Name: ANSWERS

Date:

BCI SCIENCE

SCH 4U

Reactions Rates and Reaction Mechanisms

PART A: Reaction Rates

1. A chemist carries out three trials to determine the rate of the reaction of nitrogen dioxide and oxygen at a fixed temperature. The chemist's results are shown in the chart below.

$NO_{2(g)} + O_{2(g)} \rightarrow 2N_2O_{5(g)}$

Experiment	Initial $[NO_2]$ (mol/L)	Initial $[O_2]$ (mol/L)	Initial rate of formation of N_2O_5 (mol/(L ÷ s))
1	0.025	0.011	3.1×10^{-4}
2	0.025	0.022	6.2×10^{-4}
3	0.050	0.011	6.2×10^{-4}

(a) Write the rate law expression for the reaction. Explain your logic or show your calculations.

$r = k[NO_2]^1[O_2]^1$

$\frac{rate\ 3}{rate\ 1} = \frac{[NO_2]_3^m}{[NO_2]_1^m}$ $\quad \frac{6.2\times10^{-4}}{3.1\times10^{-4}} = \frac{0.050^m}{0.025^m}$ $\quad 2^1 = 2^m$ $\quad m=1$

$\frac{rate\ 2}{rate\ 1} = \frac{[O_2]_2^n}{[O_2]_1^n}$ $\quad \frac{6.2\times10^{-4}}{3.1\times10^{-4}} = \frac{0.022^n}{0.011^n}$ $\quad 2^1 = 2^n$ $\quad n=1$

(b) Calculate the rate constant.

② $6.2\times10^{-4}\ mol/(L\cdot s) = k[0.025\ mol/L]^1[0.022\ mol/L]^1$

$k = 1.13\ \frac{L}{mol\cdot s}$

(c) A chemist runs a trial of the reaction (at the same temperature) in which the initial concentration of $[NO_2]$ is 0.0323 mol/L and the initial concentration of $[O_2]$ is 0.0157 mol/L. Predict the initial rate.

$r = 1.13\frac{L}{mol\cdot s}[NO_2]^1[O_2]^1$

$= 1.13\frac{L}{mol\cdot s}[0.0323\ mol/L]^1[0.0157\ mol/L]^1$

$= 5.72\times10^{-4}\ mol/(L\cdot s)$

2. A reaction has the following rate law. Rate = $k[A][B]^2$

Assuming a constant temperature, by what factor does the reaction rate change when the following changes are made to initial reactant concentration?

(a) [A] is tripled and [B] is doubled. How does the rate change?

$r = k[3]^1[2]^2$

r = 12 times

(b) [B] is halved and [A] remains the same. How does the rate change?

$r = k[1]^1[\frac{1}{2}]^2$

r = 1/4 or 0.25

(c) [A] is quadrupled and [B] is halved. How does the rate change?

$r = k[4]^1[\frac{1}{2}]^2$

= 1 rate remains the same

(d) [A] and [B] are halved. How does the rate change?

$r = k[\frac{1}{2}]^1[\frac{1}{2}]^2$

$= \frac{1}{8}$

3. Consider the following reaction and its corresponding rate law:

$BrO_3^-{}_{(aq)} + 5Br^-{}_{(aq)} + 6H^+{}_{(aq)} \rightarrow 3Br_2{}_{(aq)} + 3H_2O_{(l)}$ Rate = $k[BrO_3^-][Br^-][H^+]^2$

(a) What is the reaction order with respect to each reactant?

$[BrO_3^-]$ = 1st order; $[Br^-]$ = 1st order; $[H^+]$ = 2nd order

(b) What is the overall order of the reaction?

The overall order is (1+1+2) 4th order

(c) Suggest two different ways to track the rate of this reaction experimentally.

$r = -\frac{\Delta[BrO_3^-]}{\Delta t}$ disappearance

$r = \frac{1}{3}\frac{\Delta[Br_2]}{\Delta t}$ appearance

PART B: Reaction Mechanisms

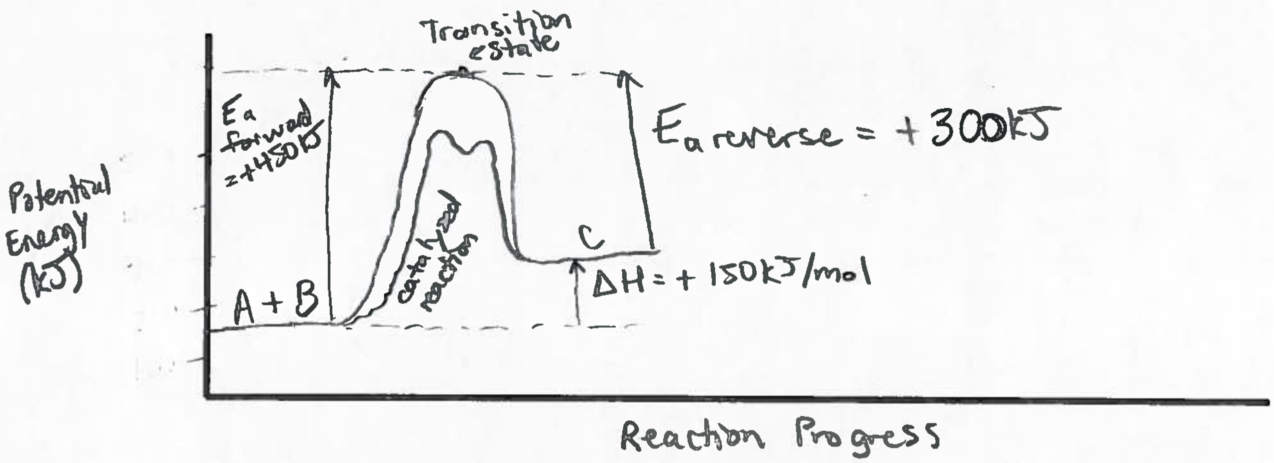
1. Assume the following reaction has a one-step mechanism:

A + B → C

Draw a potential energy diagram for the reaction that correctly incorporates each of the following labels:

ΔH = 150 kJ/mol $E_{a(fwd)}$ = 450 kJ Potential energy Reaction progress

Transition state A + B C



(a) Is the reaction endothermic or exothermic? Explain.

Endothermic as $\Delta H = +150$ kJ/mol ∴ energy is absorbed by the reaction. Also, Ea forward > Ea reverse

(b) Determine $E_{a(rev)}$ for the reaction. Add this value to your diagram.

$E_{a\ reverse} = E_{a\ forward} - \Delta H_{rxn}$

$= 450 - 150$

$= +300$ kJ

(c) How would your diagram have been different if the reaction had a two-step mechanism? Explain your answer.

A two step mechanism would have two transition states both with less Ea forward than the one step mechanism.

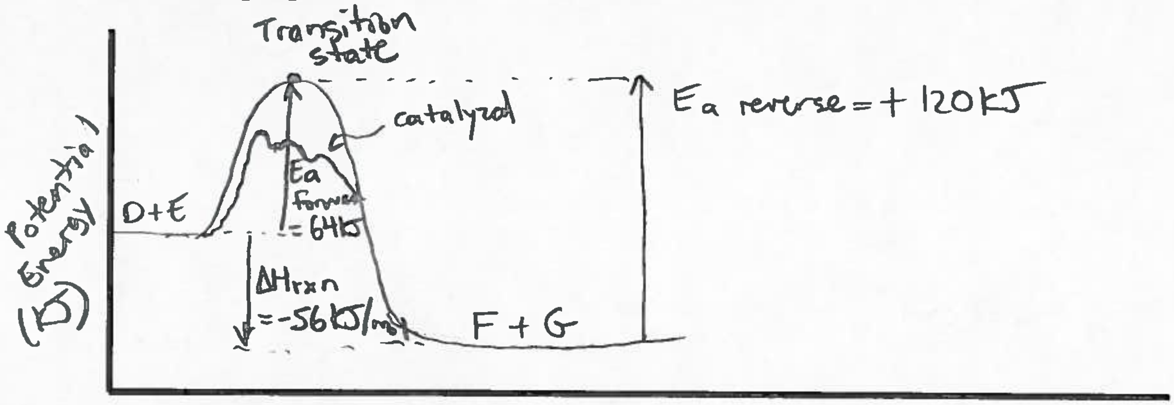
(d) A catalyst speeds up the reaction by providing an alternative, two-step mechanism. On your diagram, sketch a curve to represent the effect of the catalyst on the reaction.

2. Assume the following reaction has a one-step mechanism:

$D + E \rightarrow F + G$

Draw a potential energy diagram for the reaction that correctly incorporates each of the following labels:

$\Delta H = -56$ kJ/mol	$E_{a(rev)} = 120$ kJ	Potential energy
Reaction progress	Transition state	D + E	F + G



(a) Is the reaction endothermic or exothermic? Explain.

Exothermic as $\Delta H_{rxn} = -56$ kJ/mol. Also Ea forward < Ea reverse.

(b) Determine $E_{a(fwd)}$ for the reaction. Add this value to your diagram.

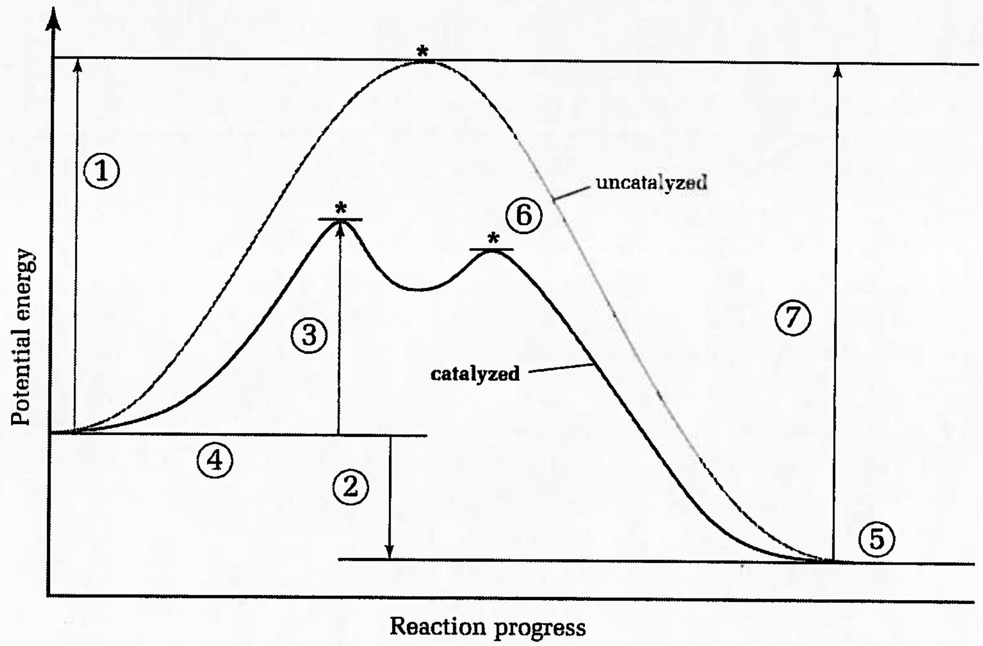
$E_{a\,forward} = E_{a\,reverse} + \Delta H_{rxn}$

$= 120 + 56$

$= 64$ kJ

(c) A catalyst speeds up the reaction by providing an alternative, three-step mechanism. On your diagram, sketch a curve to represent the effect of the catalyst on the reaction.

3. The graph below shows the energy changes involved in an uncatalyzed and a catalyzed reversible reaction. Match the following descriptions to the numbers on the graph. **Note:** There are more numbers than descriptions—some numbers do not have matching descriptions.



(a) 3 activation energy of the first step of the forward catalyzed reaction.

(b) 2 enthalpy change for the reaction.

(c) 1 activation energy of the forward uncatalyzed reaction.

(d) 6 transition state.

(e) 7 activation energy of the reverse uncatalyzed reaction.