Name _____

Practice Exam: Paper 2
Topic 6: Kinetics

SL Score	HL Score
/28	/62

SL

1. Factors that affect the rate of a chemical reaction include particle size, concentration of reactants and the temperature of the reaction.

(i) Define the term *rate of a chemical reaction*.

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(1)

(ii) List the **three** characteristic properties of reactant particles which affect the rate of reaction as described by the collision theory.

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(3)

2. On the axes below sketch **two** Maxwell-Boltzmann energy distribution curves for the same sample of gas, one at a temperature T and another at a higher temperature T'. Label both axes. Explain why raising the temperature increases the rate of a chemical reaction.

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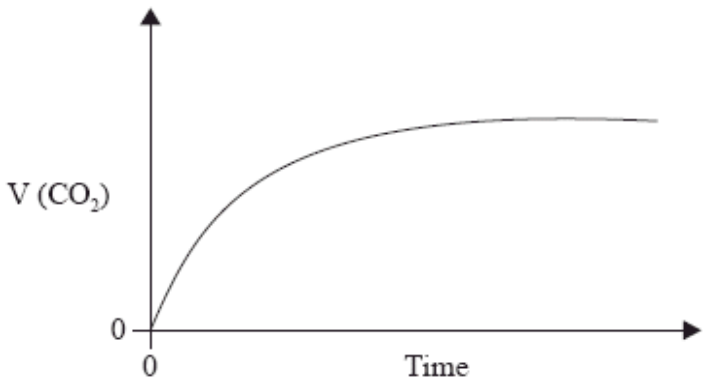
(5)

3. The graph below shows how the volume of carbon dioxide formed varies with time when a hydrochloric acid solution is added to **excess** calcium carbonate in a flask.



(i) Explain the shape of the curve.

(3)

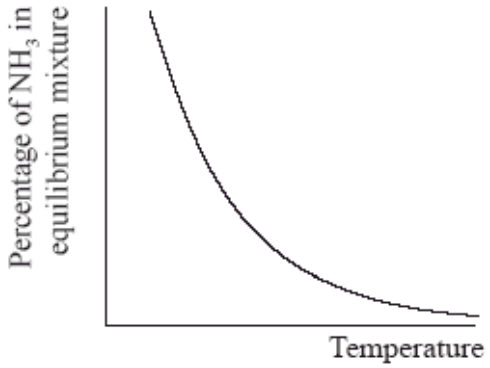
(ii) The experiment is repeated using a sample of hydrochloric acid with double the volume, but half the concentration of the original acid. Draw a second line on the graph to represent this change. Explain why the shape of the curve is different.

(3)

4. The Haber process enables the large-scale production of ammonia needed to make fertilizers.
The equation for the Haber process is given below.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

The percentage of ammonia in the equilibrium mixture varies with temperature.



(i) Use the graph to deduce whether the forward reaction is exothermic or endothermic and explain your choice.

(2)

(4 cont.)

(ii) State and explain the effect of increasing the pressure on the yield of ammonia.

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(2)

(iii) Explain the effect of increasing the temperature on the rate of reaction.

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(2)

5. (a) A solution of hydrogen peroxide, H_2O_2, is added to a solution of sodium iodide, NaI, acidified with hydrochloric acid, HCl. The yellow colour of the iodine, I_2, can be used to determine the rate of reaction.

$$H_2O_2(aq) + 2NaI(aq) + 2HCl(aq) \rightarrow 2NaCl(aq) + I_2(aq) + 2H_2O(l)$$

The experiment is repeated with some changes to the reaction conditions. For each of the changes that follow, predict, stating a reason, its effect on the rate of reaction.

(i) The concentration of H_2O_2 is increased at constant temperature.

(2)

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(ii) The solution of NaI is prepared from a fine powder instead of large crystals.

(2)

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(b) Explain why the rate of a reaction increases when the temperature of the system increases.

(3)

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HL

1. Hydrogen and nitrogen(II) oxide react according to the following equation.

$$2H_2(g) + 2NO(g) \rightleftharpoons N_2(g) + 2H_2O(g)$$

At time = *t* seconds, the rate of the reaction is: rate = $k[H_2][NO]^2$

(i) Explain precisely what the square brackets around nitrogen(II) oxide, [NO], represent in this context.

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(1)

(ii) Deduce the units for the rate constant *k*.

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(1)

2. Nitrogen monoxide reacts at 1280 °C with hydrogen to form nitrogen and water.
All reactants and products are in the gaseous phase.

(i) The kinetics of the reaction were studied at this temperature. The table shows the initial rate of reaction for different concentrations of each reactant.

experiment	**[NO(g)]/ mol dm^{-3} × 10^{-3}**	**[H_2(g)]/ mol dm^{-3} × 10^{-3}**	**Initial rate/ mol dm^{-3} s^{-1} × 10^{-5}**
1	5.00	2.00	1.25
2	10.00	2.00	5.00
3	10.00	4.00	10.00

Deduce the order of the reaction with respect to NO and H_2, and explain your reasoning.

(4)

(ii) Deduce the rate expression for the reaction.

(1)

(iii) Determine the value of the rate constant for the reaction from Experiment 3 and state its units.

(2)

3. The gas-phase decomposition of dinitrogen monoxide is considered to occur in two steps.

Step 1: $N_2O(g) \longrightarrow N_2(g) + O(g)$

Step 2: $N_2O(g) + O(g) \longrightarrow N_2(g) + O_2(g)$

The experimental rate expression for this reaction is rate = $k\,[N_2O]$.

(i) Identify the rate-determining step.

(1)

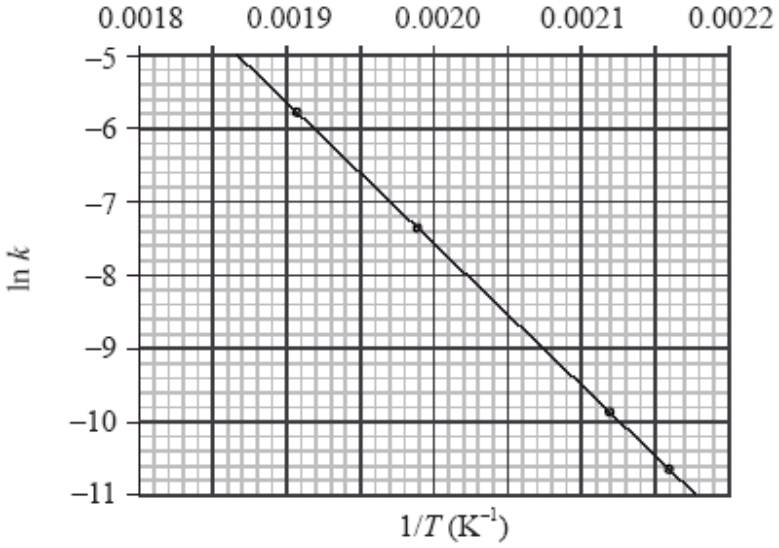
(ii) Identify the intermediate involved in the reaction.

(1)

4. The conversion of CH_3NC into CH_3CN is an exothermic reaction which can be represented as follows.

$CH_3{-}N{\equiv}C \longrightarrow$ transition state $\longrightarrow CH_3{-}C{\equiv}N$

This reaction was carried out at different temperatures and a value of the rate constant, *k,* was obtained for each temperature. A graph of ln *k* against 1/*T* is shown below.



(i) Define the term *activation energy*, E_a.

(1)

(ii) Describe qualitatively the relationship between the rate constant, *k*, and the temperature, *T*.

(1)

(4 cont.)

(iii) Construct the enthalpy level diagram and label the activation energy, E_a, the enthalpy change, ΔH, and the position of the transition state.

(3)

(iv) Calculate the activation energy, E_a, for the reaction, using Table 1 of the Data Booklet.

(4)

5. Consider the following reaction studied at 263 K.

$$2NO(g) + Cl_2(g) \rightleftharpoons 2NOCl(g)$$

It was found that the forward reaction is first order with respect to Cl_2 and second order with respect to NO. The reverse reaction is second order with respect to NOCl.

(i) State the rate expression for the forward reaction.

(1)

(ii) Predict the effect on the rate of the forward reaction and on the rate constant if the concentration of NO is halved.

(2)

(5 cont.)

(iii) 1.0 mol of Cl_2 and 1.0 mol of NO are mixed in a closed container at constant temperature. Sketch a graph to show how the concentration of NO and NOCl change with time until after equilibrium has been reached. Identify the point on the graph where equilibrium is established.

time

(4)

6. Consider the following reaction.

$$NO_2(g) + CO(g) \rightarrow NO(g) + CO_2(g)$$

Possible reaction mechanisms are:

Above 775 K: $NO_2 + CO \rightarrow NO + CO_2$ *slow*

Below 775 K: $2NO_2 \rightarrow NO + NO_3$ *slow*
$NO_3 + CO \rightarrow NO_2 + CO_2$ *fast*

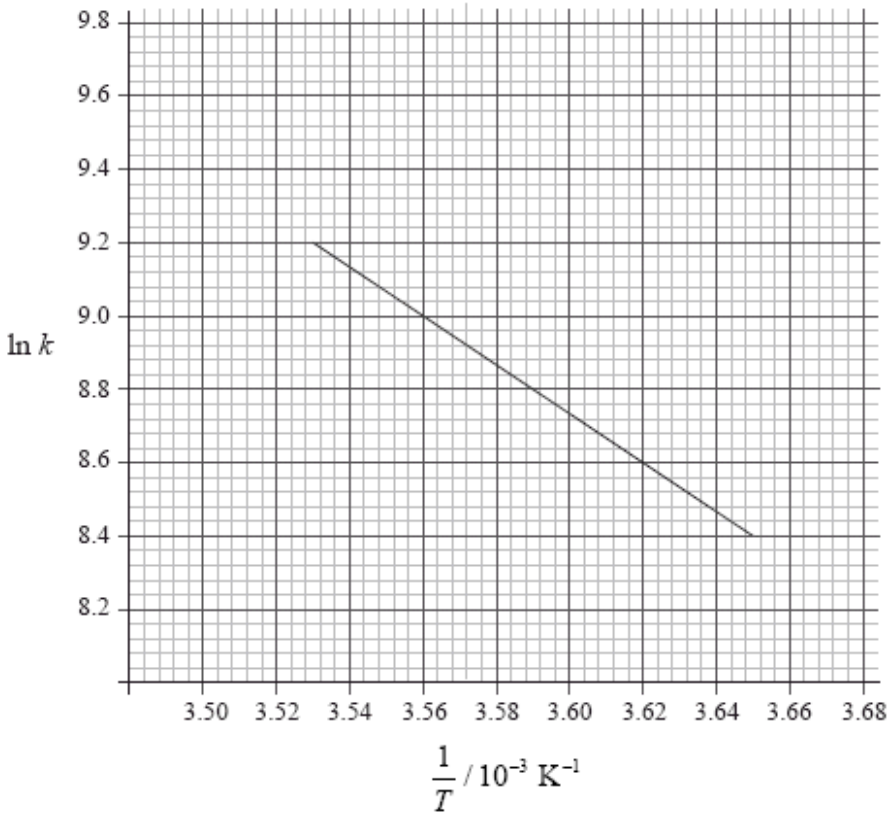
Based on the mechanisms, deduce the rate expressions above and below 775 K.

(2)

7. State **two** situations when the rate of a chemical reaction is equal to the rate constant.

(2)

8. Consider the following graph of ln k against $\frac{1}{T}$ for the first order decomposition of N_2O_4 into NO_2. Determine the activation energy in kJ mol^{-1} for this reaction.



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