Figure 1

Cl⁻ : $Cl^-$
H₃O⁺ : $H_3O^+$
Mg

Figure 2
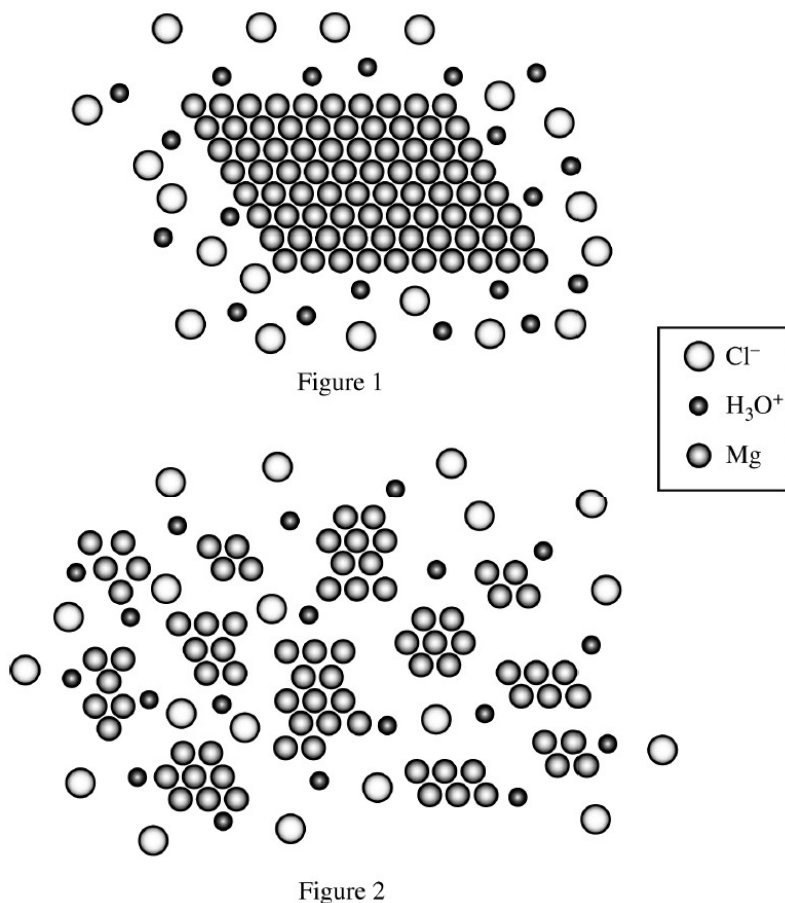
1.  Two samples of Mg(s) of equal mass were placed in equal amounts of HCl(aq) contained in two separate reaction vessels. Particle representations of the mixing of Mg(s) and HCl(aq) in the two reaction vessels are shown in Figure 1 and Figure 2 above. Water molecules are not included in the particle representations. Which of the reactions will initially proceed faster, and why?

    (A) The reaction in Figure 1, because the atoms of Mg are more concentrated than those in Figure 2

    (B) The reaction in Figure 1, because the Mg(s) in Figure 1 has a larger mass than the Mg(s) in Figure 2

    (C) The reaction in Figure 2, because more Mg atoms are exposed to HCl(aq) in Figure 2 than in Figure 1

    (D) The reaction in Figure 2, because the Mg(s) in Figure 2 has less surface area than the Mg(s) in Figure 1

$$Na_2CO_3(s) + 2\,HCl(aq) \rightarrow 2\,NaCl(aq) + H_2O(l) + CO_2(g)$$
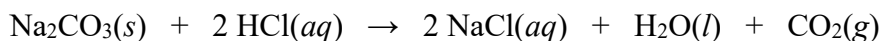
2. A student performs an investigation to study factors that affect the rate of the reaction represented by the equation shown above. Data from four different experiments are shown in the table below.

| Trial | Mass of $Na_2CO_3(s)$ (g) | Particle Size of $Na_2CO_3(s)$ | Volume of $HCl(aq)$ (mL) | Concentration of $HCl(aq)$ (M) | Time of Reaction (s) |
|-------|------|-------------|-------|------|--|
| 1 | 3.00 | large chunk | 100.0 | 1.00 | |
| 2 | 3.00 | fine powder | 100.0 | 2.00 | |
| 3 | 3.00 | large chunk | 100.0 | 2.00 | |
| 4 | 3.00 | fine powder | 100.0 | 1.00 | |

In each experiment, the student measures the time required for the reaction to go to completion. Based on the information in the data table, which trial should have the smallest value for time of reaction?

(A) Trial 1

(B) Trial 2

(C) Trial 3

(D) Trial 4

$$5\,H_2C_2O_4(aq) + 2\,MnO_4^-(aq) + 6\,H^+(aq) \rightarrow 2\,Mn^{2+}(aq) + 8\,H_2O(l) + 10\,CO_2(g)$$
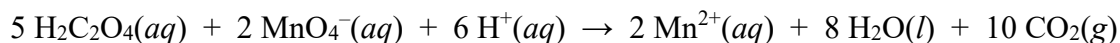
3. In a titration experiment, $H_2C_2O_4(aq)$ reacts with $MnO_4^-(aq)$ as represented by the equation above. At a certain time during the titration, the rate of disappearance of $H_2C_2O_4(aq)$ was $2.0 \times 10^{-3}$ mol/(L·s). What was the rate of disappearance of $MnO_4^-(aq)$ at the same time?

(A) $8.0 \times 10^{-4}$ mol/(L·s)

(B) $2.0 \times 10^{-3}$ mol/(L·s)

(C) $5.0 \times 10^{-3}$ mol/(L·s)

(D) $8.0 \times 10^{-3}$ mol/(L·s)

$$H_2(g) \ + \ I_2(g) \ \rightarrow \ 2 \ HI(g)$$
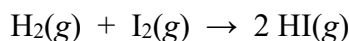
4. The rate law for the reaction represented by the equation above is $rate = k[H_2][I_2]$. Data from a kinetics experiment is shown in the table below.

| Trial | Initial [$H_2$] | Initial [$I_2$] | Initial Temperature |
|-------|-----------------|-----------------|---------------------|
| 1 | 1.0 $M$ | 1.0 $M$ | 500 K |
| 2 | 2.0 $M$ | 2.0 $M$ | 500 K |

Which of the following statements is a correct comparison of trial 2 and trial 1?

(A) In trial 2, both the initial reaction rate and the value of the rate constant, $k$, are the same as those of trial 1.

(B) In trial 2, both the initial reaction rate and the value of the rate constant, $k$, are greater than those of trial 1.

(C) In trial 2, the initial reaction rate is greater than that of trial 1, and the value of the rate constant, $k$, is the same as that of trial 1.

(D) In trial 2, the initial reaction rate is the same as that of trial 1, and the value of the rate constant, $k$, is greater than that of trial 1.

| Time (min) | 0 | 2.00 | 4.00 | 6.00 | 8.00 | 10.0 | 12.0 |
|------------|------|------|------|------|------|------|-------|
| [X] (mol/L) | 5.76 | 4.07 | 2.88 | 2.04 | 1.44 | 1.02 | 0.720 |

5. The decomposition of substance X is studied by monitoring the concentration of X over time. The data from the experiment is shown in the table above. Which of the following is the rate constant, $k$, of the decomposition reaction?

(A) 0.173 min$^{-1}$

(B) 0.347 min$^{-1}$

(C) 2.77 min$^{-1}$

(D) 4.00 min$^{-1}$

$$X(g) + 2\,Y(g) \rightarrow XY_2(g)$$
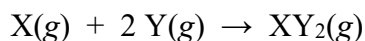
6. In order to determine the order of the reaction represented above, the initial rate of formation of $XY_2$ is measured using different initial values of [X] and [Y]. The results of the experiment are shown in the table below.

| Trial | [X] (M) | [Y] (M) | Initial Rate of Formation of $XY_2$ $(M\,s^{-1})$ |
|---|---|---|---|
| 1 | 0.50 | 0.50 | $8.0 \times 10^{-3}$ |
| 2 | 1.00 | 0.50 | $3.2 \times 10^{-2}$ |
| 3 | 1.00 | 1.00 | $6.4 \times 10^{-2}$ |

Which of the following identifies the reactant that would be consumed more rapidly in Trial 2 and provides the correct justification?

(A) X, because it has a higher molar concentration.

(B) X, because the reaction is second order with respect to X.

(C) Y, because the reaction is second order with respect to Y.

(D) Y, because the rate of disappearance will be double that of X.

$$2\,XY(g) + 2\,A_2(g) \rightarrow X_2(g) + 2\,A_2Y(g)$$

7. The equation for the reaction between $XY(g)$ and $A_2(g)$ is shown above. The initial rate of formation of $X_2$ at 400 K is measured in different trials with various initial concentrations of the reactants, as shown in the following table.

| Experiment | Initial [XY] (M) | Initial [A₂] (M) | Initial Rate of Formation of $X_2(g)$ $(M\,s^{-1})$ |
|---|---|---|---|
| 1 | 0.10 | 0.10 | $2.5 \times 10^{-4}$ |
| 2 | 0.20 | 0.10 | $5.0 \times 10^{-4}$ |
| 3 | 0.20 | 0.40 | $8.0 \times 10^{-3}$ |

What is the experimental rate law for the reaction?

(A) rate = $k[XY][A_2]$

(B) rate = $k[XY]^2[A_2]$

(C) rate = $k[XY][A_2]^2$

(D) rate = $k[XY]^2[A_2]^2$
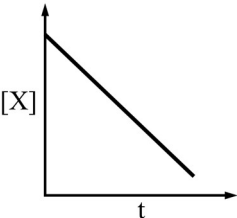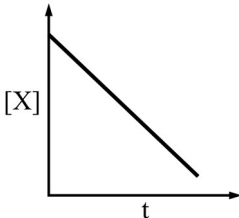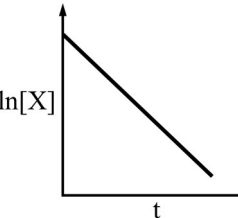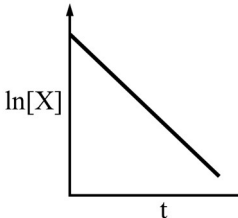
| Time (s) | [XY] (mol/L) | ln [XY] | $\dfrac{1}{[XY]}$ (L/mol) |
|---|---|---|---|
| 0 | $2.0 \times 10^{-1}$ | −1.61 | 5.00 |
| 100 | $1.6 \times 10^{-1}$ | −1.83 | 6.25 |
| 200 | $1.2 \times 10^{-1}$ | −2.12 | 8.33 |
| 300 | $8.0 \times 10^{-2}$ | −2.53 | 12.5 |

8. An experiment is performed to study the decomposition of the compound $XY(g)$, which takes place in the presence of a solid catalyst. The concentration of $XY(g)$ is monitored over time as it decomposes at 900 K. The data from the experiment are shown in the table above.

Which of the following rate laws is consistent with the data?

(A) Rate = $k$

(B) Rate = $k\,[XY]$

(C) Rate = $k\,[XY]^2$

(D) Rate = $k\,\dfrac{1}{[XY]}$

9. The data from a kinetics experiment can be used to determine the rate law. Which of the following choices has correctly identified the rate law associated with the graph of experimental data for the decomposition of substance X?

| (A) | (B) | (C) | (D) |
|---|---|---|---|
|  |  |  |  |
| rate = $k[X]$ | rate = $k[X]^2$ | rate = $k[X]$ | rate = $k[X]^2$ |

10. A sample of substance Q was placed in an evacuated container, and a decomposition reaction occurred. The concentration of Q was measured during the reaction and recorded in the table below.

| Time (s) | [Q] (mol/L) | ln[Q] | $\dfrac{1}{[Q]}$ (L/mol) |
|---|---|---|---|
| 0 | 7.5 | 2.0 | 0.13 |
| 25 | 5.5 | 1.7 | 0.18 |
| 50. | 4.1 | 1.4 | 0.24 |
| 75 | 3.0 | 1.1 | 0.33 |

Based on the experimental data, which of the following represents the order of the reaction and the value of the rate constant, $k$?

| | Reaction Order | Rate Constant, $k$ $(s^{-1})$ |
|---|---|---|
| (A) | first order | 0.012 |
| (B) | second order | 0.012 |
| (C) | first order | 0.30 |
| (D) | second order | 0.30 |