

**CHEM 1310 A/B: General Chemistry**  
**Georgia Institute of Technology**  
**Exam 3, Chapters 13 - 15**  
**November 18, 2009**  
**Williams Section**

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"Having read the Georgia Institute of Technology Academic Honor code, I understand and accept my responsibility as a member of the Georgia Tech Community to uphold the Academic Honor Code at all times." "Students are expected to act according to the highest ethical standards. The immediate objective of an Academic Honor Code is to prevent any Students from gaining an unfair advantage over other Students through academic misconduct." " Students must sign the Academic Honor Agreement affirming their commitment to uphold the Honor Code before becoming a part of the Georgia Tech community. The Honor Agreement may reappear on exams and other assignments to remind Students of their responsibilities under the Georgia Institute of Technology Academic Honor Code." "In order for an Academic Honor Code to function, members of the Georgia Tech Community must not tolerate violations of it by anyone. Community members are at their discretion to use any of three options to report suspected Honor Code violations "

I have read and understand my responsibilities under the GT Academic Honor code.

Signature \_\_\_\_\_

1. This exam has 20 multiple choice questions that are equally weighted at 5 points each.
2. A calculator and a crib sheet (8.5 x 11, front only) are permitted for use during the exam.
3. Complete the scantron card and include your name, your TA, your lecture professor, your GT ID (bubble in the appropriate numbers), and the exam version. All of this material must be submitted to receive credit.
4. Cell phones must be shut off during the exam.
5. A maximum of 50 minutes is allowed for the exam.
6. When you are finished submit your exam to your TA, show your buzz card or other photo ID for identification.
7. You may not leave the exam room until 25 minutes have lapsed.
8. A periodic table is provided at the end of the exam.
9. Only the answers submitted on the scantron card will be graded.
10. There is to be no communication with anyone other than the teaching assistant or instructor until you leave the classroom.
11. Each item is equally weighted at 5 points each. Points will be deducted for not completing the scantron card including version, bubbling in your correct student ID, or identifying your teaching assistant.

Initially, a warm brick (the system) is placed in a cold pool of water (the surroundings). Finally, the system and surroundings reach thermal equilibrium. For this process:

1. A)  $\Delta S_{\text{system}} > 0$   
B)  $\Delta S_{\text{system}} < 0$   
C)  $\Delta S_{\text{system}} = 0$   
D)  $\Delta S_{\text{system}}$  changes in a way that cannot be predicted  
E) none of the above

Answer: B cooling decreases entropy.

- 1alt. A)  $\Delta S_{\text{system}} > 0$   
B)  $\Delta S_{\text{system}} = 0$   
C)  $\Delta S_{\text{system}} < 0$   
D)  $\Delta S_{\text{system}}$  changes in a way that cannot be predicted  
E) none of the above

Answer: C cooling decreases entropy.

2. A)  $\Delta S_{\text{surroundings}} > 0$   
B)  $\Delta S_{\text{surroundings}} < 0$   
C)  $\Delta S_{\text{surroundings}} = 0$   
D)  $\Delta S_{\text{surroundings}}$  changes in a way that cannot be predicted  
E) none of the above

Answer: A warming increases entropy

2. A)  $\Delta S_{\text{surroundings}} < 0$   
B)  $\Delta S_{\text{surroundings}} > 0$   
C)  $\Delta S_{\text{surroundings}} = 0$   
D)  $\Delta S_{\text{surroundings}}$  changes in a way that cannot be predicted  
E) none of the above

Answer: B warming increases entropy

3. A)  $\Delta S_{\text{universe}} > 0$   
B)  $\Delta S_{\text{universe}} < 0$   
C)  $\Delta S_{\text{universe}} = 0$   
D)  $\Delta S_{\text{universe}}$  changes in a way that cannot be predicted  
E) none of the above

Answer: A the entropy of the universe increases for any spontaneous process

5. A 100 mL solution contains 1.0 M HNO<sub>2</sub> and 0.70 M NaNO<sub>2</sub>. 10 mL of 1.5 M HCl is added. The K<sub>a</sub> for HNO<sub>2</sub> is 7.2 x 10<sup>-4</sup>. Calculate the final pH.

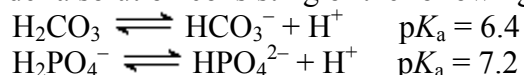
- A) 1.9  
B) 3.5  
C) 2.8  
D) 3.1  
E) 0.2

Answer C

	NaNO <sub>2</sub>	+ HCl	→	HNO <sub>2</sub>
I	0.070	0.015		0.100
C	-0.015	-0.015		+0.015
E	0.055	+0.000		0.115

$$\text{pH} = \text{pK}_a + \log(\text{Base}/\text{Acid}) = 3.14 + \log(0.055/0.115) = 2.8$$

6. Consider a solution consisting of the following two acids in water:

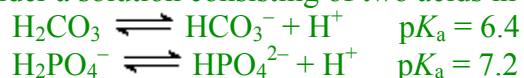


At pH 7.2, which one of the following is true?

- A) [H<sub>2</sub>CO<sub>3</sub>] > [HCO<sub>3</sub><sup>-</sup>] and [H<sub>2</sub>PO<sub>4</sub><sup>-</sup>] > [HPO<sub>4</sub><sup>2-</sup>]  
B) [H<sub>2</sub>CO<sub>3</sub>] = [HCO<sub>3</sub><sup>-</sup>] and [H<sub>2</sub>PO<sub>4</sub><sup>-</sup>] > [HPO<sub>4</sub><sup>2-</sup>]  
C) [H<sub>2</sub>CO<sub>3</sub>] = [HCO<sub>3</sub><sup>-</sup>] and [H<sub>2</sub>PO<sub>4</sub><sup>-</sup>] < [HPO<sub>4</sub><sup>2-</sup>]  
D) [H<sub>2</sub>CO<sub>3</sub>] > [HCO<sub>3</sub><sup>-</sup>] and [H<sub>2</sub>PO<sub>4</sub><sup>-</sup>] = [HPO<sub>4</sub><sup>2-</sup>]  
E) [H<sub>2</sub>CO<sub>3</sub>] < [HCO<sub>3</sub><sup>-</sup>] and [H<sub>2</sub>PO<sub>4</sub><sup>-</sup>] = [HPO<sub>4</sub><sup>2-</sup>]

Answer: E

- 6alt. Consider a solution consisting of two acids in water:



At pH 6.4, which one of the following is true?

- A) [H<sub>2</sub>CO<sub>3</sub>] > [HCO<sub>3</sub><sup>-</sup>] and [H<sub>2</sub>PO<sub>4</sub><sup>-</sup>] > [HPO<sub>4</sub><sup>2-</sup>]  
B) [H<sub>2</sub>CO<sub>3</sub>] = [HCO<sub>3</sub><sup>-</sup>] and [H<sub>2</sub>PO<sub>4</sub><sup>-</sup>] > [HPO<sub>4</sub><sup>2-</sup>]  
C) [H<sub>2</sub>CO<sub>3</sub>] = [HCO<sub>3</sub><sup>-</sup>] and [H<sub>2</sub>PO<sub>4</sub><sup>-</sup>] < [HPO<sub>4</sub><sup>2-</sup>]  
D) [H<sub>2</sub>CO<sub>3</sub>] > [HCO<sub>3</sub><sup>-</sup>] and [H<sub>2</sub>PO<sub>4</sub><sup>-</sup>] = [HPO<sub>4</sub><sup>2-</sup>]  
E) [H<sub>2</sub>CO<sub>3</sub>] < [HCO<sub>3</sub><sup>-</sup>] and [H<sub>2</sub>PO<sub>4</sub><sup>-</sup>] = [HPO<sub>4</sub><sup>2-</sup>]

Answer: B

7. 100 ml of 0.1 M HCl and 100 ml of 0.1 M CH<sub>3</sub>COOH are each titrated with 0.1 M NaOH. Which of the following would be equal for the two titrations?
- the initial pH
  - the initial [H<sup>+</sup>]
  - the buffering capacity at the pK<sub>a</sub> of CH<sub>3</sub>COOH
  - the volume of NaOH added to reach equivalence point
  - none of the above

Answer: D

1.22 moles of perfect monatomic gas is very slowly compressed from 30 L to 20 L at a constant pressure of 5.0 atm ( $R = 0.082 \text{ L-atm/mol-K}$ ;  $R = 8.31 \text{ J/mol-K}$ ;  $101 \text{ J/L-atm}$ ).

8. The heat  $q$  for this process is

- 9.8 kJ
- 9.8 kJ
- 271 kJ
- 12.7 kJ
- 12.7 kJ

Answer: E

$$T_i = PV/nR = (5.0 \text{ atm})(30 \text{ L}) / (0.082 \text{ L-atm/mol-K})(1.22 \text{ mol}) = 1500 \text{ K}$$

$$T_f = PV/nR = (5.0 \text{ atm})(20 \text{ L}) / (0.082 \text{ L-atm/mol-K})(1.22 \text{ mol}) = 1000 \text{ K}$$

$$q = nC_p\Delta T = n(5R/2)\Delta T = (1.22 \text{ mol})(5/2)(0.082 \text{ L-atm/mol-K})(1000\text{K}-1500\text{K}) = -125 \text{ L-atm}$$

$$(-125 \text{ L-atm})(101 \text{ J/L-atm}) = 12700 \text{ J} = 12.7 \text{ kJ}$$

9. The work  $w$  for this process is

- 5.05 kJ
- +5.05 kJ
- 135 kJ
- 135 kJ
- 271 kJ

Answer: B

$$w = -P\Delta V = -5(20-30) = +50 \text{ L atm}$$

$$(+50 \text{ L-atm})(101 \text{ J/L-atm}) = 5.05 \text{ kJ}$$

10. In a solution prepared by adding excess MgF<sub>2</sub>(s) [ $K_{sp} = 1.08 \times 10^{-10}$ ] to water, [Mg<sup>2+</sup>] at equilibrium is:

- $1.5 \times 10^{-4} \text{ mol/L}$
- $2.4 \times 10^{-4} \text{ mol/L}$
- $1.2 \times 10^{-4} \text{ mol/L}$
- $3.0 \times 10^{-4} \text{ mol/L}$
- $8.4 \times 10^{-6} \text{ mol/L}$

Answer D



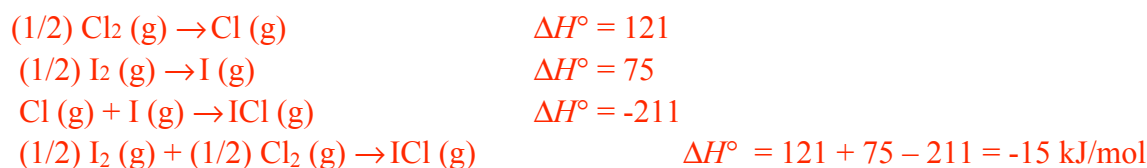
$$K_{sp} = [\text{Mg}^{2+}][\text{F}^-]^2 = [\text{Mg}^{2+}](2[\text{Mg}^{2+}])^2 = 4([\text{Mg}^{2+}]^3) = 1.08 \times 10^{-10}$$

11. Using the following data, calculate the standard heat of formation of one mole of the compound ICl (g) from I<sub>2</sub> (g) and Cl<sub>2</sub> (g):

	$\Delta H^\circ$ (kJ/mol)
Cl <sub>2</sub> (g) → 2Cl(g)	242
I <sub>2</sub> (g) → 2I (g)	150
ICl (g) → I(g) + Cl(g)	211
I <sub>2</sub> (s) → I <sub>2</sub> (g)	63

- A) -211 kJ/mol  
 B) -15 kJ/mol  
 C) -30 kJ/mol  
 D) +30 kJ/mol  
 E) 181 kJ/mol

Answer: B

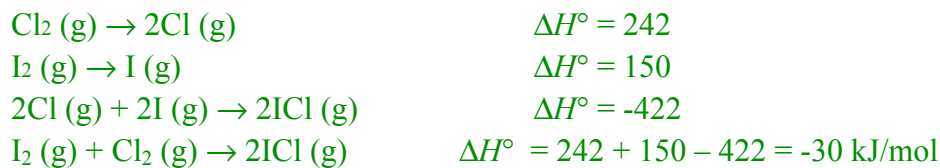


- 11alt. Using the following data, calculate the standard heat of formation of two moles of the compound ICl (g) from I<sub>2</sub> (g) and Cl<sub>2</sub> (g):

	$\Delta H^\circ$ (kJ/mol)
Cl <sub>2</sub> (g) → 2Cl(g)	242
I <sub>2</sub> (g) → 2I (g)	150
ICl (g) → I(g) + Cl(g)	211
I <sub>2</sub> (s) → I <sub>2</sub> (g)	63

- A) -211 kJ/mol  
 B) -15 kJ/mol  
 C) -30 kJ/mol  
 D) +30 kJ/mol  
 E) 181 kJ/mol

Answer: C



12. You are given a solution containing the weak base ammonia,  $\text{NH}_3$ , with a pH of 11. If a small amount of ammonium,  $\text{NH}_4^+$  (s) is added to the solution, which statement is true?
- A) The pH and the pOH both increase.
  - B) The pH and the pOH both decrease.
  - C) The pH and the pOH remain unchanged.
  - D) The pH decreases and the pOH increases.
  - E) The pH increases and pOH decreases.

Answer D

- 12alt. You are given a solution containing the weak base ammonia,  $\text{NH}_3$ , with a pH of 1.0. If a small amount of concentrated  $\text{NH}_3$  (aq) is added to the solution, which statement is true?
- A) The pH and the pOH both increase.
  - B) The pH and the pOH both decrease.
  - C) The pH and the pOH remain unchanged.
  - D) The pH decreases and the pOH increases.
  - E) The pH increases and pOH decreases.

Answer E

13. For the reaction  $\text{A} + \text{B} \rightarrow \text{C} + \text{D}$ ,  
 $\Delta H^\circ = -40 \text{ kJ/mol}$  and  $\Delta S^\circ = -50 \text{ J/mol-K}$ .  
The reaction under standard conditions is
- A) spontaneous reverse at temperatures greater than 800 K.
  - B) spontaneous forward at temperatures greater than 800 K.
  - C) spontaneous reverse only at temperatures greater than 600 K.
  - D) spontaneous forward at all temperatures.
  - E) spontaneous reverse at all temperatures.

Answer A

$\Delta H < 0 \Rightarrow$  spontaneous forward at low T.

$\Delta S < 0 \Rightarrow$  spontaneous reverse at high T.

Crossover Temperature =  $\Delta H/\Delta S = 40/0.050 = 800 \text{ K}$ . Spontaneous reverse at  $T > 800\text{K}$

- 13alt. For the reaction  $\text{A} + \text{B} \rightarrow \text{C} + \text{D}$ ,  
 $\Delta H^\circ = 40 \text{ kJ/mol}$  and  $\Delta S^\circ = 50 \text{ J/mol-K}$ .  
The reaction under standard conditions is
- A) spontaneous reverse at temperatures greater than 800 K.
  - B) spontaneous forward at temperatures greater than 800 K.
  - C) spontaneous reverse only at temperatures greater than 600 K.
  - D) spontaneous forward at all temperatures.
  - E) spontaneous reverse at all temperatures.

Answer B

$\Delta H < 0 \Rightarrow$  spontaneous reverse at low T.

$\Delta S < 0 \Rightarrow$  spontaneous forward at high T.

Crossover Temperature =  $\Delta H/\Delta S = 40/0.050 = 800 \text{ K}$ . Spontaneous reverse at  $T > 800 \text{ K}$

14. Consider the freezing of liquid water at  $-10^\circ\text{C}$  and 1 atm. For this process what are the signs for  $\Delta H$ ,  $\Delta S$ , and  $\Delta G$ ?

	$\Delta H$	$\Delta S$	$\Delta G$
A)	+	-	0
B)	-	+	0
C)	-	+	-
D)	+	-	-
E)	-	-	-

Answer: E

The process is spontaneous;  $\Delta G < 0$ , exothermic;  $\Delta H < 0$ , and it changes directions at high temperature;  $\Delta S < 0$

15. Which of the following are state functions?

- A) work, heat
- B) work, heat, enthalpy, energy
- C) enthalpy, energy, entropy
- D) work, heat, enthalpy
- E) heat, enthalpy, energy

Answer: C

- 15alt. Which of the following are state functions?

- A) work, heat
- B) work, heat, enthalpy, energy
- C) work, heat, enthalpy
- D) enthalpy, energy, entropy
- E) heat, enthalpy, energy

Answer: C

16. For the vaporization of a liquid at its boiling point  $T_b$ , the change in entropy and the change in enthalpy are related by

- A)  $\Delta S_{\text{vap}} = \Delta H_{\text{vap}}/T_b$
- B)  $\Delta S_{\text{vap}} = T_b \Delta H_{\text{vap}}$
- C)  $\Delta S_{\text{vap}} = T_b / \Delta H_{\text{vap}}$
- D)  $T_b = \Delta H_{\text{vap}} \Delta S_{\text{vap}}$
- E) There is no general relation covering these vaporization quantities.

Answer: A;  $\Delta G = \Delta H_{\text{vap}} - T_b \Delta S_{\text{vap}} = 0$  at the boiling point

17.  $\Delta G = -RT\ln(K) + RT\ln(Q)$

Which of the following must be true at equilibrium?

- A)  $Q = K$
- B)  $\Delta G < 0$
- C)  $\Delta G^\circ < 0$
- D)  $\Delta E = 0$
- E)  $\Delta S < 0$

Answer: A

18. For a particular process  $q = -10$  kJ and  $w = 25$  kJ. Which of the following statements is true?

- A) Heat flows from the surroundings to the system.
- B) The system does work on the surroundings.
- C)  $\Delta E = -35$  kJ.
- D) All of the above are true.
- E) None of the above are true.

Answer E

19. 100 kJ of heat is added at constant pressure to two solid objects, each containing  $10^{22}$  molecules. Which object experiences the smallest change in temperature?

- A) The object with the larger molar heat capacity.
- B) The object with the smaller molar heat capacity.
- C) The objects undergo the same change in temperature regardless of the molar heat capacity.
- D) You need to know the initial temperature to answer this question.
- E) You need to know the volumes of the objects

Answer: A

20. This exam version is

- A) A
- B) B
- C) C
- D) D
- E) E

Answer: A