Unit 4: Kinetics Practice Test
AP Chemistry

Name Key

1. A kinetics experiment is set up to collect the gas that is generated when a sample of chalk, consisting primarily of solid $CaCO_3$, is added to a solution of ethanoic acid, CH_3COOH. The rate of reaction between $CaCO_3$ and CH_3COOH is determined by measuring the volume of gas generated at 25°C and 1 atm as a function of time. Which of the following experimental conditions is most likely to increase the rate of gas production?
(A) Decreasing the volume of ethanoic acid solution used in the experiment
(B) Decreasing the concentration of the ethanoic acid solution used in the experiment
(C) Decreasing the temperature at which the experiment is performed
(D) Decreasing the particle size of the $CaCO_3$ by grinding it into a fine powder

2. Which of the following statements best explains why an increase in temperature of 10°C can substantially increase the rate of a chemical reaction?
(A) The activation energy (E_a) for the chemical reaction is lowered.
(B) The number of effective collisions between reactant particles is increased.
(C) The magnitude of ΔH for the chemical reaction is lowered.
(D) The fraction of reactant molecules that have kinetic energy greater than E_a is lowered.

$$5\,H_2O_2(aq) + 2\,MnO_4^-(aq) + 6\,H^+(aq) \longrightarrow 2\,Mn^{2+}(aq) + 8\,H_2O(l) + 5\,O_2(g)$$

3. At a certain point during the reaction represented by the equation above, the rate of appearance of $O_2(g)$ was 1.0×10^{-3} mol/(L•s). What was the rate of disappearance of MnO_4^- at the same time?
(A) 2.5×10^{-3} mol/(L•s)
(B) 4.0×10^{-3} mol/(L•s)
(C) 2.5×10^{-4} mol/(L•s)
(D) 4.0×10^{-4} mol/(L•s)

$$X + 2\,Y \longrightarrow Z + 3\,Q$$

4. For the reaction represented above, the initial rate of decrease in [X] was $2.8 \times 10^{-3}\ M\,s^{-1}$. What was the initial rate of decrease in [Y]?
(A) $1.4 \times 10^{-3}\ M\,s^{-1}$
(B) $2.8 \times 10^{-3}\ M\,s^{-1}$
(C) $5.6 \times 10^{-3}\ M\,s^{-1}$
(D) The initial rate of decrease in [Y] cannot be determined without additional information.

5. The rate law for the reaction of nitrogen dioxide and chlorine is found to be rate = $k\,[NO_2]^2[Cl_2]$. By what factor does the rate of the reaction change when the concentrations of both NO_2 and Cl_2 are doubled?
(A) 2 (B) 4 (C) 6 (D) 8

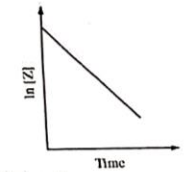
$$X_2 + Y_2 \rightarrow X_2Y_2$$
$$\text{rate} = k[X_2]$$

6. A reaction and its experimentally determined rate law are represented above. A chemist proposes two different possible mechanism for the reaction, which are given below.

Mechanism 1		Mechanism 2	
$X_2 \rightarrow 2\,X$	(*slow*)	$X_2 \rightarrow 2\,X$	(*slow*)
$X + Y_2 \rightarrow XY_2$	(*fast*)	$X + Y_2 \rightarrow XY + Y$	(*fast*)
$X + XY_2 \rightarrow X_2Y_2$	(*fast*)	$X + XY \rightarrow X_2Y$	(*fast*)
		$X_2Y + Y \rightarrow X_2Y_2$	(*fast*)

Based on the information above, which of the following is true?
(A) Only mechanism 1 is consistent with the rate law.
(B) Only mechanism 2 is consistent with the rate law.
(C) Both mechanism 1 and mechanism 2 are consistent with the rate law
(D) Neither mechanism 1 nor mechanism 2 is consistent with the rate law.

7. Consider the reaction represented by the equation:
$2\,X + 2\,Z \longrightarrow X_2Z_2$. During a reaction in which a large excess of reactant X was present, the concentration of reactant Z was monitored over time. A plot of the natural logarithm of the concentration of Z versus time is shown in the figure at right. The order of the reaction with respect to reactant Z is



(A) zero order (B) first order (C) second order (D) third order

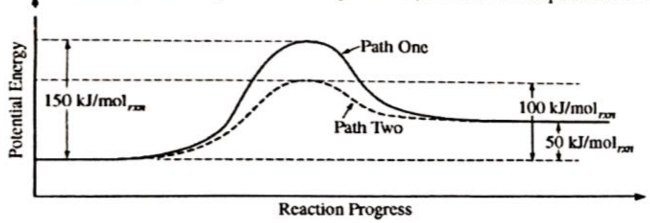
$$NO(g) + NO_3(g) \longrightarrow 2\,NO_2(g) \qquad \text{rate} = k[NO][NO_3]$$

8. The reaction represented above occurs in a single step that involves the collision between a particle of NO and a particle of NO_3. A scientist correctly calculates the rate of collisions between NO and NO_3 that have sufficient energy to overcome the activation energy. The observed reaction rate is only a small fraction of the calculated collision rate. Which of the following best explains the discrepancy?
(A) The energy of collisions between two reactant particles is frequently absorbed by collision with a third particle.
(B) The two reactant particles must collide with a particular orientation in order to react.
(C) The activation energy for a reaction is dependent on the concentrations of the reactant particles.
(D) The activation energy for a reaction is dependent on the temperature.

The following two questions relate to the information below:

$$XY_2 \rightarrow X + Y_2$$

The equation above represents the decomposition of a compound XY_2. The diagram below shows two reaction profiles (path one and path two) for the decomposition of XY_2.



9. Which of the following most likely accounts for the difference between reaction path one and reaction path two?
(A) A higher temperature in path one
(B) A higher temperature in path two
(C) ~~The presence of a catalyst in path one~~
(D) The presence of a catalyst in path two

10. Which of the following statements is true concerning reaction path one?
(A) The magnitude of the overall ΔE for the reaction is the same for both the forward and reverse directions in path one.
(B) The sign of the overall ΔE for the reaction is the same for both the forward and reverse directions in path one.
(C) The magnitude of E_a for the reaction is the same for both the forward and reverse directions in path one.
(D) The rate of the reaction is the same for both the forward and reverse directions in path one.

$$2\,NO(g) + O_2(g) \longrightarrow 2\,NO_2(g)$$

11. Consider the following mechanism for the reaction represented above.

Step 1: $2\,NO \rightleftarrows N_2O_2$ (fast reversible)

Step 2: $N_2O_2 + O_2 \longrightarrow 2\,NO_2$ (slow) $\rightarrow$ rate $= k[N_2O_2][O_2]$

$= k[NO]^2[O_2]$

Which of the following statements is true?
(A) Step 1 represents a unimolecular reaction.
(B) Increasing the concentration of NO will decrease the overall rate of the reaction.
(C) Raising the temperature will have no effect on the numerical value of the rate constant.
(D) The rate law that is consistent with the mechanism is $rate = k[NO]^2[O_2]$.

Step 1: $Cl(g) + O_3(g) \longrightarrow ClO(g) + O_2(g)$

Step 2: $ClO(g) + O(g) \longrightarrow Cl(g) + O_2(g)$

12. A proposed mechanism for destruction of ozone gas in the stratosphere is represented above.
Which of the following is evidence that the mechanism is occurring?
(A) The presence of $Cl(g)$ increases the rate of the overall reaction.
(B) The presence of $ClO(g)$ cannot be detected throughout the course of the reaction.
(C) The concentration of $O_2(g)$ steadily increases as the reaction proceeds.
(D) When the concentration of O_3 is doubled, the reaction rate is unchanged.

The following two questions relate to the information below:

$$2\,N_2O_5(g) \longrightarrow 4\,NO_2(g) + O_2(g)$$

13. A sample of N_2O_5 was placed in an evacuated container, and the reaction represented above occurred. The value of $P_{N_2O_5}$, the partial pressure of $N_2O_5(g)$, was measured during the reaction and recorded in the table below.

Time (min)	$P_{N_2O_5}$ (atm)	$\ln(P_{N_2O_5})$	$\frac{1}{P_{N_2O_5}}$ (atm^{-1})
0	150	5.0	0.0067
100	75	4.3	0.013
200	38	3.6	0.027
300	19	2.9	0.053

Which of the following correctly describes the reaction?
(A) The decomposition of N_2O_5 ~~is a zero-order reaction.~~
(B) The decomposition of N_2O_5 is a first-order reaction.
(C) The decomposition of N_2O_5 is a second-order reaction.
(D) The overall reaction order is 3.

14. Based on the information in the data table above, which of the following best represents both the ~~numerical value and~~ the units of the rate constant for this reaction?
(A) $k = 0.007\ min^{-1}$
(B) ~~$k = 0.7\ min^{-1}$~~
(C) $k = 0.007\ M^{-1}\ min^{-1}$
(D) $k = 0.7\ M^{-1}\ min^{-1}$

1. A sample of $C_2H_4(g)$ is placed in a previously evacuated, rigid 2.0 L container at 450 K. $C_2H_4(g)$ reacts readily with $HCl(g)$ to produce $C_2H_5Cl(g)$, as represented by the following equation.

$$C_2H_4(g) + HCl(g) \longrightarrow C_2H_5Cl(g) \qquad \Delta H° = -72.6 \text{ kJ/mol}$$

It is proposed that the formation of $C_2H_5Cl(g)$ proceeds via the following two-step mechanism.

Step 1: $C_2H_4 + HCl \longrightarrow C_2H_5^+ + Cl^-$ (rate-determining step)

Step 2: $C_2H_5^+ + Cl^- \longrightarrow C_2H_5Cl$ (fast step)

(a) Write the rate law for the reaction that is consistent with the reaction mechanism above.

$\boxed{\text{Rate} = k[C_2H_4][HCl]}$

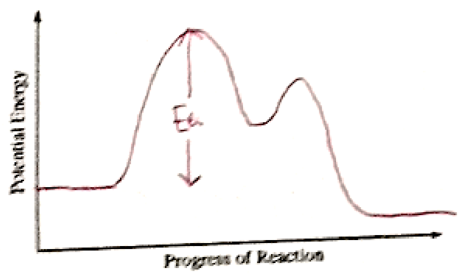
(b) Identify a species that behaves as an intermediate in the reaction mechanism above.

$C_2H_5^-$, Cl^-

(c) Using the axes provided at right, draw a curve that shows the energy changes that occur during the progress of the reaction.

Your curve should illustrate both the proposed two-step mechanism and the enthalpy change for the reaction.

On the diagram, clearly indicate the activation energy (E_a) for the rate-determining step in the reaction.



$$CH_3CH_2NH_2 \longrightarrow C_2H_4 + NH_3$$

2. An experiment is carried out to measure the rate of the reaction represented above, which is first-order. A 4.70 x 10^{-3} mol sample of $CH_3CH_2NH_2$ is placed in a previously evacuated 2.00 L container at 773 K. After 20.0 minutes, the concentration of the $CH_3CH_2NH_2$ is found to be 3.60 x 10^{-4} mol/L.

(a) Calculate the rate constant for the reaction at 773 K. Include units with your answer.

$$\ln(3.6\times10^{-4}) - \ln\left(\frac{4.70\times10^{-3}\text{ mol}}{2 \text{ L}}\right) = -k(20)$$

$\boxed{k = 0.0938 \text{ min}^{-1}}$

(b) Calculate the initial rate of the reaction at 773 K. The units of your answer should be $M\,\text{min}^{-1}$.

$$\text{rate} = k[CH_3CH_2NH_2]$$

$$= 0.0938 \times \frac{4.70\times10^{-3}}{2} = \boxed{2.20\times10^{-4}\ M/\text{min}}$$

(c) Calculate the half-life for the disappearance of ethylamine for the reaction at 773 K. The units of your answer should be in minutes.

$$t_{1/2} = \frac{0.693}{k} = \frac{0.693}{0.0938 \text{ min}^{-1}} = \boxed{7.39 \text{ min}}$$

(d) If $\frac{1}{[CH_3CH_2NH_2]}$ is plotted versus time for this reaction, would the plot result in a straight line? If yes, explain why you think the plot should be linear. If no, explain why you think the plot would be nonlinear and indicate what sort of plot would result in a straight line.

linear for 2nd order reactions

No.

Since the reaction is 1^{st} order, a plot of $\ln[CH_3CH_2NH_2]$ vs time will be linear

$2A + B \longrightarrow C + D$

3. The following results were obtained when the reaction represented above was studied at 25°C.

Experiment	Initial [A]	Initial [B]	Initial Rate of Formation of C (mol L^{-1} min^{-1})
1	0.40	0.40	0.0115
2	0.40	0.60	0.0173
3	1.2	1.2	0.104
4	1.5	?	0.0864

(a) Determine the order of the reaction with respect to A and to B. Justify your answer.

exp1+2 1st order for B

exp1+3 1st order for A

(b) Write the rate law for the reaction. rate= k[A][B]

(c) Calculate the value of the rate constant. Include units in your answer.

$0.115 = k(0.4)(0.4)$

$\boxed{k = 0.0719\ M^{-1}min^{-1}}$

(d) Determine the initial rate of disappearance of [A] in Experiment 3. Include units in your answer.

$0.104\,C \times \frac{2A}{1C} = \boxed{0.208\ M/min}$

(e) Determine the initial concentration of [B] in Experiment 4. Include units in your answer.

$0.0864 = 0.0719(1.5)(B)$

$\boxed{[B] = 0.80\,M}$

(f) The following represents the proposed reaction mechanism. Identify the rate-determining step in the mechanism. Justify your answer in terms of the stoichiometry of the rate-determining step and the rate law that you wrote in part (b).

Step 1: $A + B \longrightarrow C + M$

Step 2: $M + A \longrightarrow D$

Step 1. The rate law matches the stoichiometry of step 1

(g)

Experiment	Initial [A]	Initial [B]	Temperature	Initial Rate of Formation of C (mol L^{-1} min^{-1})
1	0.40	0.40	25°C	0.0015
5	0.40	0.40	50°C	?

A new experiment was performed using the same conditions as Experiment 1, except that the temperature of the reaction was carried out at 50°C instead of 25°C.

(i) Will the initial rate of formation of C under these conditions be higher, lower, or the same as 0.0115 mol L^{-1} min^{-1} ? Justify your answer with reference to collision theory.

Higher

At a higher temperature, reactant molecules will move faster and the frequency + force of collisions will increase.

(ii) Will the value of the rate constant *k* under these conditions be higher, lower, or the same as the answer obtained in part (c)? Justify your answer with reference to the rate law.

Increase

Since the rate law is rate=k[A][B] and if the rate increases but the concentration of reactants remain the same, then k must increase