

# 16.1 Rate Expression & Reaction Mechanism

## Question Paper

Course	DIPB Chemistry
Section	16. Chemical Kinetics (HL only)
Topic	16.1 Rate Expression & Reaction Mechanism
Difficulty	Hard

**Time allowed:** 50  
**Score:** /39  
**Percentage:** /100

### Question 1a

a)

The conversion of hydrogen and iodine into hydrogen iodide proceeds via a three step reaction mechanism:

- $\text{I}_2(\text{g}) \rightleftharpoons 2\text{I}(\text{g})$  fast
- $\text{H}_2(\text{g}) + \text{I}(\text{g}) \rightleftharpoons \text{H}_2\text{I}(\text{g})$  fast
- $\text{H}_2\text{I}(\text{g}) + \text{I}(\text{g}) \rightarrow 2\text{HI}(\text{g})$  slow

Write the rate equation for this reaction and show how the mechanism is consistent with the stoichiometric equation.

[2]

**[2 marks]**

### Question 1b

b)

An investigation into the rate of reaction between hydrogen and iodine was carried out at 298 K and the data obtained is shown below.

Experiment	$[\text{H}_2] / \text{mol dm}^{-3}$	$[\text{I}_2] / \text{mol dm}^{-3}$	Initial rate / $\text{mol dm}^{-3} \text{ s}^{-1}$
1	0.0258	0.0137	$6.43 \times 10^{-22}$
2	0.0258	0.0274	$1.29 \times 10^{-21}$
3	0.0516	0.0137	$1.29 \times 10^{-21}$

Determine the rate equation for the reaction and justify your answer.

[3]

**[3 marks]**

### Question 1c

c)

Calculate the rate constant using Expt 2 data, including its units.

[1]

[1 mark]

**Question 1d**

d)

Using section 11 of the Data booklet, determine whether the forward reaction is favoured by an increase in temperature.

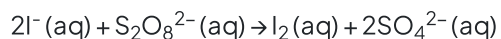
[1]

[1 mark]

**Question 2a**

a)

The reaction between iodide ions and persulfate ions is a 'clock' reaction and often used to study reaction kinetics.



Deduce the redox changes taking place in the reaction.

[2]

[2 marks]

**Question 2b**

b)

A persulfate-iodide clock reaction was studied and the following rate data obtained.

Experiment	$[\text{S}_2\text{O}_8^{2-}] / \text{mol dm}^{-3}$	$[\text{I}^{-}] / \text{mol dm}^{-3}$	Initial rate / $\text{mol dm}^{-3} \text{s}^{-1}$
1	0.25	0.10	$8.0 \times 10^{-3}$
2	0.10	0.10	$3.2 \times 10^{-3}$
3	0.20	0.30	$1.92 \times 10^{-2}$

Deduce the order with respect to persulfate ions and iodide ions.

[2]

[2 marks]

## Question 2c

c)

Determine the rate equation for the reaction and calculate rate constant, including the units.

[2]

**[2 marks]**

## Question 2d

d)

Four mechanisms are proposed for the persulfate-iodide reaction. Deduce which mechanism(s) is/are consistent with the rate equation in part c) and justify your answer.

Mechanism 1:

- $I^-(aq) + I^-(aq) \rightarrow I_2^{2-}(aq)$  *slow*
- $I_2^{2-}(aq) + S_2O_8^{2-}(aq) \rightarrow I_2(aq) + 2SO_4^{2-}(aq)$  *fast*

Mechanism 2:

- $I^-(aq) + S_2O_8^{2-}(aq) \rightarrow S_2O_8I^{3-}(aq)$  *slow*
- $S_2O_8I^{3-}(aq) + I^-(aq) \rightarrow I_2(aq) + 2SO_4^{2-}(aq)$  *fast*

Mechanism 3:

- $I^-(aq) + S_2O_8^{2-}(aq) \rightarrow S_2O_8I^{3-}(aq)$  *fast*
- $S_2O_8I^{3-}(aq) + I^-(aq) \rightarrow I_2(aq) + 2SO_4^{2-}(aq)$  *slow*

Mechanism 4:

- $2I^-(aq) + S_2O_8^{2-}(aq) \rightarrow I_2(aq) + 2SO_4^{2-}(aq)$  *slow*

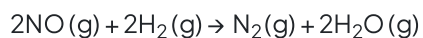
[3]

**[3 marks]**

### Question 3a

a)

The reaction between nitrogen monoxide and hydrogen produces nitrogen and water:



Rate data for this reaction is shown below.

Experiment	[NO] / mol dm <sup>-3</sup>	[H <sub>2</sub> ] / mol dm <sup>-3</sup>	Initial rate / mol dm <sup>-3</sup> s <sup>-1</sup>
1	0.001	0.004	0.002
2	0.002	0.004	0.008
3	0.004	0.001	0.016

What is the *molecularity* of the reaction?

[1]

[1 mark]

### Question 3b

b)

Draw a sketch graphs of:

i)

Rate against concentration of NO.

[1]

ii)

Rate against concentration of H<sub>2</sub>

[1]

[2 marks]

### Question 3c

c)

Suggest a possible mechanism for the reaction.

[2]

[2 marks]

**Question 3d**

d)

Suggest a Lewis structure for  $\text{N}_2\text{O}_2$  and draw the shape of the molecule.

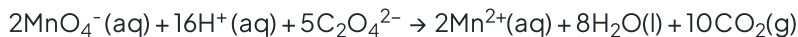
[2]

**[2 marks]**

### Question 4a

a)

The rate of reaction between manganate(VII) ions and oxalate ions,  $C_2O_4^{2-}$ , can be investigated by measuring how the concentration of manganate(VII) varies with time.



The rate is first order with respect to oxalate ions and the general rate equation for the reaction is:

$$\text{rate} = k[MnO_4^-]^p[C_2O_4^{2-}]^q[H^+]^r$$

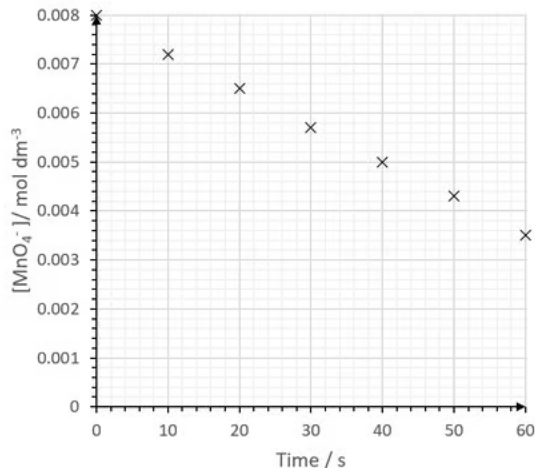
i)

Suggest how the change in manganate(VII) concentration can be measured.

[1]

ii)

A student investigated how the concentration of manganate(VII) affected the rate of reaction and produced the following results. The oxalate ions and acid were in excess.



Determine the rate of reaction.

[2]

[3 marks]

### Question 4b

b)

The student used an acid concentration of  $1.0 \text{ mol dm}^{-3}$ . She then varied it, keeping the other concentrations constant. She measured the rate of reaction and found the following results:

$[\text{H}^+]/\text{mol dm}^{-3}$	Relative rate of reaction
0.5	0.0025
0.25	0.0013
0.01	0.0005

Identify the relationship between the relative rate of reaction and  $\text{H}^+$ , and hence determine the order of reaction with respect to  $\text{H}^+$  ions.

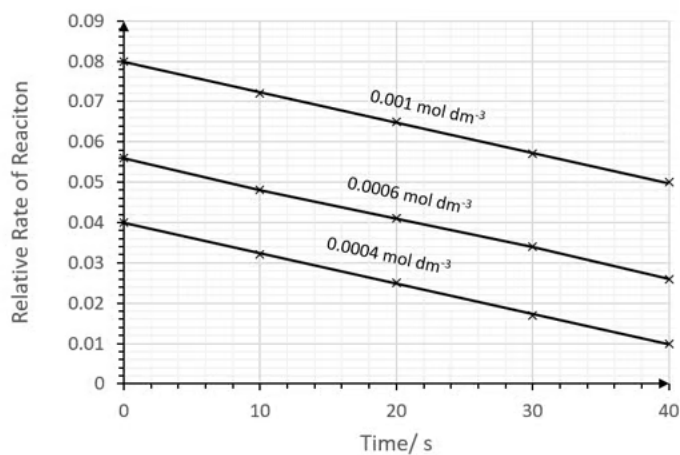
[2]

[2 marks]

### Question 4c

c)

The student varied the concentration of  $[\text{MnO}_4^-]$  and plotted the rate against time at three different concentrations:



i)

Deduce, with a reason, the order of reaction with respect to  $\text{MnO}_4^-$ .

[2]

ii)

Write the rate expression for the reaction.

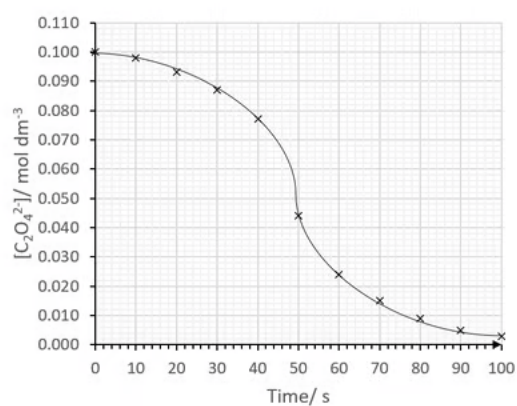
[1]

[3 marks]



### Question 4d

d)  
The student then measured the reaction time for different concentrations of  $\text{C}_2\text{O}_4^{2-}$  and obtained a curve as follows:



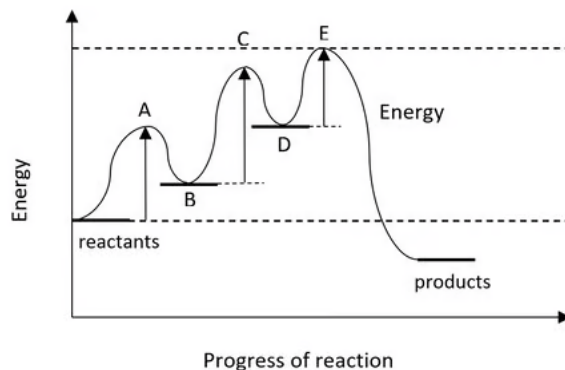
Comment on the shape of the graph.

[2]

[2 marks]

### Question 5a

a)  
A reaction proceeds by a three step mechanism. The energy profile for the reaction is shown below:



Explain the difference between points A, C, E and B, D on the profile.

[4]

[4 marks]

### Question 5b

b)  
Deduce which step is the rate determining step of the reaction, giving a reason.

[2]

[2 marks]