

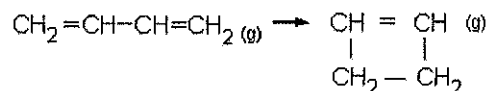
Reaction Rate Review

- Measurements taken during the reaction: $\text{CO}_{(g)} + \text{NO}_{2(g)} \rightarrow \text{CO}_{2(g)} + \text{NO}_{(g)}$ showed a concentration of carbon monoxide of 0.019 mol/L at 27 min and 0.013 mol/L at 45 min. Calculate the average rate, over this 18 min period, of each of the following:
 - the loss of carbon monoxide
 - the gain of carbon dioxide
- In the following reaction the average rate of loss of carbon monoxide, over a set period is 0.15 mol/Ls. $2\text{CO}_{(g)} \rightarrow \text{CO}_{2(g)} + \text{C}_{(s)}$ What is the average rate of production of carbon dioxide during the same period?
- At high temperatures, ammonia reacts with oxygen to produce nitrogen monoxide and steam: $4\text{NH}_{3(g)} + 5\text{O}_{2(g)} \rightarrow 4\text{NO}_{(g)} + 6\text{H}_2\text{O}_{(g)}$
In one experiment the average rate of decomposition of ammonia was found to be 4.5×10^{-2} mol/Ls. For this same time interval calculate the following:
 - the rate of the production of water
 - the rate of the production of nitrogen monoxide
 - the rate at which oxygen is consumed
- Give two reasons why most molecular collisions do not lead to a molecule reaction.
- What is meant by the term activation energy?
- In the following reaction the enthalpy of the forward reaction is $\Delta H = -36 \text{ kJ/mol}$:
 $\text{A} + \text{B} \rightarrow \text{C}$. The activation energy for the forward reaction is 73 kJ/mol
 - Draw an energy diagram for this reaction.
 - What is the activation energy for the reverse reaction?
- For the reaction, in solution, between bromoethane and hydroxide ion,
 $\text{C}_2\text{H}_5\text{Br}_{(aq)} + \text{OH}^-_{(aq)} \rightarrow \text{C}_2\text{H}_5\text{OH}_{(aq)} + \text{Br}^-_{(aq)}$
It was found that doubling the concentration of the hydroxide ion caused the rate to double. When the concentration of both reactants was doubled, the rate of the reaction increased by a factor of four. What is the order of the reaction with respect to:
 - hydroxide ions?
 - bromoethane?
 - the overall reaction order?
- What are three factors affecting the rate of a chemical reaction?
- Which of the following are likely to be very rapid reactions? Why?
 - $\text{Zn}^{2+}_{(aq)} + \text{S}^{2-}_{(aq)} \rightarrow \text{ZnS}_{(aq)}$
 - $\text{H}_2\text{SO}_{4(aq)} + 2\text{NaOH}_{(aq)} \rightarrow \text{Na}_2\text{SO}_{4(aq)} + 2\text{H}_2\text{O}_{(l)}$
 - $\text{Zn}_{(s)} + \text{S}_{(s)} \rightarrow \text{ZnS}_{(s)}$
- Explain the term activated complex
- Why does an increase in temperature increase the rate of a reaction?
- The following reaction is extremely slow at room temperatures; but with even a very small spark proceeds with explosive violence. $2\text{H}_{2(g)} + \text{O}_{2(g)} \rightarrow 2\text{H}_2\text{O}_{(g)}$
Explain this observation.
- Although methane, the main component of natural gas, burns readily in oxygen. $\text{CH}_{4(g)} + 2\text{O}_{2(g)} \rightarrow \text{CO}_{2(g)} + 2\text{H}_2\text{O}_{(g)}$ this reaction is so slow at room temperature that it is not detectable. Explain this observation.

14. Briefly describe the collision theory of reaction rates.
15. Using collision theory explain why aqueous reactions involving simple ions are usually much faster than those involving complex molecules.
16. What does the highest point in an energy diagram of a reaction represent?
17. Distinguish between the activation energy of a reaction and the activated complex in a reaction.
18. Distinguish between homogenous catalysis and heterogeneous catalysis.
19. Why is the rate of a reaction fastest at the beginning of the reaction?
20. What is the *order* of a chemical reaction?
21. How can the order of a reaction be determined?
22. Distinguish between reaction rate and reaction rate constant.
23. Would the reaction rate constant change if:
 - a) the concentration of the reactant increased?
 - b) the pressure of a gaseous reactant increased?
 - c) the temperature was increased?

Explain your answers

24. What is the order of the reactions with the following rate laws?
 - a) Rate = $k [A] [B]$
 - b) Rate = $k [B]^2$
 - c) Rate = $k [A] [B]^2$
25. At high temperatures (250°C) butadiene gas is converted to cyclobutene gas



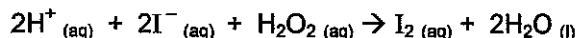
In one experiment the following data were obtained.

Time (s)	Concentration of butadiene (mol/L)
190	0.0162
600	0.0148
1245	0.0129
2180	0.0110

Calculate the average rate of loss of butadiene during these time periods:

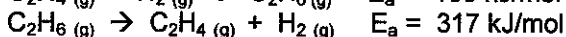
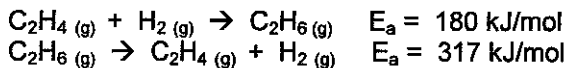
- a) between 190 and 600 seconds
- b) between 190 and 2180 seconds

26. The rate of appearance of I_2 in aqueous solution, in the reaction of I⁻ ion with hydrogen peroxide, was found to be 3.7×10^{-5} mol/Ls over a time interval.



During the interval, what was the rate of disappearance of each of the following?

- a) H_2O_2
b) I⁻
27. For the following reactions, activation energies were determined as follows:



- a) Draw an energy level diagram for this reversible reaction.
b) Calculate the ΔH for each reaction.
28. For the following reaction, activation energy is 254 kJ. $C_2H_5Cl_{(l)} \rightarrow C_2H_4(g) + HCl_{(g)}$
And for this next reaction, activation energy is 219 kJ $C_2H_5Br_{(l)} \rightarrow C_2H_4(g) + HBr_{(g)}$

Which substance would decompose more rapidly under normal conditions?

29. The initial rate of thermal decomposition of gaseous acetaldehyde $CH_3CHO_{(g)} \rightarrow CH_4(g) + CO_{(g)}$ was measured using different initial concentrations of the reactant. The results are summarized below.

Initial $[CH_3CHO]$ mol/L	Initial Rate of decomposition of CH_3CHO mol/Ls
0.050	0.005
0.10	0.020
0.20	0.081
0.30	0.181

From these data determine the relationship between rate of decomposition and the concentration of acetaldehyde.

30. The initial rate of production of bromine in the gaseous reaction $4HBr_{(g)} + O_{2(g)} \rightarrow 2Br_{2(g)} + 2H_2O_{(g)}$ was measured using different initial concentrations of each reactant. The results are summarized below.

Initial $[HBr]$ mol/L	Initial $[O_2]$ mol/L	Initial Rate of Reaction mol/Ls
0.010	0.010	0.0042
0.010	0.020	0.0083
0.020	0.020	0.0168
0.030	0.010	0.0126

Determine the relationship between rate of decomposition and the concentration of each reactant.

31. From the data in Question 29 determine the following:
- a) rate law for the reaction
b) the order of the reaction
c) k, the rate constant

32. From the data in Question 30 determine the following:

- rate law for the reaction
- the order of the reaction
- k , the rate constant

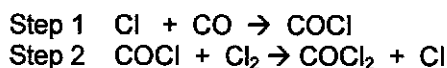
33. For the general reaction $A + B \rightarrow \text{Products}$, the following data is obtained

[A] mol/L	[B] mol/L	Initial Rate mol/Ls
0.10	0.20	0.030
0.20	0.20	0.120
0.10	0.30	0.031

- Estimate the order of the reaction with respect to both A and B.
 - Give the rate law for the reaction.
 - Calculate k , the rate constant for the reaction.
 - Calculate the initial rate of the reaction if $[A] = 0.50 \text{ mol/L}$, $[B] = 0.050 \text{ mol/L}$
34. Some proportion of photochemical smog, now found in a number of Canadian cities, is thought to be due to the light-initiated breakdown of nitrogen dioxide producing nitrogen monoxide and atomic oxygen. A scientist decides to study the subsequent reaction of nitrogen monoxide with molecular oxygen.

$2\text{NO}_{(g)} + \text{O}_{2(g)} \rightarrow 2\text{NO}_{2(g)}$ She finds that when the initial concentration of the oxygen is doubled and that of the nitrogen monoxide is held constant, the initial reaction rate doubles. On the basis of this information only, which of the following statements is/are true?

- The reaction is first order with respect to nitrogen monoxide.
 - The reaction is first order with respect to oxygen.
 - The reaction is first order overall.
 - The reaction is second order overall.
 - More kinetic experiments have to be conducted before the overall order of the reaction can be determined.
35. Phosgene, COCl_2 , one of the poison gases used during World War I, is formed from chlorine and carbon monoxide. The mechanism is thought to proceed by:



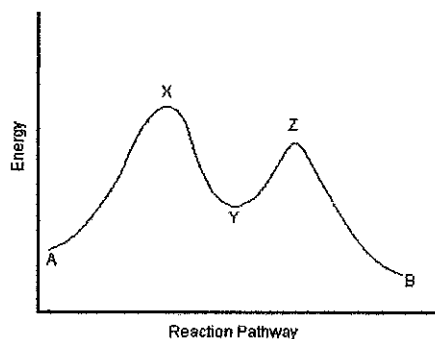
- Write the overall reaction equation.
 - Identify any reaction intermediates.
 - Identify any catalysts.
36. Under certain specific conditions, data for the reaction $2\text{H}_{2(g)} + \text{O}_{2(g)} \rightarrow 2\text{H}_2\text{O}_{(g)}$ is obtained by measuring the rate of production of water.

[H ₂] mol/L	[O ₂] mol/L	Initial Rate of Production of H ₂ O mol/L min
0.020	0.020	0.0036
0.040	0.020	0.0144
0.020	0.040	0.0073

Determine the rate law for the reaction and calculate the value of k , the specific rate constant.

37. The hydrolysis of a tosylate derivative of a naturally-occurring organic terpene compound, has an initial reaction rate of 6.15×10^{-7} mol/Ls at 25.0°C . Assuming that a 10°C increase in temperature doubles the reaction rate, calculate the initial rate of this same reaction at a temperature of
- 15.0°C
 - 55.0°C
38. Which one of the following sets can be correctly identified with the forward reaction in the energy diagram below.

Set	Reactant	Activated Complex	Reaction Intermediates	Catalyst(s)	Product(s)
1	A	X	Z	Y	B
2	B	X,Z	Y	-	A
3	A	X,Z	Y	-	B
4	A	X	Y	Z	B
5	A	Z	-	X,Y	A



39. Redraw the energy diagram for the reaction in question 38, labelling the activation energy for both the forward and reverse reactions, and indicating the enthalpy change for the forward reaction.
40. Draw the energy level diagram for the reaction $X + Y \rightarrow Z$ using the following information.
- The mechanism consists of two elementary steps.
 - The second elementary step is the rate determining step.
 - The reaction is exothermic.
41. Ozone in the upper atmosphere protects the earth from harmful ultraviolet radiation by absorbing it and re-emitting the energy as radiation of a different wavelength. One threat to the ozone layer is thought to involve nitrogen monoxide from supersonic transport (sst) exhaust. The proposed mechanism involves three steps:
- Step 1 $\text{O}_3 \rightarrow \text{O}_2 + \text{O}$
 Step 2 $\text{NO} + \text{O}_3 \rightarrow \text{NO}_2 + \text{O}_2$
 Step 3 $\text{NO}_2 + \text{O} \rightarrow \text{NO} + \text{O}_2$

- What is the role of NO_2 in this catalyzed mechanism?