Chemistry 2710 Spring 2001 Test 1

Name: _____

Student number: _____

Aids allowed: Calculator. One $8\frac{1}{2} \times 11$-inch piece of paper containing any information you need. No other printed materials (e.g. periodic tables) are allowed.
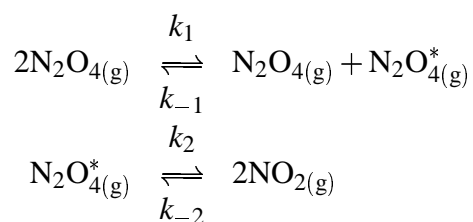
Instructions: Answer all questions in the spaces provided. Use the backs of the printed pages for rough work. If you run out of room for a particular question, you may write in the empty space on this page. Graphs should be drawn on the graph paper attached and clearly labeled with the corresponding question number.

Make sure to explain in detail the procedures used to obtain the answers you present. For instance, if you get a slope by performing a linear regression on your calculator, say so. If you determined something from a graph, refer to the graph in explaining your answer.

1. Suppose that, for a reaction $A \rightarrow 3B$, $1.4 \times 10^{-4}\,\text{mol/L}$ of product accumulates in the first $3.5\,\text{s}$ of the reaction. What is the initial rate? [3 marks]

2. Dinitrogen tetraoxide (N_2O_4) decomposes to NO_2 in the gas phase. The decomposition mechanism is a variation on the Lindemann mechanism:

$$2N_2O_{4(g)} \underset{k_{-1}}{\overset{k_1}{\rightleftharpoons}} N_2O_{4(g)} + N_2O^*_{4(g)}$$

$$N_2O^*_{4(g)} \underset{k_{-2}}{\overset{k_2}{\rightleftharpoons}} 2NO_{2(g)}$$

$N_2O^*_4$ represents an energized molecule of N_2O_4.

   (a) What is the overall reaction? [2 marks]

   (b) If the pressure of N_2O_4 is sufficiently low, the first step can be made rate-determining. If an initial rate study were made in this pressure range, what would be the observed rate law? [2 marks]

(c) Relate the equilibrium constant for the overall reaction to the elementary rate constants.
[7 marks]

3. The following initial rate data were obtained for a reaction with the stoichiometry A → B:

a (μmol/L)	1.35	1.49	2.33	2.82	3.04
v ($mol\,L^{-1}s^{-1}$)	15.7	16.5	20.6	22.7	23.5

Are these data consistent with a simple rate law? If so, what is the order? [10 marks]

4. Suppose that a company wants to remove a pollutant X from a solution produced as a byprod-
uct of an industrial process. Their research department finds a reaction $X + A \rightarrow Y + 2Z$
which converts the pollutant into the harmless substances Y and Z.

(a) Preliminary experiments indicate that the rate of the reaction only depends on the con-
centration of X and that the order with respect to X is either 2 or 3. To determine the
order of the reaction, an experiment was performed in which the concentration of the
product Z was followed as a function of time:

t (min)	0	3.22	6.58	10.02	13.91
z (mmol/L)	0	13.0	22.6	30.0	36.4

In this experiment, the initial concentration of X was 0.0400 mol/L. What is the order
of the reaction and rate constant? [10 marks]

(b) The industrial waste produced by this company contains X at a concentration of 0.2 mol/L
and is considered safe when this concentration drops below $1\,\mu\text{mol}/\text{L}$. If the reaction
conditions are more or less as given above, how long would the treatment of the indus-
trial waste take? In your opinion, is this an acceptable length of time? [4 marks]

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5. In class, we showed that the D to L ratio for amino acids changes with time according to

$$t = \frac{1}{2k} \ln \left(\frac{\left(1 + \frac{[D]}{[L]}\right)\left(1 - \frac{[D]_0}{[L]_0}\right)}{\left(1 - \frac{[D]}{[L]}\right)\left(1 + \frac{[D]_0}{[L]_0}\right)} \right).$$

How would you determine the value of the rate constant k? Be specific about what would need to be measured and how the data should be treated. [6 marks]