TEST: RATES OF REACTION

SCH 4UE 05 – 06

Name: _____
(Total Score: /)

Part A: Multiple Choice (5)

1. The rate expression for a reaction is shown below:

$$\text{rate} = k[A]^2[B]^2$$

Which statements are correct for this reaction?

I. The reaction is second order with respect to both A and B.
II. The overall order of the reaction is 4.
III. Doubling the concentration of A would have the same effect on the rate of reaction as doubling the concentration of B.

A. I and II only
B. I and III only
C. II and III only
D. I, II and III

2. The rate of a reversible reaction is altered by the addition of a heterogeneous catalyst. Which statement correctly describes the role of the catalyst?

A. It alters the enthalpy change of the reaction.
B. It decreases the activation energy of the forward reaction.
C. It increases the activation energy of the reverse reaction.
D. It increases the rate of the forward reaction but decreases the rate of the reverse reaction.

3. Consider the following statements.

I. The rate constant of a reaction increases with increase in temperature.
II. Increase in temperature decreases the activation energy of the reaction.
III. The term *A* in the Arrhenius equation ($k = Ae^{-Ea/RT}$) relates to the energy requirements of the collisions.

Which statement(s) is/are correct?

A. I only
B. II only
C. I and III only
D. II and III only

4. The rate of a reaction between two gases increases when the temperature is increased and a catalyst is added. Which statements are both correct for the effect of these changes on the reaction.

Multiple Choice Answer	**increasing the temperature**	**Adding a catalyst**
A	collision frequency increases	activation energy increases
B	activation energy increases	activation energy does not change
C	activation energy does not change	activation energy decreases
D	activation energy increases	collision frequency increases

5. The rate equation for the reaction between andO_2 and NO is: O_2

$$\text{Rate} = k[O_2][NO]^2$$

By what factor would the rate of this reaction increase if the concentrations of O_2 and NO are both doubled?

A. 1/8 B. 3 C. 4 D. 8

Short Answer and Problems

1. Given the following steps in the mechanism for a chemical reaction:

$$A + B \longrightarrow C \quad \text{fast}$$
$$B + C \longrightarrow D + E \quad \text{slow}$$
$$D + F \longrightarrow A + E \quad \text{fast}$$

Identify which species, if any, are:

a. Catalysts in this reaction, 1

b. Intermediates in this reaction. 1

c. Write the rate law for this reaction. 1

d. Deduce the overall order of this reaction. 1

e. State and explain what would happen to the initial rate if the initial concentration of A was doubled and that of B was halved. 3

f. Sketch a graph you would expect if concentration of B was plotted against the rate of the reaction, whilst concentration of all the other species were kept constant. 2

2. The following data were obtained for the reaction of nitrogen monoxide gas, $NO_{(g)}$, with oxygen gas to form nitrogen dioxide gas, $NO_{2(g)}$, at 25 ^{O}C.

Experiment	**[NO] mol dm^{-3}**	**[O_2] mol dm^{-3}**	**Initial rate (mol dm^{-3} s^{-1})**
1	0.50	0.20	3.0×10^{-3}
2	0.50	0.40	6.0×10^{-3}
3	1.00	0.80	4.8×10^{-3}

(i) Calculate the order with respect to the two reactants and write the rate expression for the reaction. Show your reasoning. 5

(ii) Explain why the following mechanism is **not** consistent with the rate expression. 2

$$NO_{(g)} + O_{2(g)} \longrightarrow NO_{2(g)} + O_{(g)} \quad \text{slow}$$
$$NO_{(g)} + O_{(g)} \longrightarrow NO_{2(g)} \quad \text{fast}$$

(iii) Explain why the following mechanism is consistent with the rate expression, but is unlikely. 2

$$2NO_{(g)} + O_{2(g)} \longrightarrow 2\,NO_{2(g)}$$

(iv) Explain why the following mechanism is consistent with the rate expression. 3

$NO_{(g)} + O_{2(g)} \longrightarrow NO_{3(g)}$ fast
$NO_{3(g)} + NO_{(g)} \longrightarrow 2NO_{2(g)}$ slow

(v) Explain why the following mechanism is also consistent with the rate expression. 2

$NO_{(g)} + NO_{(g)} \longrightarrow N_2O_{2(g)}$ fast
$N_2O_{2\,(g)} + O_{2(g)} \longrightarrow 2NO_{2(g)}$ slow

(vi) It is plausible that the first step in a possible mechanism for the reaction above is:

$NO_{(g)} + NO_{(g)} \rightleftharpoons N_2O_{2(g)}$

Draw a Lewis structure for NO and N_2O_2. What feature of the electronic structure of NO would suggest that this is a likely first step in the reaction. 4

(vii) Explain why the enthalpy change for this step is -163 kJ mol^{-1}, given that the average bond energy for the N — N bond in compounds of nitrogen is + 163 kJ mol^{-1}. 2

(viii) NO_2 reacts with aqueous sodium hydroxide according to the following equation:

$$2\ OH^{-1} + 2\ NO_2 \longrightarrow NO_2^{-1} + NO_3^{-1} + H_2O$$

What type of reaction is this? Justify your answer. 2

4. Heterogenous catalysis is used in the fight against air pollution. Harmful gases produced in a car engine are passed through a catalytic converter to reduce environmental damage.

a. (i)Explain the term heterogeneous as applied to a catalytic converter, and briefly explain how the mechanism of heterogeneous catalysis. 4

(ii) Name the products formed when the following compounds are passed through a catalytic converter.

carbon monoxide: 1

hydrocarbons: 1

(iii) Explain why leaded petrol must not be used in cars fitted with a catalytic converter. 1

b. (i) In the catalytic converter oxides of nitrogen, NO_x, are converted into nitrogen in an exothermic reaction. Explain using a potential energy diagram, how a catalytic converter increases the rate of conversion of NOx to nitrogen. 3

(ii) The conversion of NO_x, to nitrogen is extremely *slow* at room temperature as well as being *exothermic*. Explain why NO_x, with respect to nitrogen, may be described as kinetically stable and thermodynamically unstable. 2

5. The following reaction is described as first order with respect to N_2O_5:

$$2\ N_2O_{5\ (g)} \longrightarrow 4NO_{2\ (g)} + O_{2(g)}$$

a. Write the rate expression for the reaction. 1

b. Explain what is meant by the term half-life for this reaction. 1

c. State what is characteristic about the half-life of a first order reaction. 1

d. The rate constant at a certain temperature for this reaction is $5.2 \times 10^{-3}\ s^{-1}$. Calculate the time taken for the concentration of N_2O_5 to decrease from 0.10 mol dm^{-3} to 0.010 mol dm^{-3}. 3

e. Briefly describe how you would determine the activation energy for the reaction above. 3