

## Recitation Worksheet 6: Exam 2 Review

Name

MyID

### Instructions:

1. This recitation worksheet is for the exam 2 review.
2. You **do not need** to submit it to GradeScope.
3. The answer key has been posted with this worksheet to eLC.
4. The **recitation session in the exam week (Feb 27 – Mar 3) is still mandatory**. The attendance will be recorded.

### Chapter 17 – Spontaneity, Entropy, and Free Energy (Thermodynamics)

1. Which of the following processes have a  $\Delta S > 0$ ?

- 
- A.  $\text{CH}_3\text{OH}(\text{l}) \rightarrow \text{CH}_3\text{OH}(\text{g})$
  - B.  $2\text{H}_2(\text{g}) + \text{O}_2(\text{g}) \rightarrow 2\text{H}_2\text{O}(\text{g})$
  - C.  $\text{BaF}_2(\text{s}) \rightarrow \text{Ba}^{2+}(\text{aq}) + 2\text{F}^{-}(\text{aq})$
  - D.  $2\text{NaHCO}_3(\text{s}) \rightarrow \text{Na}_2\text{CO}_3(\text{s}) + \text{H}_2\text{O}(\text{g}) + \text{CO}_2(\text{g})$
  - E.  $\text{Mg}(\text{s}) + \text{Cl}_2(\text{g}) \rightarrow \text{MgCl}_2(\text{s})$

2. Which of the following pairs has the member with the greater molar entropy listed first? Select all that apply. All systems are at 25 °C.

- 
- A.  $\text{NO}(\text{g})$ ,  $\text{N}_2\text{O}_4(\text{g})$
  - B.  $\text{Ar}(\text{g})$ ,  $\text{Ne}(\text{g})$
  - C.  $\text{H}_2\text{S}(\text{g})$ ,  $\text{H}_2\text{S}(\text{aq})$
  - D.  $\text{Li}(\text{s})$ ,  $\text{Pb}(\text{s})$
  - E.  $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_3(\text{l})$ ,  $\text{CH}_2=\text{CHCH}=\text{CHCH}_3(\text{l})$

3. Which of the following pairs has the process/member with the lower molar entropy listed first? Select all apply.

- 
- A. 0.01 mole  $\text{H}_2$  liquid at -253 °C and 1 atm and 0.01 mole  $\text{H}_2$  gas at 25 °C and 1 atm
  - B.  $\text{MgCl}_2(\text{s}) \rightarrow \text{Mg}^{2+}(\text{aq}) + 2\text{Cl}^{-}(\text{aq})$  at 25 °C and 1 atm and  $\text{Mg}_3(\text{PO}_4)_2(\text{s}) \rightarrow 3\text{Mg}^{2+}(\text{aq}) + 2\text{PO}_4^{3-}(\text{aq})$
  - C.  $\text{CH}_3\text{CH}_2\text{OCH}_2\text{CH}_3(\text{l})$  at 25 °C and 1 atm and  $\text{CH}_3\text{OCH}_3(\text{l})$  at 25 °C and 1 atm
  - D.  $\text{MgO}(\text{s})$  at 25 °C and 1 atm and  $\text{NaCl}(\text{s})$  at 25 °C and 1 atm

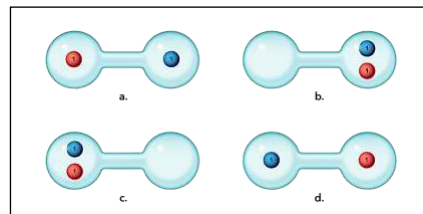
4. A sample of water is heated at a constant pressure of one atmosphere. Initially, the sample is ice at 260 K, and at the end the sample consists of steam at 400 K. In which of the following 5K temperature intervals would there be the greatest increase in the entropy of the sample?

- 
- A. From 260 K to 265 K
  - B. From 275 K to 280 K
  - C. From 360 K to 365 K
  - D. From 370 K to 375 K

### Recitation Worksheet 6: Exam 2 Review

5. Imagine two different gases, for simplicity represented as red and blue spheres, in separate containers. Imagine starting with one red gas atom and one blue gas atom in separate containers. Once the containers are connected, the gases mix between the two containers in 4 possible ways as shown in the accompanying image. If one additional blue atom is added to the mixture, how many different combinations are possible?

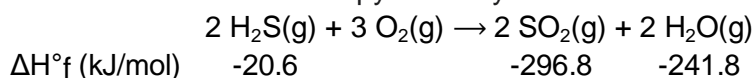
- A. 4  
B. 6  
C. 8  
D. 12  
E. 16



6. Which of the following statements are false? Select all apply

- A. The change in entropy in a system depends on the initial and final states of the system and the path taken from one state to the other.  
B. The entropy of the universe is continuously increasing  
C. Any irreversible process results in an overall increase in entropy.  
D. When a system is at equilibrium, the reaction is spontaneous in forward direction  
E. Entropy increases with the number of microstates of the system.

7. Sulfur dioxide,  $\text{SO}_2$ , is a colorless gas or liquid with a strong, choking odor. The combustion of  $\text{H}_2\text{S}$  produces  $\text{SO}_2$  releasing energy to the environment. The entropy of the system is  $-153.2 \text{ J/K}$  at  $25^\circ\text{C}$ .



- A. Calculate the  $\Delta S_{\text{univ}}$  at  $25^\circ\text{C}$  using the given information. Assume the temperature and pressure is constant.

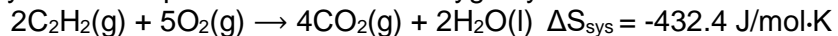
J/K

- B. Is this reaction spontaneous or non-spontaneous?

- I. Spontaneous  
II. Non-spontaneous

### Recitation Worksheet 6: Exam 2 Review

8. The combustion of acetylene in the presence of excess oxygen yields carbon dioxide and water:



Calculate the molar entropy change when 0.256g  $\text{CO}_2$  produced.

J/mol·K

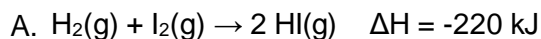
9. Assume that substance X has the enthalpy of vaporization of 5.2 kJ/mol at its normal boiling point (456 °C). If 2 moles of X condense by releasing heat to the surroundings at 456 °C, what is the entropy change in the surroundings?

J/K

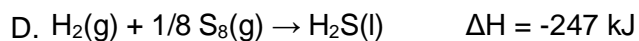
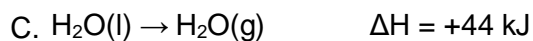
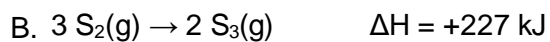
10. Which of the following processes have a positive entropy change?

- A. Condensation of a liquid  
B. Increasing the volume of 1.0 mol of an ideal gas at constant temperature  
C. Dissolving sugar in water  
D. Heating 1.0 mol of an ideal gas at constant volume

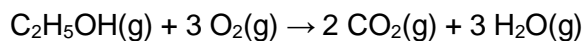
11. Predict whether the reactions will tend to be spontaneous at either high or low temperatures, at all temperatures, or at no temperature



### Recitation Worksheet 6: Exam 2 Review



12. Using values for the standard enthalpies of formation ( $\Delta H_f^\circ$ ) and standard molar entropy ( $\Delta S^\circ$ ) shown, calculate the thermodynamic values for the complete combustion of ethanol:



Compound	$\Delta H_f^\circ$ (kJ/mol)	$\Delta S^\circ$ (J/mol K)
$\text{C}_2\text{H}_5\text{OH}(\text{g})$	-234	283
$\text{CO}_2(\text{g})$	-394	214
$\text{H}_2\text{O}(\text{g})$	-242	189
$\text{O}_2(\text{g})$	0	205

- A. The standard enthalpy change ( $\Delta H^\circ$ )

kJ/mol

- B. The standard entropy change ( $\Delta S^\circ$ )

J/mol·K

## Recitation Worksheet 6: Exam 2 Review

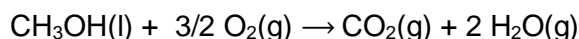
C. Calculate  $\Delta G^\circ$  at 298 K

 kJ/mol

D. Is this reaction spontaneous or non-spontaneous at 298K under standard conditions?

- 
- I. Spontaneous  
 II. Non-spontaneous

13. Methanol ( $\text{CH}_3\text{OH}$ ) is used a rocket fuel. Using only the signs of  $\Delta H^\circ$  and  $\Delta S^\circ$ , predict the signs and temperature dependence for the combustion of methanol



A.  $\Delta S^\circ$   (Insert > 0 or < 0)

$\Delta H^\circ$   (Insert > 0 or < 0)

B. Is the sign of  $\Delta G^\circ$  for this reaction temperature dependent?

- 
- i. The sign of  $\Delta G^\circ$  for this reaction is temperature dependent because  $\Delta S^\circ > 0$  and  $\Delta H^\circ < 0$   
 ii. The sign of  $\Delta G^\circ$  for this reaction is not temperature dependent because  $\Delta S^\circ > 0$  and  $\Delta H^\circ < 0$   
 iii. The sign of  $\Delta G^\circ$  for this reaction is temperature dependent because  $\Delta S^\circ < 0$  and  $\Delta H^\circ > 0$   
 iv. The sign of  $\Delta G^\circ$  for this reaction is not temperature dependent because  $\Delta S^\circ < 0$  and  $\Delta H^\circ > 0$

14. A reaction with a low enthalpy of reaction value is not spontaneous at low temperature but becomes spontaneous at high temperature. What are the signs for  $\Delta H^\circ$  and  $\Delta S^\circ$ , respectively?

- 
- A. +, -  
 B. -, -  
 C. -, +  
 D. +, +  
 E. Insufficient data is provided to answer this question

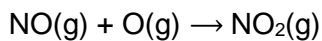
15. Given the following data, determine the molar free energy of combustion of propane gas ( $\text{C}_3\text{H}_8$ )

$\Delta G$ ( $\text{C}_3\text{H}_8$ , g)	-23.5 kJ/mol
$\Delta G$ ( $\text{CO}_2$ , g)	-394.4 kJ/mol
$\Delta G$ ( $\text{H}_2\text{O}$ , g)	-105.6 kJ/mol

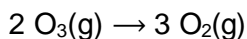
 kJ/mol

### Recitation Worksheet 6: Exam 2 Review

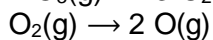
16. Calculate  $\Delta G^\circ_{\text{rxn}}$  using the following information.



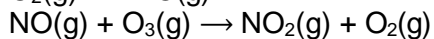
$$\Delta G^\circ_{\text{rxn}} = ?$$



$$\Delta G^\circ_{\text{rxn}} = +489.6 \text{ kJ}$$



$$\Delta G^\circ_{\text{rxn}} = +463.4 \text{ kJ}$$



$$\Delta G^\circ_{\text{rxn}} = -199.5 \text{ kJ}$$

kJ/mol

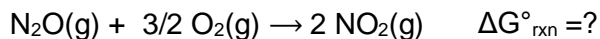
17. Indicate which of the following has the highest entropy at 298 K.

- A. 0.5 g of HCN
- B. 1 mol of HCN
- C. 2 kg of HCN
- D. 2 mol of HCN
- E. All of the above have the same entropy at 298 K

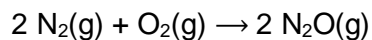
18. The dissolution of ammonium nitrate in water is a spontaneous endothermic process. It is spontaneous because the system undergoes \_\_\_\_\_.

- A. A decrease in enthalpy
- B. An increase in entropy
- C. An increase in enthalpy
- D. A decrease in entropy
- E. An increase in free energy

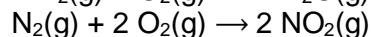
19. Find  $\Delta G^\circ_{\text{rxn}}$  for the reaction below



Using the following information



$$\Delta G^\circ_{\text{rxn}} = +208.4 \text{ kJ/mol}$$

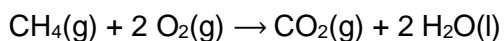


$$\Delta G^\circ_{\text{rxn}} = +102.6 \text{ kJ/mol}$$

kJ/mol

### Recitation Worksheet 6: Exam 2 Review

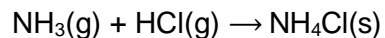
20. What is the standard entropy change when **10.0 g of methane** reacts with **10.0 g of oxygen**?



Substance	$S^\circ$ (J/mol · K)
CH <sub>4</sub> (g)	186.2
O <sub>2</sub> (g)	205.0
H <sub>2</sub> O (l)	70.0
CO <sub>2</sub> (g)	213.6

J/K

21. From the data given in the following table, determine  $\Delta_r S^\circ$  for the reaction below. All data below are at 298K

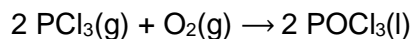


Compound	$\Delta_f H^\circ$ , kJ/mol	$\Delta_f G^\circ$ , kJ/mol
NH <sub>3</sub> (g)	-46.11	-16.48
HCl (g)	-92.31	-95.30
NH <sub>4</sub> Cl (s)	-314.4	-202.9

J/mol·K

## Recitation Worksheet 6: Exam 2 Review

22. At 298 K, for the reaction



$\Delta_r H^\circ = -620.2 \text{ kJ/mol}$  and the standard molar entropies, in  $\text{J/mol}\cdot\text{K}$  are  $\text{PCl}_3(\text{g}) = 311.8$ ,  $\text{O}_2(\text{g}) = 205.1$ , and  $\text{POCl}_3(\text{l}) = 222.4$ .

A. Determine  $\Delta_r G^\circ$  at 298 K in  $\text{kJ/mol}$

$\text{kJ/mol}$

B. Is this reaction spontaneous in the forward or the reverse direction when the reactants and products are in their standard states?

- 
- i. The reaction is spontaneous in the forward direction because  $\Delta_r G^\circ$  has a positive value
  - ii. The reaction is spontaneous in the forward direction because  $\Delta_r G^\circ$  has a negative value
  - iii. The reaction is spontaneous in the reverse direction because  $\Delta_r G^\circ$  has a negative value
  - iv. The reaction is spontaneous in the reverse direction because  $\Delta_r G^\circ$  has a positive value
  - v. The direction of spontaneity cannot be determined

## Chapter 11 – Solutions

23. 15.2 g of methanol ( $\text{CH}_3\text{OH}$ ) is added to 19.2 L of ethanol. What is the molality of the methanol in the ethanol? (Note: assume the density of the ethanol is 0.987 g/ml)

m

24. A sample of mineral water contains  $5.24 \times 10^{-2} \text{ g}$  of NaCl in 2.88 L. If the density of the water is 1.00 g/ml, how many ppm of NaCl is this equal to?

ppm



**Recitation Worksheet 6: Exam 2 Review**

25. A solution of glucose ( $\text{C}_6\text{H}_{12}\text{O}_6$ ) is made by adding 4.88 g of glucose with  $\text{H}_2\text{O}$  to yield a total volume of 533 ml. What is the resulting molarity of the glucose in this solution?

M

26. What is the freezing point and boiling point of an aqueous solution of  $\text{LiCl}$  that contains 2.58 g of  $\text{LiCl}$  and 10.0 ml of water (assume density of  $\text{H}_2\text{O}$  is 1 g/ml)?  $K_f(\text{H}_2\text{O}) = 1.86\text{ }^\circ\text{C}/\text{m}$  and  $K_b(\text{H}_2\text{O}) = 0.512\text{ }^\circ\text{C}/\text{m}$ .

Freezing point

$^\circ\text{C}$

Boiling point

$^\circ\text{C}$

27. A 555 g sample of an aqueous solution contains 92.1 g of glucose. The vapor pressure of pure water at  $20.0\text{ }^\circ\text{C}$  is 17.5 mm Hg. What is the vapor pressure of the water in the glucose solution at  $20.0\text{ }^\circ\text{C}$ ?

mmHg

**Recitation Worksheet 6: Exam 2 Review**

28. A sports drink contains 1.22 g of NaCl and 23.5 g Glucose ( $C_6H_{12}O_6$ ) in 250 ml of the drink. What are the mole fractions of the NaCl and glucose in the sports drink? (Note: assume that the density of the sports drink is identical to pure water).

A. Mole fraction of NaCl

B. Mole fraction of Glucose

29. An aqueous solution of NaCl is 4.43% by mass. 15.7ml of this solution is added to 185 ml of  $H_2O$ . What is the mass % of NaCl in this new solution? Assume the density of the solutions is 1.00 g/mL.

 %

30. A 778 g sample of aqueous solution contains 133.0 g of RbBr. The vapor pressure of pure water at 20.0 °C is 17.5 mm Hg. What is the vapor pressure of the water in the RbBr solution at 20.0 °C?

mmHg

### Recitation Worksheet 6: Exam 2 Review

31. An aqueous solution of an unknown solute is made by adding 43.8 g of the solute to 325 g of water. This solution lowers the freezing point of the water by 0.935 °C. What is the molecular mass of the unknown solute?  $K_f(\text{H}_2\text{O}) = 1.86\text{ °C/m}$ .

g/mol

32. A sample of drinking water is found to contain  $5.83 \times 10^{-11}$  moles of mercury in a 75 ml sample. How many parts per billion of mercury is this? (Assume density of the solution is equal to pure water).

ppb

33. A sample of homemade whiskey from a cheap backyard still has a mole fraction of ethanol of 0.35. What would be the mole fraction of the ethanol and water **in the vapor** of this sample at 40 °C? (At 40 °C the vapor pressure of  $\text{H}_2\text{O}$  is 55 mm Hg and ethanol: 135 mm Hg).

A.  $X_{\text{ETOH}}$

B.  $X_{\text{H}_2\text{O}}$

### Recitation Worksheet 6: Exam 2 Review

34. The concentration of ethanol ( $\text{C}_2\text{H}_6\text{O}$ ) in some wines is as high as 13% by mass. At what temperature will this 3.2 m ethanol solution freeze?  $K_f(\text{H}_2\text{O}) = 1.86^\circ\text{C}/\text{m}$ .

$^\circ\text{C}$

35. An experiment was performed to determine the molar mass of an unknown solid. A solution of 2.016 g of the unknown solid dissolved in 50.00 g of the nonpolar solvent benzene was prepared, and the freezing point of the resulting solution was determined to be  $4.35^\circ\text{C}$ . What is the molar mass of the unknown solid? The freezing point of pure benzene is  $5.50^\circ\text{C}$  and  $K_f(\text{benzene}) = 5.12^\circ\text{C}/\text{m}$ .

g/mol

36. The osmotic pressure of a solution of 20.00 g NaOH dissolved in a total volume of 500.0 mL was compared to the osmotic pressure of a solution of 14.61 g of NaCl dissolved in a total volume of 250.0 mL. Is the osmotic pressure of the NaOH solution higher, lower, or the same as the osmotic pressure of the NaCl solution?

- A. Higher  
B. Lower  
C. The same

37. Consider the following pairs of liquids. Which pairs are **miscible**?

1. Benzene,  $\text{C}_6\text{H}_6$ , and hexane,  $\text{C}_6\text{H}_{14}$
2. Water and methanol,  $\text{CH}_3\text{OH}$
3. Water and hexane

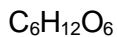
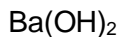
- A. 1, 2 only  
B. 2 only  
C. 1 only  
D. 1, 2, 3  
E. 2, 3 only

### Recitation Worksheet 6: Exam 2 Review

38. The vapor pressure of a solution containing a nonvolatile solute is directly proportional to the

- 
- A. Molality of the solvent.
  - B. Osmotic pressure of the solute.
  - C. Molarity of the solvent.
  - D. Mole fraction of solvent.
  - E. Mole fraction of solute.

39. What are the ideal Van't Hoff factors for these compounds?



40. Which of the following concentration measures will change in value as the temperature of a solution changes?

- 
- A. Mass percent
  - B. Mole fraction
  - C. Molality
  - D. Molarity
  - E. All of these

41. Rank the following compounds according to increasing solubility in water.

- 
- I.  $\text{CH}_3\text{--CH}_2\text{--CH}_2\text{--CH}_3$
  - II.  $\text{CH}_3\text{--CH}_2\text{--O--CH}_2\text{--CH}_3$
  - III.  $\text{CH}_3\text{--CH}_2\text{--CH}_2\text{--CH}_2\text{--OH}$

42. Which of the following favors the solubility of an ionic solid in a liquid solvent?

- 
- A. A large magnitude of the solvation energy of the ions
  - B. A small magnitude of the lattice energy of the solute
  - C. A large polarity of the solvent
  - D. All of the above
  - E. None of the above

43. What partial pressure of oxygen gas is required in order for 0.00316 g of the gas to dissolve in 16.8 mL of pure water? The Henry's law constant for oxygen gas is  $1.3 \times 10^{-3} \text{ M} \cdot \text{atm}^{-1}$ .

 atm

### Recitation Worksheet 6: Exam 2 Review

44. The molar mass of a solid as determined by freezing point depression is 10% higher than the true molar mass. Which of the following experimental errors could not account for this discrepancy?

- 
- A. Not all the solid was dissolved.
  - B. More than the recorded amount of solvent was pipetted into the solution.
  - C. The solid dissociated slightly into two particles when it dissolved.
  - D. Some solid was left on the weighing paper.
  - E. Before the solution was prepared, the container was rinsed with solvent and not dried.

45. Consider pure water separated from an aqueous sugar solution by a semipermeable membrane, which allows water to pass freely but not sugar. After some time has passed, the concentration of sugar solution:

- 
- A. Will have increased
  - B. Will have decreased
  - C. Will not have changed
  - D. Might have increased or decreased depending on other factors
  - E. Will be the same on both sides of the membrane

46. Which of the following solutions would have the highest osmotic pressure?

- 
- A. 0.15 M NaCl, sodium chloride
  - B. 0.15 M CaCl<sub>2</sub>, calcium chloride
  - C. 0.2 M CH<sub>3</sub>OH, methanol
  - D. 0.2 M C<sub>6</sub>H<sub>12</sub>O<sub>6</sub>, glucose
  - E. 0.2 M C<sub>12</sub>H<sub>22</sub>O<sub>11</sub>, sucrose

47. When 22.5 g of an unknown compound is added to 250.0 g water, the freezing point is  $-0.930^{\circ}\text{C}$ . If the empirical formula of this unknown compound is CH<sub>2</sub>O, what is the molecular formula?  $K_f(\text{H}_2\text{O}) = 1.86^{\circ}\text{C/m}$ .

