

Recitation Worksheet Four

Name:

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Textbook:

Chemistry & Chemical Reactivity

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Instructions:

- This recitation worksheet covers Ch. 14.5-14.7, 18.1-18.3
- Please enter your first and last name as it appears on the eLC roster (do not use a nickname that is not reflected in eLC).
- Your UGA myID is a combination of letters and numbers (example: Dr. Abdelrahman's MyID is ema88805@uga.edu). **Do not use your 81x number.**
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- The following criteria **must** be met to be eligible for full credit:
 - You must make sure the pages are in the correct order and have the same layout as the original worksheet when submitting to Gradescope regardless of your submission type.
 - Answers must be written in the corresponding answer boxes.
 - You must show your work when appropriate.
- This worksheet is due no later than **12:00 PM (noon) on the Saturday, September 21st.**
- A periodic table and formula sheet are attached to the end of this worksheet. Please keep these attached to your worksheet in the correct order when submitting to Gradescope.

1. For a reversible reaction $A + B \rightleftharpoons C + D$, the enthalpy change of the forward reaction is -41 kJ/mol and the activation energy for the forward reaction is 64 kJ/mol. What is the activation energy in kJ/mol for the reverse reaction?

kJ/mol

2. Which of the following statements about catalysts is **FALSE**:

A. Catalysts do not appear in the balanced equation.
B. Catalysts reduce the activation energy for a reaction.
C. Biological catalysts are called enzymes.
D. Catalysts do not alter the mechanism of the reaction and never appear in the rate law.
E. Since catalysts are recycled, even a small amount of catalyst can accelerate a reaction.

3. The rate law for the reaction $2 XY + Z_2 \rightarrow 2 XYZ$ can be written as $\text{rate} = k [XY] [Z_2]$. Which choice could possibly represent the mechanism for this reaction?

A. Step 1: $Z_2 \rightarrow Z + Z$ (slow)
Step 2: $XY + Z \rightarrow XYZ$ (fast)
Step 3: $XY + Z \rightarrow XYZ$ (fast)

B. Step 1: $XY + Z_2 \rightarrow XYZ + Z$ (slow)
Step 2: $XY + Z \rightarrow XYZ$ (fast)

C. Step 1: $XY + Z_2 \rightarrow XYZ_2$ (slow)
Step 2: $XYZ_2 \rightarrow XYZ + Z$ (fast)

D. Step 1: $2 XY \rightleftharpoons X_2Y_2$ (fast)
Step 2: $X_2Y_2 + Z_2 \rightarrow 2 XYZ$ (slow)

E. Not enough information is provided to predict the mechanism of this reaction.

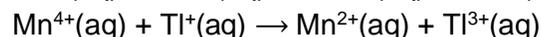
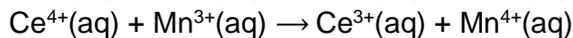
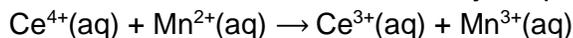
4. For the first-order reaction $\text{N}_2\text{O}_5(\text{g}) \rightarrow 2 \text{NO}_2(\text{g}) + \frac{1}{2} \text{O}_2(\text{g})$. If $t_{1/2} = 22.5 \text{ h}$ at $20.0 \text{ }^\circ\text{C}$ and 1.50 h at $40.0 \text{ }^\circ\text{C}$, calculate the activation energy in kJ/mol of this reaction.

kJ/mol

5. The *uncatalyzed* reaction between $\text{Ce}^{4+}(\text{aq})$ and $\text{Ti}^+(\text{aq})$ is very slow and occurs in a single elementary step given by



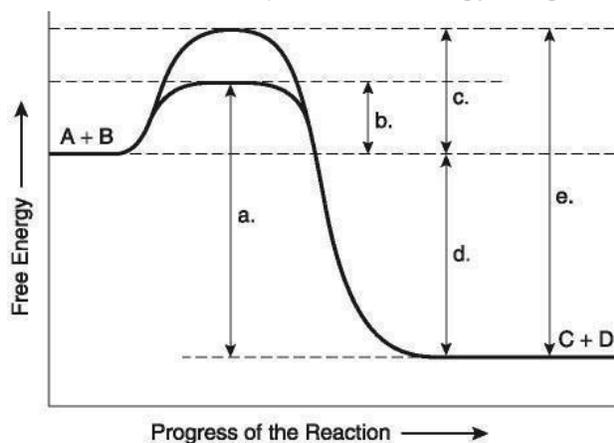
Mn^{2+} can be utilized as a catalyst to increase the rate of this reaction. The *catalyzed* reaction is a three-step mechanism provided below. The overall rate law for the *catalyzed* process is $\text{rate} = k [\text{Ce}^{4+}][\text{Mn}^{2+}]$.



Which statements regarding the *uncatalyzed* and *catalyzed* reactions between $\text{Ce}^{4+}(\text{aq})$ and $\text{Ti}^+(\text{aq})$ are **TRUE**? Select all that apply.

- A. The rate law of the of the *uncatalyzed* reaction is $\text{rate} = k[\text{Ce}^{4+}][\text{Ti}^+]$.
- B. The *uncatalyzed* single elementary step reaction is slow because the probability of a three-particle collision is low.
- C. From the mechanism of the *catalyzed* process, Mn^{3+} is an intermediate.
- D. From the mechanism of the *catalyzed* process, the second step is the slow rate determining step.

6. For reaction $A + B \rightarrow C + D$, see the potential energy diagram below to answer the questions:



A. Which letter shows the change in energy for the overall reaction?

B. Which letter shows the activation energy without a catalyst?

C. Which letter shows the activation energy with a catalyst?

7. Determine the activation energy in kJ/mol for the reaction using the information in the table:

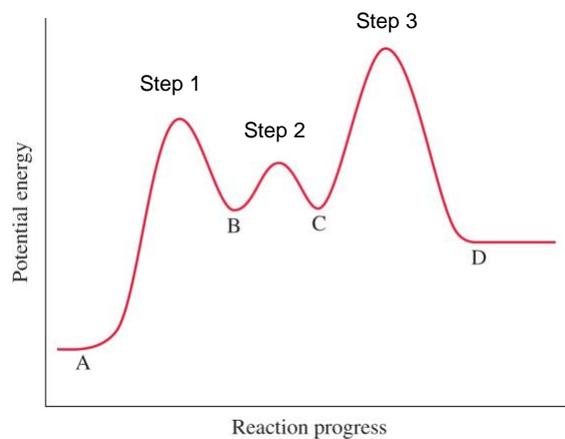
Temperature ($^{\circ}\text{C}$)	Rate Constant ($\text{M}^{-1}\text{s}^{-1}$)
330	0.98
550	1.60

kJ/mol

8. Using the potential energy diagram to the right, answer the following questions:

A. What are the intermediates in the reaction? Insert letters without spaces in the answer box, example **ABCD**.

B. How many transition states are there? Insert a number, example 1, 2, 3, etc.



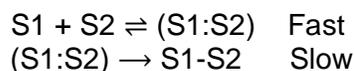
C. Which step has the largest rate constant? Insert a number, example 1, 2, 3, etc.

D. Which step has the smallest rate constant? Insert a number, example 1, 2, 3, etc.

E. Is step 1 of the reaction exothermic or endothermic?

F. Is the overall reaction exothermic or endothermic?

9. A mechanism has been proposed for the formation of a double helix DNA is given by:



If S1 and S2 represent strand 1 and strand 2 respectively, which of the statements are **TRUE**? Select all that apply. Insert letters without spaces in the answer box, example **ABCD**.

- A. (S1:S2) represent the reaction intermediate in the mechanism.
- B. The rate for the formation of the DNA strand can be written as rate = $k[S1][S2]$.
- C. The rate for the formation of the DNA strand can be written as rate = $k[(S1+S2)]$.
- D. The second step in the mechanism is the rate determining step.
- E. The activation energy of the fast first step is higher and therefore it has a lower rate constant compared to the second slow step.

10. Which of the following statements regarding the rates of chemical reactions is **TRUE**?

- A. Reaction rates can be calculated only from collision frequency
- B. The addition of a catalyst to a reaction can increase the rate of the reaction only if the temperature of the reaction increases
- C. Reaction rates increase with temperature because a fraction of reactant molecules have higher kinetic energies compared to activation energy
- D. $E_a < \Delta H < 0$ conditions can exist for a chemical reaction

11. In which of the following reactions will result in an increase in entropy? Select all that apply. Insert letters without spaces in the answer box, example **ABCD**.

- A. $\text{CaO(s)} + \text{H}_2\text{O(l)} \rightarrow \text{Ca(OH)}_2\text{(s)}$
- B. $\text{Si(s)} + 2 \text{Cl}_2\text{(g)} \rightarrow \text{SiCl}_4\text{(g)}$
- C. $\text{CuSO}_4 \cdot 3 \text{H}_2\text{O(s)} + 2 \text{H}_2\text{O(g)} \rightarrow \text{CuSO}_4 \cdot 5 \text{H}_2\text{O(s)}$
- D. $\text{C}_6\text{H}_6\text{(l)} + \frac{15}{2} \text{O}_2\text{(g)} \rightarrow 6 \text{CO}_2\text{(g)} + 3 \text{H}_2\text{O(g)}$
- E. $\text{H}_2\text{S(g)} + \text{O}_2\text{(g)} \rightarrow \text{H}_2\text{O(g)} + \text{SO}_2\text{(g)}$ (not balanced)
- F. $\text{CCl}_4\text{(l)} \rightarrow \text{CCl}_4\text{(g)}$
- G. $2 \text{HgO(s)} \rightarrow 2 \text{Hg(l)} + \text{O}_2\text{(g)}$

12. Calculate the entropy change in the surroundings that occur when 35.0 g of acetone (molar mass = 58.08 g/mol) condenses at its normal boiling point (56.1 °C). ΔH_{vap} of acetone is 29.1 kJ/mol.

J/K

13. Determine the boiling point for iron in °C from the given information: $\Delta H_{vap} = 349.6$ kJ/mol and $\Delta S_{vap} = 111.55$ J/(mol·K).

°C

14. Which of the following has the substance with the greater entropy listed first? Select all that apply. Insert letters without spaces in the answer box, example **ABCD**.

A. 1 mol Br₂(l) at 1 atm and 8 °C and 1 mol Br₂(s) at 1 atm and -8 °C
B. 10.0 mol of Na(s) at 1 atm and 5 °C and 100.0 g of Na(s) at 1 atm and 5 °C
C. MgS at 1 atm and 25 °C and KBr at 1 atm and 25 °C
D. 0.284 mol O₂ at 15.0 bar and 22.3 °C and 0.312 mol SO₂ at 0.110 bar and 32.5 °C

15. Which of the following has the highest standard molar entropy?

A. N₂F₄(g)
B. N₂H₄(g)
C. NO(g)
D. NH₄CO₂NH₂(s)
E. NH₄OH(aq)

16. Which of the following statements is **true** regarding the **second law** of thermodynamics? Select all that apply. Insert letters without spaces in the answer box, example **ABCD**.

- A. $\Delta S_{\text{sys}} + \Delta S_{\text{surr}} > 0$ for any spontaneous process
- B. $\Delta S_{\text{sys}} = -\Delta S_{\text{surr}}$ for a reversible process
- C. The entropy of a perfect crystal at absolute zero (0 K) is zero
- D. The energy of the universe is conserved in any process
- E. All the above of the statements are true

17. Which of the following processes are spontaneous or non-spontaneous? Insert (S) for spontaneous and (NS) for non-spontaneous.

A. Splitting of water into hydrogen gas and oxygen gas

B. Dissolving table salt (NaCl) in water

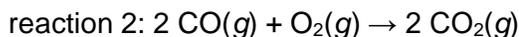
C. Ripening of a banana

D. Vaporization of $\text{Br}_2(\text{l})$ at $60.0\text{ }^\circ\text{C}$ (boiling point of $\text{Br}_2(\text{l}) = 58.8\text{ }^\circ\text{C}$)

E. Combustion of natural gas (natural gas is a mixture of methane and ethane)

F. Driving a car up the hill

18. Without doing any calculations, determine whether the standard entropy change, ΔS° is positive or negative for each of the following reactions.



- A. ΔS° is positive for both reactions.
- B. ΔS° is positive for reaction 1 but negative for reaction 2.
- C. ΔS° is positive for reaction 2 but negative for reaction 1.
- D. ΔS° is negative for both reactions.

Extra Practice Questions: these questions will not be graded

1. A factor that decreases the activation energy for a reaction:

- I) decreases the rate constant
- II) increases the rate constant
- III) has no effect on the rate constant
- IV) increases the product yield
- V) might be a catalyst

- A. I and IV
- B. II and IV
- C. I, IV, and V
- D. IV and III
- E. II and V

2. A catalyst:

- I) lowers activation energy
- II) provides an alternate reaction pathway
- III) is consumed in the reaction and therefore does not appear in the chemical equation of each mechanism
- IV) speeds a reaction
- V) is heterogeneous if it is in a different phase than the reactants

- A. I, III, and IV
- B. I, IV, and V
- C. II, III, and IV
- D. II and IV
- E. I, II, IV, and V

3. Activation energy is:

- A. energy at the bottom of the reaction curve
- B. the heat energy in joules required to break the bonds in one reactant
- C. an energy that a catalyst brings to the system to activate one of the reactants
- D. the kinetic energy of solution stirring that brings the reaction to start
- E. minimum kinetic energy that molecules must bring to their collisions for a chemical reaction to occur

4. The entropy of gaseous _____ is the largest at 25 °C and 1 atm.

- A. C₂H₂
- B. H₂
- C. C₂H₆
- D. CH₄
- E. C₂H₄

5. For a process to be at equilibrium, it is necessary that

- A. $\Delta S_{\text{sys}} = \Delta S_{\text{surr}}$.
- B. $\Delta S_{\text{sys}} = -\Delta S_{\text{surr}}$.
- C. $\Delta S_{\text{sys}} = 0$.
- D. $\Delta S_{\text{sys}} = 0$ and $\Delta S_{\text{surr}} = 0$.

6. Place the following in order of **decreasing** standard molar entropy.

$\text{H}_2\text{O}(l)$ $\text{H}_2\text{O}(g)$ $\text{H}_2\text{O}(s)$

- A. $\text{H}_2\text{O}(g) > \text{H}_2\text{O}(l) > \text{H}_2\text{O}(s)$
- B. $\text{H}_2\text{O}(s) > \text{H}_2\text{O}(l) > \text{H}_2\text{O}(g)$
- C. $\text{H}_2\text{O}(g) > \text{H}_2\text{O}(s) > \text{H}_2\text{O}(l)$
- D. $\text{H}_2\text{O}(l) > \text{H}_2\text{O}(s) > \text{H}_2\text{O}(g)$
- E. $\text{H}_2\text{O}(s) > \text{H}_2\text{O}(g) > \text{H}_2\text{O}(l)$

Formula Sheet

Length

1 kilometer = 0.62137 mile
1 inch = 2.54 centimeters (exactly)
1 Ångstrom = 1×10^{-10} meter

Energy

1 joule = $1 \text{ kg}\cdot\text{m}^2/\text{s}^2$
1 calorie = 4.184 joules
1 Calorie = 1 kilocalorie = 1000 calories
1 L·atm = 101.325 joules

Pressure

1 pascal = $1 \text{ N}/\text{m}^2 = 1 \text{ kg}/\text{m}\cdot\text{s}^2$
1 atmosphere = 101.325 kilopascals = 760 mm Hg = 760 torr = 14.70 lb/in²
1 bar = 1×10^5 Pa (exactly)

Temperature

0 K = -273.15°C
K = $^\circ\text{C} + 273.15$
 $^\circ\text{C} = (5/9)(^\circ\text{F} - 32)$

Mass

1 kg = 2.205 lbs

Volume

1 mL = $1 \text{ cm}^3 = 1 \text{ cc}$

Constants

$c = 2.998 \times 10^8 \text{ m}/\text{sec}$
 $h = 6.626 \times 10^{-34} \text{ J}\cdot\text{sec}^{-1}$
 $R = 0.08206 \text{ L}\cdot\text{atm}/\text{mol}\cdot\text{K} = 8.314 \text{ J}/\text{mol}\cdot\text{K}$
Specific heat of water = 4.184 J/g·K
Mass of an electron: $9.109 \times 10^{-31} \text{ kg}$
Mass of a proton: $1.673 \times 10^{-27} \text{ kg}$
 $RH = 2.18 \times 10^{-18} \text{ J}$
Specific heat of water = 4.184 J/g·K
STP = 273.15 K and 1 atm
Avogadro's number: 6.022×10^{23}

Equations

d (density) = m/V

$P_1V_1 = P_2V_2$

$V_1/T_1 = V_2/T_2$

$P_1V_1/n_1T_1 = P_2V_2/n_2T_2$

$PV = nRT$

$(P + a(n^2/V^2))\cdot(V - nb) = nRT$

molar mass (M) = mRT/PV

density (d) = MP/RT

$x_A = n_A/n_{\text{tot}} = P_A/P_{\text{tot}} = V_A/V_{\text{tot}}$

$P_{\text{tot}} = P_A + P_B + \dots$

$n_{\text{tot}} = n_A + n_B + \dots$

$$\mu_{rms} = \sqrt{\frac{3RT}{M}}$$

$$\frac{\text{Rate of effusion A}}{\text{Rate of effusion B}} = \sqrt{\frac{MW_B}{MW_A}}$$

$$Q = C \times \Delta T = c_{\text{specific}} \times m \times \Delta T$$

$$Q = n \times \Delta H \text{ (kJ/mol)} = m \times \Delta H \text{ (kJ/g)}$$

$$w = -P\Delta V$$

$$\Delta E = q + w$$

$$\Delta H^\circ = \sum n\Delta H_f^\circ(\text{products}) - \sum n\Delta H_f^\circ(\text{reactants})$$

$$\Delta H^\circ = \sum n\Delta H^\circ(\text{bonds broken}) - \sum n\Delta H^\circ(\text{bonds formed})$$

$$E = hv$$

$$c = \lambda\nu$$

$$\lambda = h/mv$$

$$\Delta E = -2.18 \times 10^{-18} J \left(\frac{1}{n_f^2} - \frac{1}{n_i^2} \right)$$

$$\ln\left(\frac{P_2}{P_1}\right) = \frac{\Delta H_{vap}}{R} \left(\frac{1}{T_1} - \frac{1}{T_2} \right)$$

$$C_g = kP_g$$

$$P_{\text{solution}} = P_{\text{solvent}} X_{\text{solvent}}$$

$$P_{\text{solution}} = \sum P_j = \sum P_j X_j$$

$$\Delta T_b = K_b m_i$$

$$\Delta T_f = K_f m_i$$

$$\pi = MRT_i$$

Thermodynamic and Electrochemistry

$$S = k_b \times \ln(W)$$

$$k_b = 1.381 \times 10^{-23} \text{ J/K}$$

$$\Delta S = q_{\text{rev}}/T$$

$$\Delta S_{\text{surr}} = q_{\text{surr}}/T = -q_{\text{rev}}/T$$

$$\Delta S_{\text{univ}} = \Delta S_{\text{sys}} + \Delta S_{\text{surr}}$$

$$\Delta S^\circ_{\text{rxn}} = \sum \nu S^\circ_{\text{products}} - \sum \nu S^\circ_{\text{reactants}}$$

$$\Delta H^\circ_{\text{rxn}} = \sum \nu H^\circ_{\text{products}} - \sum \nu H^\circ_{\text{reactants}}$$

$$\Delta G^\circ_{\text{rxn}} = \sum \nu G^\circ_{\text{products}} - \sum \nu G^\circ_{\text{reactants}}$$

$$\Delta G = \Delta H - T\Delta S$$

$$\Delta G = \Delta G^\circ + RT \cdot \ln Q$$

$$R = 8.314 \text{ J/mol}\cdot\text{K}$$

$$\Delta G^\circ = -RT \cdot \ln K$$

$$\Delta G = -nFE_{\text{cell}}$$

$$F = 96485 \text{ J/(V}\cdot\text{mol e}^-)$$

$$E^\circ_{\text{cell}} = RT/nF \ln K$$

$$E^\circ_{\text{cell}} = (0.0257/n) \ln K = (0.0592/n) \log K$$

$$E_{\text{cell}} = E^\circ_{\text{cell}} - (RT/nF) \ln Q$$

$$E_{\text{cell}} = E^\circ_{\text{cell}} - (0.0257/n) \ln Q$$

$$\text{Electrolysis: } Q \text{ (total charge)} = I \times t = n \times F$$

Integrated Rate Laws & half-life

$$\ln \frac{[A]}{[A]_0} = -kt$$

$$\frac{1}{[A]} = kt + \frac{1}{[A]_0}$$

$$[A] = -kt + [A]_0$$

$$t_{1/2} = \frac{[A]_0}{2k}$$

$$t_{1/2} = \frac{\ln 2}{k} = \frac{0.693}{k}$$

$$t_{1/2} = \frac{1}{k[A]_0}$$

$$\ln \frac{k_2}{k_1} = -\frac{E_a}{R} \left(\frac{1}{T_2} - \frac{1}{T_1} \right)$$

Equilibrium and Acid / Base

$$K_p = K_c \times (RT)^{\Delta n}$$

$$\text{pH} = -\log[\text{H}_3\text{O}^+]$$

$$K_w = 1.0 \times 10^{-14} \text{ at } 25^\circ\text{C}$$

$$K_w = [\text{H}_3\text{O}^+] \times [\text{OH}^-]$$

$$K_w = K_a \times K_b$$

$$\text{p}K_a = -\log[K_a]$$

$$\text{Buffer: pH} = \text{p}K_a + \log \frac{[\text{A}^-]}{[\text{HA}]}$$

$$\ln \frac{K_2}{K_1} = \frac{\Delta H_{rxn}^\circ}{R} \left(\frac{1}{T_1} - \frac{1}{T_2} \right)$$

Periodic Table of the Elements

1 H 1.01	2 He 4.00																	18																
3 Li 6.94	4 Be 9.01	5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18																	1										
11 Na 22.99	12 Mg 24.31	13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.06	17 Cl 35.45	18 Ar 39.95																	1										
19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.87	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.38	31 Ga 69.72	32 Ge 72.63	33 As 74.92	34 Se 78.97	35 Br 79.90	36 Kr 83.80																	1
37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.95	43 Tc [97]	44 Ru 101.07	45 Rh 102.91	46 Pd 106.42	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.76	52 Te 127.60	53 I 126.90	54 Xe 131.29																	1
55 Cs 132.91	56 Ba 137.33	57 La 138.91	58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm [145]	62 Sm 150.36	63 Eu 151.96	64 Gd 157.25	65 Tb 158.93	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.05	71 Lu 174.97																	1	
87 Fr [223]	88 Ra [226]	89 Ac [227]	90 Th 232.04	91 Pa 231.04	92 U 238.03	93 Np [237]	94 Pu [244]	95 Am [243]	96 Cm [247]	97 Bk [247]	98 Cf [251]	99 Es [252]	100 Fm [257]	101 Md [258]	102 No [259]	103 Lr [262]																	1	
104 Rf [267]	105 Db [268]	106 Sg [269]	107 Bh [270]	108 Hs [269]	109 Mt [277]	110 Ds [281]	111 Rg [282]	112 Cn [285]	113 Nh [286]	114 Fl [290]	115 Mc [290]	116 Lv [293]	117 Ts [294]	118 Og [294]																	1			
172 Hf 178.49	173 Ta 180.95	174 W 183.84	175 Re 186.21	176 Os 190.23	177 Ir 192.22	178 Pt 195.08	179 Au 196.97	180 Hg 200.59	181 Tl 204.38	182 Pb 207.2	183 Bi 208.98	184 Po [209]	185 At [210]	186 Rn [222]																	1			