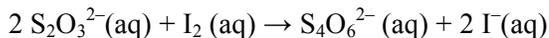# Calculating Rates with Stoichiometry

1. If NOCl(g) is decomposing at a rate of 1.1×10^{-8} mol/L/min in the following reaction:

$2 \text{ NOCl(g)} \rightarrow 2 \text{ NO(g)} + Cl_2(g)$

a) What is the rate of formation of NO(g)?
b) What is the rate of formation of Cl_2(g)?

2. Thiosufate ion is oxidized by iodine according to the following reaction:

$2 S_2O_3^{2-}(aq) + I_2 (aq) \rightarrow S_4O_6^{2-} (aq) + 2 I^-(aq)$

If, in a certain experiment, 0.0080 mol of $S_2O_3^{2-}$ is consumed in 1.0 L of solution each second, What is the rate of consumption of I_2? At what rates are $S_4O_6^{2-}$ and I^- produced in this solution?

3. If the decomposition of N_2O_5 gas occurs at a rate of 0.20 $molL^{-1}s^{-1}$, what would be the rate of formation of NO_2 gas and O_2 gas if the equation for the reaction is

$2 N_2O_5(g) \rightarrow 4 NO_2(g) + O_2(g)$

4. If ammonia gas, NH_3, reacts at a rate of 0.090 mol/Ls according to the reaction

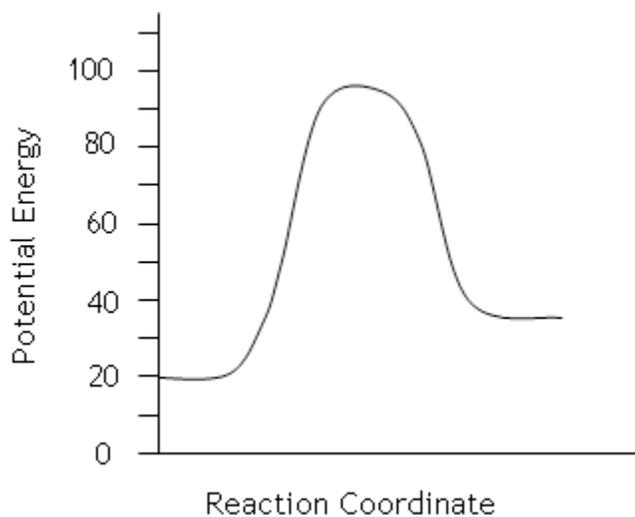$4 NH_3(g) + 5 O_2(g) \rightarrow 4 NO(g) + 6 H_2O(g)$
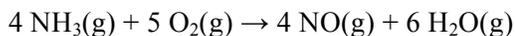
   a) at what rate does oxygen gas react under the same conditions?
      b) what is the rate of formation of water?
      c) what is the rate of production of nitrogen monoxide?

1

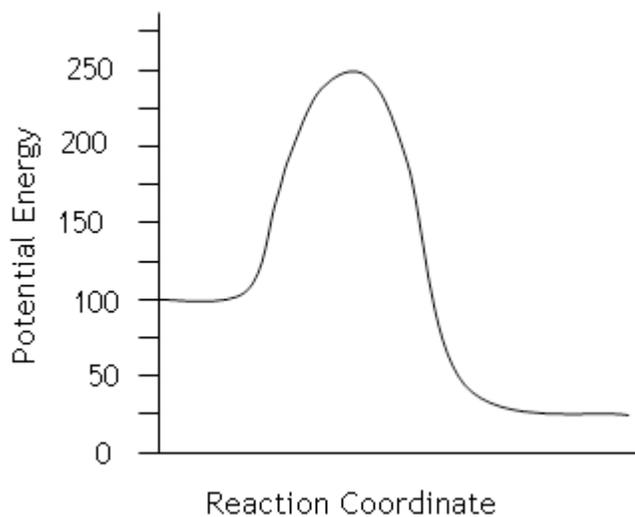# Reaction Coordinate / PE Diagram Exercises

Answer the following questions:

1. Given the following reaction coordinate diagram

    a) What is the activation energy of the reaction shown by the diagram?
    b) What is the enthalpy change for this reaction?
    c) Is this reaction endothermic or exothermic?

2. Given the following reaction coordinate diagram

    a) What is the activation energy of the reaction in the diagram to the left?
    b) What is the enthalpy change for this reaction?
    c) Is this reaction endothermic or exothermic?
    d) What would be the activation energy of the **reverse** reaction?

2

3. Given the following reaction coordinate diagram

Potential Energy (y-axis: 0, 10, 20, 30, 40, 50)
Reaction Coordinate (x-axis)
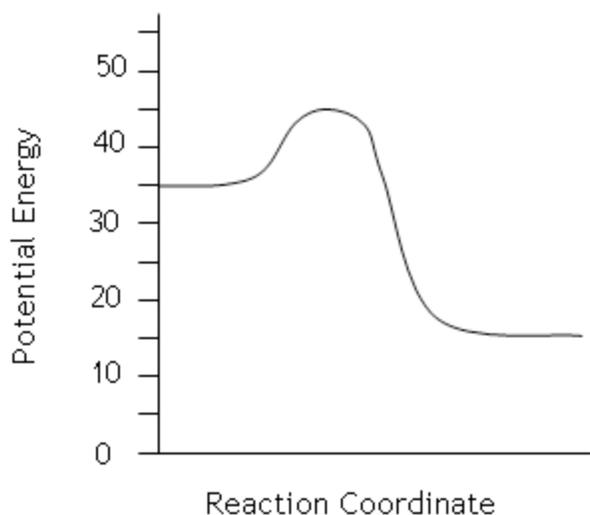
   a) What is the activation energy of the diagram to the left?
   b) What is the enthalpy change for this reaction?
   c) Is this reaction endothermic or exothermic?
   d) What would be the activation energy of the reverse reaction?

4. What is the activated complex or transition state and how is it related to reaction rates? Label the position of the activated complex in each of the diagrams above.

5. Does every collision between reactant particles produce a reaction? Explain.

6. Explain why the enthalpy change for an exothermic reaction is negative, even though the container gets warmer.
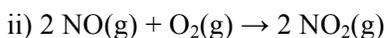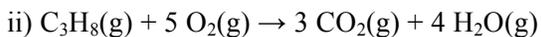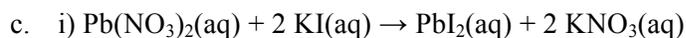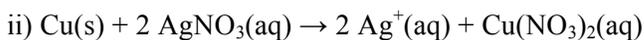
3

Factors affecting Rate

1) In general, what effect does an increase in the concentration of the reactants have on the rate of the reaction? (explain using the collision theory)

2) How do changes each of the following factors affect the rate of a chemical reaction? Use diagrams to clarify your explanations.

        a) temperature
        b) particle size
        c) pressure

3. Which equation of the following pairs of equations would occur the fastest at under the same conditions. Explain your answers.

  a. i) $Zn^{2+}(aq) + S^{2-}(aq) \rightarrow ZnS(s)$

    ii) $Zn(s) + S(s) \rightarrow ZnS(s)$

  b. i) $2\ H_2O_2(aq) \rightarrow 2\ H_2O(l) + O_2(l)$

    ii) $Cu(s) + 2\ AgNO_3(aq) \rightarrow 2\ Ag^+(aq) + Cu(NO_3)_2(aq)$

  c. i) $Pb(NO_3)_2(aq) + 2\ KI(aq) \rightarrow PbI_2(aq) + 2\ KNO_3(aq)$

    ii) $C_3H_8(g) + 5\ O_2(g) \rightarrow 3\ CO_2(g) + 4\ H_2O(g)$

  d. i) $2\ Fe(s) + 3\ O_2(g) \rightarrow 2\ Fe_2O_3(s)$

    ii) $2\ NO(g) + O_2(g) \rightarrow 2\ NO_2(g)$
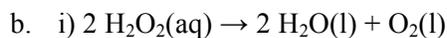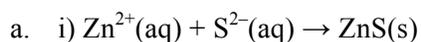
Reaction Mechanism

1. Given the following reaction mechanism:

$$H_2O_2 + I^- \rightarrow H_2O + IO^-$$
$$H_2O_2 + IO^- \rightarrow H_2O + O_2 + I^-$$
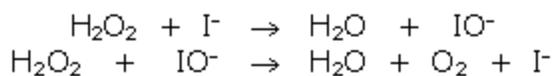
    a) Write the balanced net reaction.

    b) Identify the reaction intermediate(s).

    c) Identify the catalyst(s).

2. Examine the following reaction mechanism:

$$P + Q \rightarrow I_1 + R \qquad slow$$

$$I_1 + P \rightarrow I_2 + W \qquad moderate$$

$$I_2 + S \rightarrow T \qquad fast$$
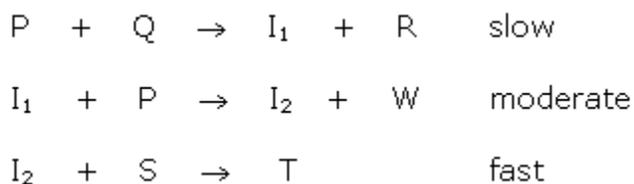
    a) Write out the net reaction.

    b) Identify the overall rate of the net reaction.

    c) Increasing [P] , increases the rate of the net reaction.

       Increasing [Q] , increases the rate of the net reaction.
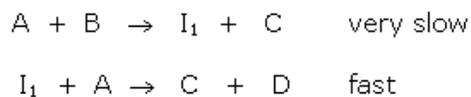
       Increasing [S] , has no effect of the rate.

       Explain why this is possible.

3. Write the net reaction for the mechanism.

$$A + B \rightarrow I_1 + C \qquad very\ slow$$

$$I_1 + A \rightarrow C + D \qquad fast$$

4. A proposed mechanism for the preparation of the poisonous liquid nitrobenzene ($C_6H_5NO_2$) is

$$C_6H_6 + NO_2^+ \rightarrow C_6H_6NO_2^+ \qquad slow$$
$$H_2SO_4 \rightarrow H^+ + HSO_4^- \qquad v.\ fast$$
$$C_6H_6NO_2^+ + HSO_4^- \rightarrow C_6H_5NO_2 + H_2SO_4 \qquad fast$$
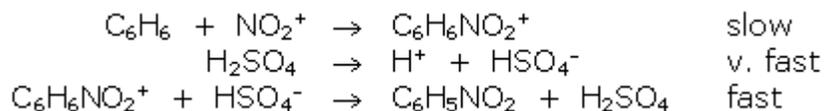
    a) What is the RDS? Why?

       b) What is the net reaction?

       c) Without H_2SO_4 this is a very slow reaction. Explain.

5

Answer the following questions. Be sure to show your work.

1. A first-order reaction initially proceeds at a rate of 0.500 mol/Ls.

   What will be the rate when half the starting material remains? When one-fourth of the starting material remains?

2. Assume the $N_2O(g)$ and $O_2(g)$ react according to the rate law

   Rate = $k[N_2O] [O_2]$

   How does the rate change if:
   a) the concentration of O_2 is doubled?
   b) the volume of the enclosing vessel is reduced by half?

3) Assume that $NO(g)$ and $H_2(g)$ react according to the rate law

   Rate = $k[NO]^2 [H_2]$

   How does the rate change if:
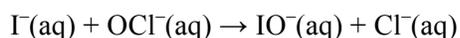   a) the concentration of H_2 is tripled?
   b) the concentration of NO is doubled?
   c) the volume of the enclosing vessel is reduced by half?

4) For the reaction: $A + 2 B \rightarrow 2 C$

[A] mol/L	[B] mol/L	Rate (mol/Lmin)
1.0	1.0	0.50
3.0	1.0	1.5
3.0	2.0	3.0

Find the rate law and calculate the value of the specific rate constant.

5) The reaction:

   $I^-(aq) + OCl^-(aq) \rightarrow IO^-(aq) + Cl^-(aq)$

   Was studied and the following data were obtained:

Trial	$[I^-]$ mol/L	$[OCl^-]$ mol/L	Initial Rate (mol/L•s)
1.0	0.12	0.18	7.91×10^{-2}
2.0	0.060	0.18	3.95×10^{-2}
3.0	0.24	0.090	7.91×10^{-2}
4.0	0.060	0.090	1.98×10^{-2}

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    a.   What is the rate law?
    b.   What is the value of the rate constant?

6) For the reaction: $A + B + C \rightarrow D$

Trial	[A] mol/L	[B] mol/L	[C] mol/L	Initial Rate (mol/L·min)
1.0	1.0	2.0	0.50	0.35
2.0	2.0	2.0	0.50	1.40
3.0	2.0	1.0	0.50	1.40
4.0	1.0	2.0	1.0	0.70

Find the rate law and calculate the value of the specific rate constant.

7) For the reaction: $X + Y + Z \rightarrow S$

Trial	[X] mol/L	[Y] mol/L	[Z] mol/L	Initial Rate (mol/Lmin)
1.0	0.45	0.20	0.55	0.66
2.0	1.35	0.20	0.55	5.94
3.0	0.45	0.60	0.55	1.98
4.0	0.45	0.60	1.10	1.98

Find the rate law and calculate the value of the specific rate constant.

8) The reaction $CH_3COCH_3 + I_2 \rightarrow CH_3COCH_3 + HI$ is run in the presence of an excess of acid. The following data were obtained:

Trial	Initial [I_2] (mol/L)	Initial [CH_3COCH_3] (mol/L)	Initial Rate (mol/Ls)
1.0	0.100	0.100	1.16×10^{-7}
2.0	0.100	0.0500	5.79×10^{-8}
3.0	0.500	0.0500	5.77×10^{-8}

    a.   What is the rate law?
    b.   What is the value of the rate constant?
    c.   What is the rate if the concentration of CH_3COCH_3 is 0.0700 mol/L and the concentration of I_2 is 0.0850 mol/L
    d.   What is the concentration of I_2 if the concentration of CH_3COCH_3 is 0.0250 mol/L and the rate is 3.10×10^8 mol/Ls?

9) For the reaction A + 2 B → C + D, the following data was collected

Trial	Initial [A] (mol/L)	Initial [B] (mol/L)	Initial Rate ($molL^{-1}s^{-1}$)
1.0	0.0100	0.0240	1.45×10^{-4}
2.0	0.0100	0.0120	7.25×10^{-5}
3.0	0.0200	0.0480	5.80×10^{-4}

What is the rate law?

10) For the reaction 3 A + B → 2 C + D, the following data was collected

Trial	Initial [A] (mol/L)	Initial [B] (mol/L)	Initial Rate ($molL^{-1}h^{-1}$)
1.0	0.0012	0.042	3.6×10^{-2}
2.0	0.00060	0.084	3.6×10^{-2}
3.0	0.00060	0.021	9.0×10^{-3}

What is the rate law?

11) For the elementary reaction $H_2 + I_2 \rightarrow 2$ HI
   a) Write the rate law.
   b) Find k if HI is produced at a rate of 1.0×10^{-4} mol/Lmin when $[H_2] = 0.025$ mol/L and $[I_2] = 0.050$ mol/L.
   c) What is the rate of production of HI if the concentration of both reactants is 0.10 mol/L and the temperature is the same as in (b)?
   d) How would the rate be affected if $[H_2]$ is doubled AND the $[I_2]$ is halved?

12) For the one step reaction A(g) + 2 B(g) ? C(g)
   a) What is the rate law?
   b) How does the rate change if
      i) [A] is doubled?
      ii) [B] is tripled?
      iii) The volume of the container is doubled?

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