



# Essential Pre-Uni Chemistry M1.1

A Level



- Equation 1:  $A \longrightarrow B$   
Equation 2:  $A + B \longrightarrow C$   
Equation 3:  $A + B \longrightarrow C + D$   
Equation 4:  $2 A + B \longrightarrow C + D$

- Rate law 1:  $\text{rate} = k$   
Rate law 2:  $\text{rate} = k[A]$   
Rate law 3:  $\text{rate} = k[A]^2$   
Rate law 4:  $\text{rate} = k[A][B]$   
Rate law 5:  $\text{rate} = k[A][B]^2$   
Rate law 6:  $\text{rate} = k[A][B][\text{cat}]$

## Part A   Equation 1: order of reaction

A reaction described by equation 1 gets three times faster when the concentration of A is tripled. Give the order of reaction with respect to A.

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Give the overall order of the reaction.

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## Part B   Equation 2: rate law

If equation 2 proceeds as a single step, which rate law will it follow?

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### Part C Second order rate laws

Which rate law(s) is/are second order overall?

- ☐ 3 and 5
- ☐ 3 and 4
- ☐ 1 and 2
- ☐ 4 and 6
- 

### Part D Units of $k$

In which rate law(s) is/are the units of the rate constant,  $k$ ,  $\text{mol dm}^{-3} \text{s}^{-1}$ ? If your answer includes more than one rate law, please list them as one number in ascending order: to answer rates laws 2, 4 and 6, type 246.

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### Part E Law 6: power of $\text{dm}$

In rate law 6, the rate constant,  $k$ , has units which include  $\text{dm}$  raised to which power?

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### Part F Law 5: reaction order of B

What is the order of reaction with respect to B in rate law 5?

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### Part G Constant half-life

Which rate law(s) describe a reaction in which reactant A always has constant half-life? If your answer includes more than one rate law, please list them as one number in ascending order: to answer rates laws 2, 4 and 6, type 246.

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**Part H**    **Law 2: rate constant**

In rate law 2, if  $[A] = 0.020 \text{ mol dm}^{-3}$ , and the rate of reaction  $= 1.2 \times 10^{-3} \text{ mol dm}^{-3} \text{ s}^{-1}$ , find the value of  $k$ .

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**Part I**    **Law 2: rate of reaction**

In rate law 2, if  $k$  has a value of 150, find the rate of reaction when  $[A] = 0.80 \text{ mol dm}^{-3}$ .

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**Part J**    **Law 3:  $[A]$**

In rate law 3, find  $[A]$  at which the reaction rate  $= 0.025 \text{ mol dm}^{-3} \text{ s}^{-1}$  if  $k = 0.0040 \text{ dm}^3 \text{ mol}^{-1} \text{ s}^{-1}$ .

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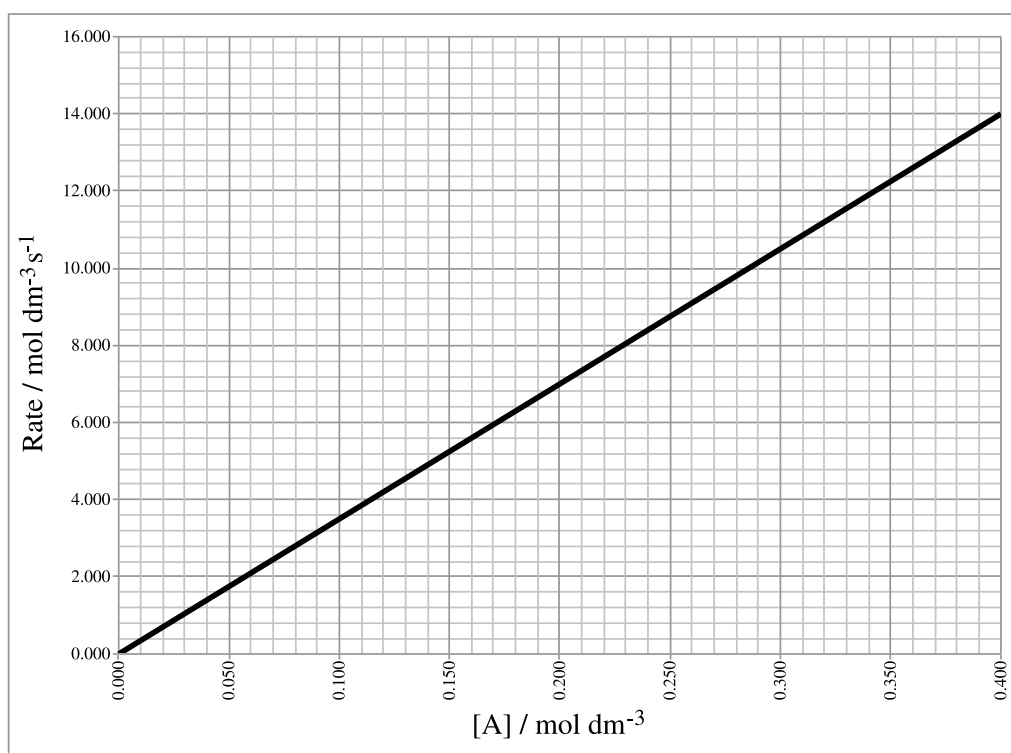


## Essential Pre-Uni Chemistry M1.10

A Level

Equation 2:  $A + B \longrightarrow C$ Rate law 4:  $\text{rate} = k[A][B]$ 

A reaction described by equation 2 and obeying rate law 4 gave the following initial rates for different initial concentrations of A without varying the initial concentration of B:



Estimate the initial concentration of B if the rate constant is  $140 \text{ dm}^3 \text{ mol}^{-1} \text{ s}^{-1}$ . Give your answer to 2 significant figures.



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Use the data in the table below to find the order of reaction with respect to A, B and the catalyst, X, the overall order of reaction, and the value and units of the rate constant,  $k$ .

$[A] / \text{mol dm}^{-3}$	$[B] / \text{mol dm}^{-3}$	$[X] / \text{mol dm}^{-3}$	Rate / $\text{mol dm}^{-3} \text{s}^{-1}$
0.50	0.080	0.0020	$3.2 \times 10^{-3}$
0.50	0.080	0.0010	$8.0 \times 10^{-4}$
0.75	0.080	0.0010	$1.2 \times 10^{-3}$
0.75	0.040	0.0010	$6.0 \times 10^{-4}$

### Part A Order with respect to A

Order with respect to A:

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### Part B Order with respect to B

Order with respect to B:

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### Part C Order with respect to X

Order with respect to X:

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### Part D Overall order

Overall order:

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Value of  $k$ :

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## Essential Pre-Uni Chemistry M1.7

A Level



Equation 1:  $A \longrightarrow B$

Rate law 1:  $\text{rate} = k$

Rate law 2:  $\text{rate} = k[A]$

Rate law 3:  $\text{rate} = k[A]^2$

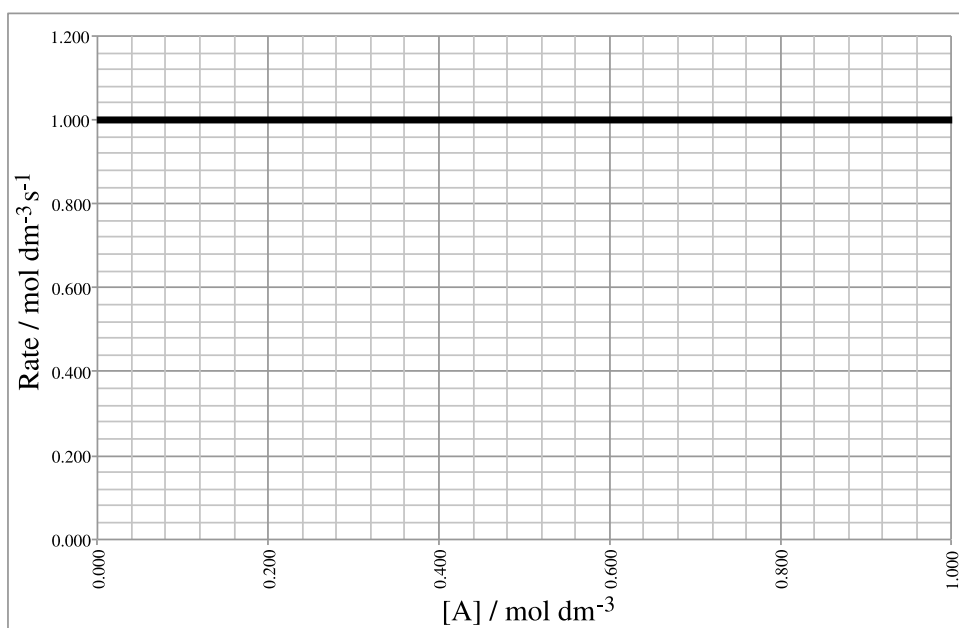
Rate law 4:  $\text{rate} = k[A][B]$

Rate law 5:  $\text{rate} = k[A][B]^2$

Rate law 6:  $\text{rate} = k[A][B][\text{cat}]$

### Part A Rate vs [A]

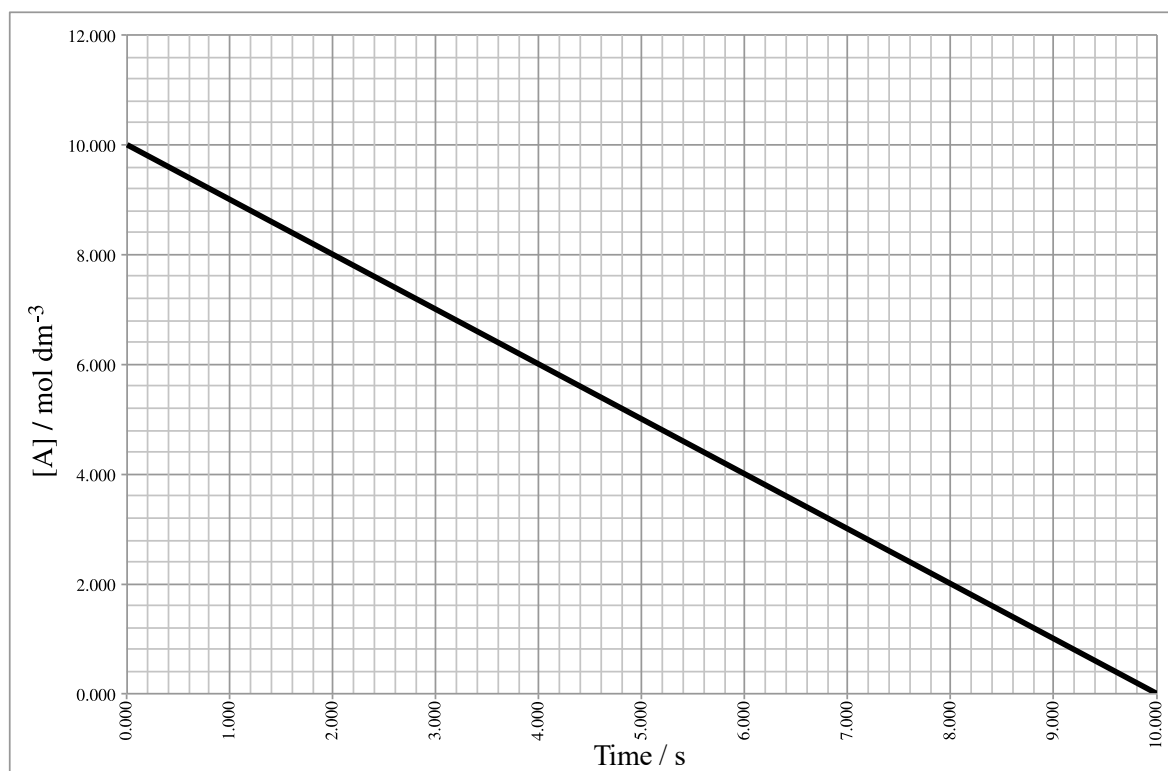
A reaction described by equation 1 shows the behaviour of the graph in **Figure 1**.



Which rate law does it follow?

## Part B [A] vs time

A reaction described by equation 1 shows the behaviour of the graph in **Figure 2**.



Which rate law does it follow?

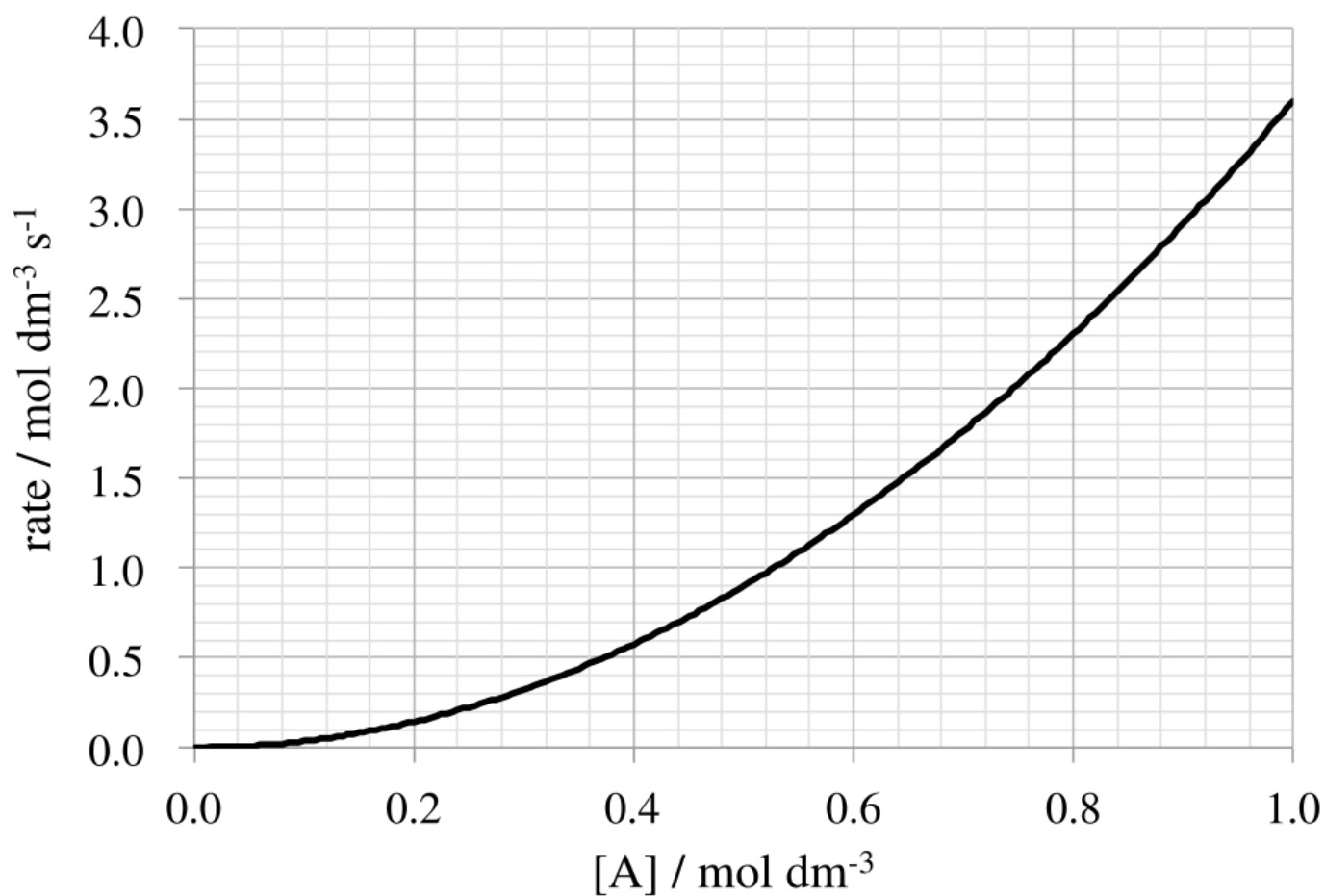


## Essential Pre-Uni Chemistry M1.9

A Level

Equation 1:  $A \longrightarrow B$ Rate law 3:  $\text{rate} = k[A]^2$ 

A reaction described by equation 1 and following rate law 3 is investigated and the following graph is produced from the data obtained:

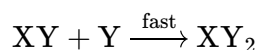
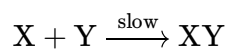


Estimate the rate constant,  $k$ . Give your answer to 2 significant figures.



# Rate Equations and Mechanisms

The two steps in the gas phase reaction  $X + 2 Y \longrightarrow XY_2$  are given below:



What is the rate equation for the overall reaction?

- ☐ rate =  $k[XY]^1[Y]^1$
- ☐ rate =  $k[X]^0[Y]^2$
- ☐ rate =  $k[X]^1[Y]^2$
- ☐ rate =  $k[X]^1[Y]^1$
- ☐ rate =  $k[X]^0[Y]^1$

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# Acetone

Further A



In an acid medium, ketones react with iodine by the following equation:



Experiments were run to determine the partial orders of this reaction with respect to  $\text{RCOCH}_3$ ,  $\text{I}_2$  and  $\text{H}^+$ , using the isolation method. Two reagents were added in great excess to the third, so their concentrations stay approximately constant over the course of the reaction. Compare the different experiments to answer the questions below.

Experiment 1: Using  $0.10 \text{ mol dm}^{-3}$  ketone,  $0.10 \text{ mol dm}^{-3}$  acid and  $1.0 \times 10^{-3} \text{ mol dm}^{-3}$  iodine:

Time/ s	$[\text{I}_2]/\text{mol dm}^{-3}$
0	$1.0 \times 10^{-3}$
5	$7.5 \times 10^{-4}$
10	$5.0 \times 10^{-4}$
15	$2.5 \times 10^{-4}$

Experiment 2: Using  $0.10 \text{ mol dm}^{-3}$  ketone,  $1.0 \times 10^{-3} \text{ mol dm}^{-3}$  acid and  $0.10 \text{ mol dm}^{-3}$  iodine:

Time/ s	$[\text{H}^+]/\text{mol dm}^{-3}$
0	$1.0 \times 10^{-3}$
100	$9.5 \times 10^{-4}$
200	$9.0 \times 10^{-4}$
400	$8.2 \times 10^{-4}$
1000	$6.1 \times 10^{-4}$

Experiment 3: Using  $1.0 \times 10^{-3} \text{ mol dm}^{-3}$  ketone,  $0.10 \text{ mol dm}^{-3}$  acid and  $0.10 \text{ mol dm}^{-3}$  iodine:

Time/ s	$[\text{ketone}]/\text{mol dm}^{-3}$
0	$1.0 \times 10^{-3}$
100	$9.5 \times 10^{-4}$
300	$8.6 \times 10^{-4}$

500	$7.8 \times 10^{-4}$
700	$7.0 \times 10^{-4}$

## Part A Order of reaction

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What are the reaction orders with respect to the ketone, iodine and acid? Give your answer in the form  $abc$  with no spaces.

**Part B**    **Apparent rate constant**

What is the value of the apparent rate constant in experiment 2?

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**Part C**    **Actual rate constant**

What is the value of the actual rate constant?

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# Mushroom Kinetics

A Level



Vitamin D is essential for healthy bone structure. Mushrooms are a rich source of ergosterol, a precursor of vitamin  $D_2$ . Cultivated mushrooms grown in the dark have little vitamin  $D_2$ , but when exposed to UV light, ergosterol is converted into vitamin  $D_2$ .

In a kinetics experiment, different mushroom varieties were irradiated with UV light for varying periods of time and then analysed for their concentrations of ergosterol and vitamin  $D_2$ .

The kinetics of production of vitamin  $D_2$  from ergosterol were expected to be of the form:

$$\text{rate of production of vitamin } D_2 = k[\text{ergosterol}]^a$$

where  $k$  is the rate constant for the particular mushroom,  $[\text{ergosterol}]$  is the concentration of the reactant ergosterol, and  $a$  is the order of reaction with respect to the concentration of ergosterol.

The following data shows the quantity of  $D_2$  produced over 40 minutes of irradiation, measured in micrograms per gram of dry mushroom.

Time / min	Oyster mushroom $D_2$ / $\mu\text{g}$ per g of dry mushroom	Button mushroom $D_2$ / $\mu\text{g}$ per g of dry mushroom
0	7	3
5	12	4
10	17	5
15	21	7
20	25	8
25	29	9
30	33	11
35	37	12
40	42	14

### Part A Determining the order

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By examining this data, what is the value of  $a$ , the observed order of reaction with respect to [ergosterol]? If you are struggling, graph the data.

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### Part B Determining the rate constant

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Using the data, determine the rate constant for the production of vitamin  $D_2$  from oyster mushrooms in units of ( $\mu\text{g per g dry mushroom s}^{-1}$ ).

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### Part C Amount of $D_2$

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Estimate the amount of vitamin  $D_2$  in 10 g of dried button mushrooms that have been irradiated for 1 hour.

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### Part D Effect of temperature

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The rate constant for the production of vitamin  $D_2$  is found to vary with temperature according to the Arrhenius equation:

$$k = A \times e^{\frac{-E_a}{RT}}$$

where  $k$  is the rate constant at temperature  $T$ ;

$A$  is an unknown constant, called the pre-exponential factor;

$E_a$  is the activation energy for the reaction;

$T$  is the temperature in  $K$ ;

$R$  is the gas constant ( $8.314 \text{ J mol}^{-1} \text{ K}^{-1}$ ).

Given that the rate constant for the production of vitamin  $D_2$  from shiitake mushrooms at  $35^\circ\text{C}$  is twice that at  $25^\circ\text{C}$ , calculate the activation energy for the reaction.

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# Reaction Profiling

A Level



An energy profile and an overall reaction equation for a reaction is shown below. This is called an E1 reaction, and is similar to the S<sub>N</sub>1 substitution, but it is an elimination reaction.

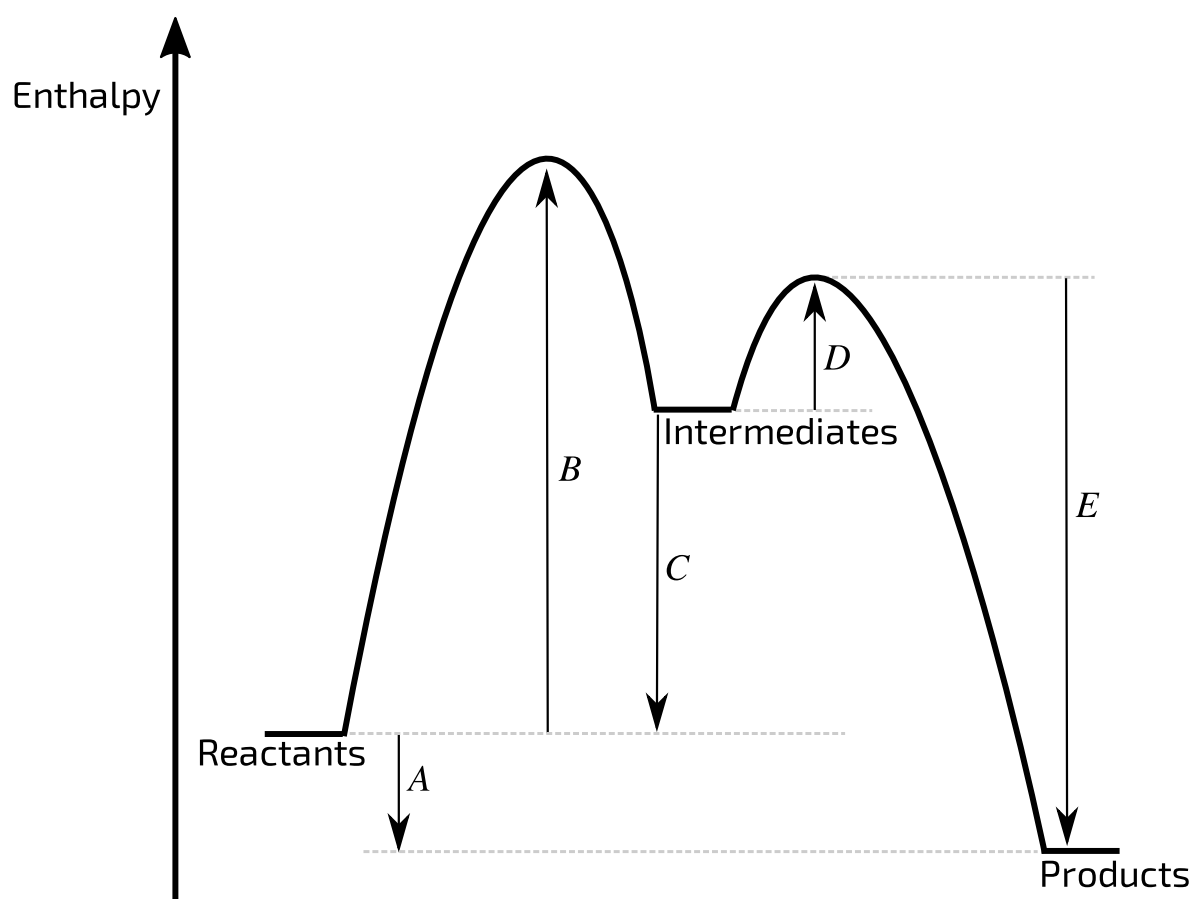
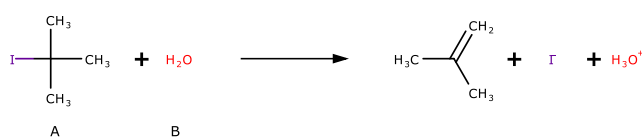


Figure 2: E1 reaction profile

## Part A Rate determining step

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Which reactants participate in the rate determining step?

- ☐ Any other combination
  - ☐ B
  - ☐ A and B
  - ☐ A
  - ☐ None of them
- 

## Part B Intermediate

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What is the shape of the intermediate?

- ☐ Linear
  - ☐ Bent Linear
  - ☐ Tetrahedral
  - ☐ Octahedral
  - ☐ Trigonal Bipyramidal
  - ☐ Trigonal planar
- 

## Part C Activation energy

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On the reaction profile what is the apparent activation energy of the reaction?

- ☐  $D - C$
  - ☐  $E - C + D$
  - ☐  $-A - C$
  - ☐  $-E$
  - ☐  $B + E - A$
  - ☐  $B$
-

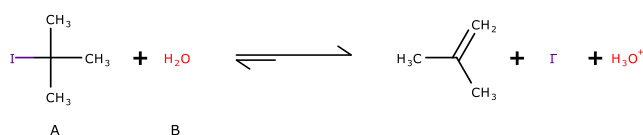
## Part D Enthalpy change

What is the overall enthalpy change of the reaction?

- ☐  $D - C$
- ☐  $-C$
- ☐  $E + D$
- ☐  $A$
- ☐  $E - C + D$
- 

## Part E Reaction yield

Now consider the reaction as a reversible reaction. What would happen to the yield of the reaction if the temperature at which it occurs was raised?



- ☐ Something Else
- ☐ Increase
- ☐ Decrease
- ☐ Stay the same
-

## Part F Yield change

Why does the yield change in the way it does?

- ☐ Le Chatelier's Principle
  - ☐ Hess' Law
  - ☐ Avogadro's Law
  - ☐ Markovnikov's Rule
  - ☐ Snell's Law
- 

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# General Rate Constant

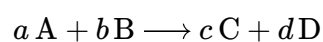
A Level



## Part A   General expression for rate constant

Think about what a generalised expression for the rate constant,  $k$ , of a reaction with two reactants would look like.

Perhaps consider the following general equation to help with your expression.



The lower case letters denote the stoichiometric coefficients.

## Part B   Units of the rate constant

Hence, or otherwise, determine the generalised form of the units of the rate constant.

- ☐  $\text{mol}^{1+(a+b)} \text{ dm}^{-3(a+b)+3} \text{ s}^{-1}$
- ☐  $\text{mol}^{1-(a+b)} \text{ dm}^{3(a+b)-3} \text{ s}^{-1}$
- ☐  $\text{mol}^{1-(a+b)} \text{ dm}^{3(ab)} \text{ s}^{-1}$
- ☐  $\text{mol}^{1-a+b} \text{ dm}^{a+b-3} \text{ s}^{-1}$
- ☐  $\text{mol}^{1-(ab)} \text{ dm}^{-3+(ab)} \text{ s}^{-1}$
- ☐  $\text{mol}^{-(a+b)} \text{ dm}^{(a+b)} \text{ s}^{-1}$

### Part C    Special case

In which special case are the units of the rate constant simply  $\text{s}^{-1}$ ? Write down the equation which must be satisfied for this to occur (it should include  $a$  and  $b$ ).

## Part D Zeroth order

If both  $a = 0$  and  $b = 0$ , what are the units of the rate constant?

- ☐  $\text{s}^{-1}$
  - ☐  $\text{mol}^0 \text{dm}^0 \text{s}^0$
  - ☐  $\text{mol dm}^{-3} \text{s}^{-1}$
  - ☐  $\text{mol dm}^{-3}$
  - ☐  $\text{mol}^2 \text{dm}^{-6} \text{s}^{-1}$
  - ☐  $\text{mol}^{-1} \text{dm}^3 \text{s}^{-1}$
-