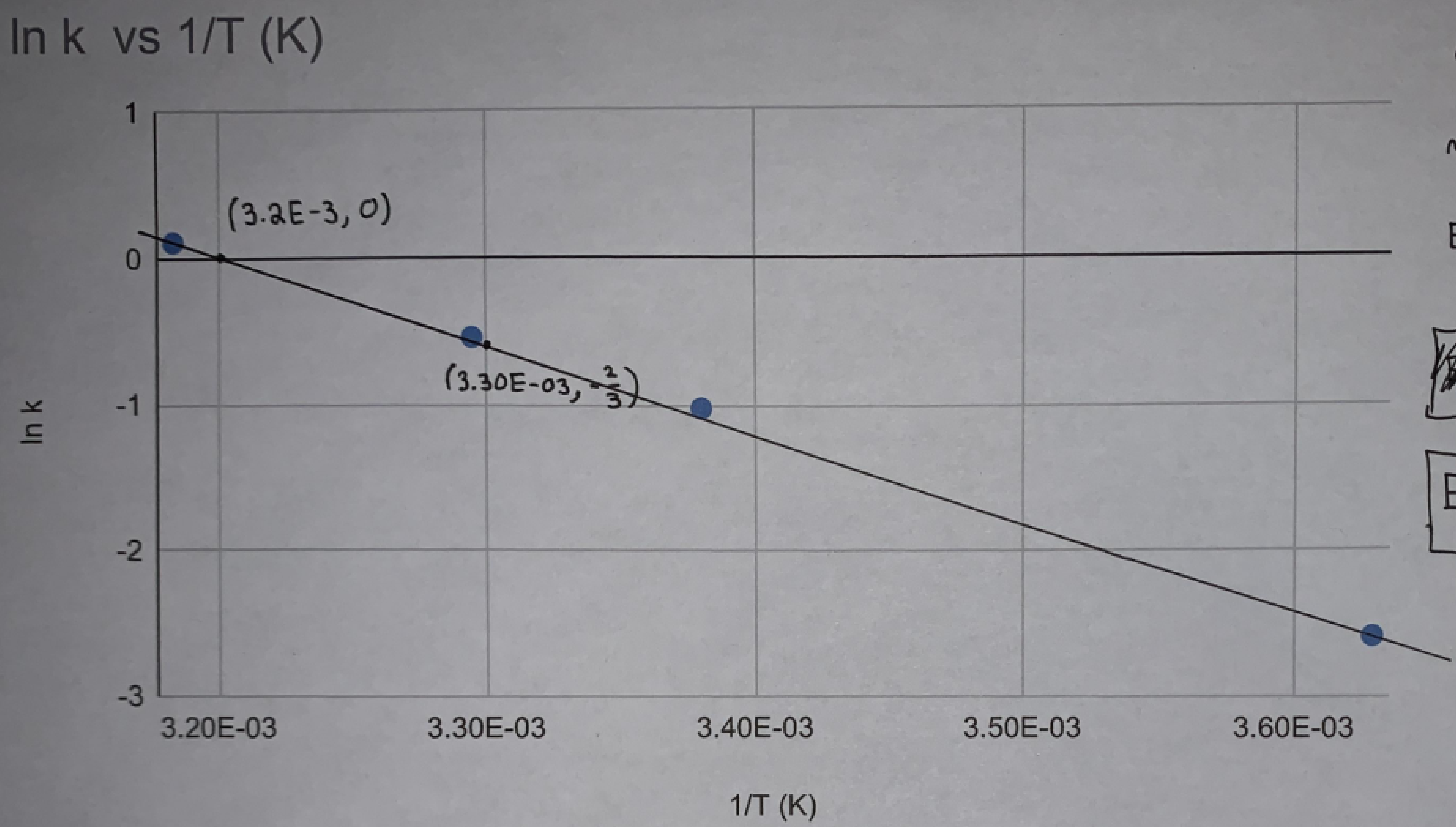
Submit Table I (completed) with your Lab Report.

Table I. The Effect of Temperature on the Reaction Rate of KI and $(NH_4)_2S_2O_8$.

Run	$[KI]^*$ mol/liter	$[(NH_4)_2S_2O_8]^*$ mol/liter	$[S_2O_3^{2-}]^*$ mol/liter	$\Delta[I_2]^{**}$ Formed mol/liter	Δt sec	$\Delta[I_2]/\Delta t$ mol/liter-s	k	Temp °C
1.	$1.657 \cdot 10^{-2}$	$2.347 \cdot 10^{-2}$	0.05864 $2.347 \cdot 10^{-2}$	$1.174 \cdot 10^{-2}$	84	$1.398 \cdot 10^{-4}$	0.3594 $s^{-1} M^{-1}$	22.7
2.	$1.654 \cdot 10^{-2}$	$2.349 \cdot 10^{-2}$	$2.349 \cdot 10^{-2}$	$1.175 \cdot 10^{-2}$	402	$2.922 \cdot 10^{-5}$	0.07520 $s^{-1} M^{-1}$	2.50
3.	$1.652 \cdot 10^{-2}$	$2.351 \cdot 10^{-2}$	$2.351 \cdot 10^{-2}$	$1.175 \cdot 10^{-2}$	52	$2.260 \cdot 10^{-4}$	0.5620 $s^{-1} M^{-1}$	30.3
4.	$1.655 \cdot 10^{-2}$	$2.348 \cdot 10^{-2}$	$2.348 \cdot 10^{-2}$	$1.174 \cdot 10^{-2}$	27	$4.348 \cdot 10^{-4}$	1.119 $s^{-1} M^{-1}$	41.0
with $CuSO_4$	$1.650 \cdot 10^{-2}$	$2.353 \cdot 10^{-2}$	$2.353 \cdot 10^{-2}$	$1.177 \cdot 10^{-2}$	7	$1.681 \cdot 10^{-3}$	4.329 $s^{-1} M^{-1}$	22.5

* The molarity recorded should be the molarity in the solution, after mixing but before reaction, not the molarity of the reactants in the stock solution. Hint - Recall Prelab Question 2.

** $\Delta[I_2]$ is the amount of I_2 formed during Δt, that is, before the blue colour appears. Hint - How is this amount $\Delta[I_2]$ related to $[S_2O_3^{2-}]$ initially in solution?



$$m = \frac{\Delta y}{\Delta x}$$

$$m = E_a$$

$$E_a = \frac{0 - (-\frac{2}{3})}{3.20 \cdot 10^{-3} - 3.30 \cdot 10^{-3}}$$

$$\boxed{E_a = -6\,667 \text{ J/mol}}$$