Chemistry 1A Fall 2000

Midterm Exam III, version B
November 14, 2000

(Closed book, 90 minutes, 155 points)

Name: _____ Section Number: _____

SID: _____ T.A. Name: _____

Identification Sticker

Exam information, extra directions, and useful hints to maximize your score:

- Write your name on all 8 pages.
- There are two parts to the exam: 1) multiple choice and 2) short answer problems.
- **For the multiple choice problems, fill in the Scantron™ form AND circle the answer on your exam.**
- Answer the questions you know how to do first, then work on the questions you skipped.
- Show all work on the short answer problems for which you want credit and do not forget to include units!

Unit Prefixes

milli, m (x 10^{-3})	micro, μ (x 10^{-6})	nano, n (x 10^{-9})
kilo, k (x 10^{3})	mega, M (x10^{6})	giga, G (x 10^{9})

Some possibly useful information:

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

$$\Delta S^{o} = \sum S^{o}(\text{products}) - \sum S^{o}(\text{reactants})$$

$\Delta G = \Delta H - T\Delta S$ $C_p°(H_2O, l) = 1$ cal/K·g

$\Delta E = q + w$ $S = k_B \ln W$

1 Cal = 1000 cal

Compound	$\Delta H_f°$ (kJ/mol) at 25°C	S° (J/mol-K) at 25°C
CO (gas)	-110.5	197.7
CO_2 (gas)	-393.5	213.6
H_2 (gas)	0	130.6
H_2O (liquid)	-285.8	70.0
CH_3OH	-238.7	126.8
C_2H_5OH	-277.7	160.7
CH_3COOH	-484.5	159.8

Bond	Average Bond Enthalpy (kJ/mol)
C-H	413
C-C	348
C-O	360
O=O	497
O-H	463
H-H	436

(Do not write in the box below.)

Page	Points
2-4	/ 48
5-6	/ 60
7-8	/ 47
Total	/ 155

 Name:_____

Part 1: Multiple Choice.
(4 pts each, 48 pts total)
Instructions: Bubble in the correct answer on your Scantron sheet AND circle the answer on your exam. Each question has one correct answer.

1.) The answer to question 1 is **B**. Bubble in **B** on your Scantron™ form.

2.) Which has $K \neq P_{CO_2}$ at equilibrium?

A.) $Na_2CO_3\,(solid) \rightleftharpoons Na_2O(solid) + CO_2\,(gas)$

B.) $CaCO_3(solid) \rightleftharpoons CaO(solid) + CO_2\,(gas)$

C.) $C(solid) + O_2\,(gas) \rightleftharpoons CO_2\,(gas)$

D.) $CO_2\,(solid) \rightleftharpoons CO_2\,(gas)$

E.) $2\,MgO(solid) + C(solid) \rightleftharpoons 2\,Mg(solid) + CO_2\,(gas)$

3.) For the exothermic formation of ammonia, $N_2(gas) + 3\,H_2\,(gas) \rightleftharpoons 2\,NH_3(gas)$ which will act to favor the formation of ammonia?

A.) high pressure B) high volume C.) high temperature

D.) catalyst E.) all of the above

4.) Which of the following is true for the isothermal expansion of an ideal gas?

A.) $w > 0$ B.) $\Delta T > 0$ C.) $\Delta V < 0$ **D.) $\Delta S_{Sys} > 0$** E.) $\Delta S_{Surr} > 0$

5.) Which of the following has the greatest entropy?

A.) 1 mole of water at 25 ^oC and 1 atm

B.) 1 mole of water at 100 ^oC and 1 atm

C.) 0.5 moles of water plus 0.5 moles of steam at 100 ^oC and 1 atm

D.) 1 mole of steam at 100 ^oC and 1 atm

E.) 1 mole of steam at 100 ^oC and 0.5 atm

 Name:_____

6.) Which is true for the following exothermic reaction at 1 atm?

$$Fe(solid) + CO(gas) \rightleftharpoons FeO(solid) + C(solid)$$

A.) Proceeds spontaneously at all temperatures
B.) Proceeds spontaneously at no temperatures
C.) Proceeds spontaneously at high temperatures
D.) Proceeds spontaneously only at 0 K
E.) Proceeds spontaneously at low temperatures

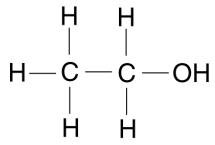
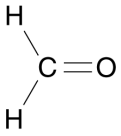
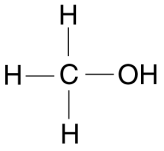
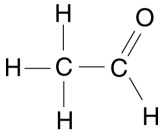
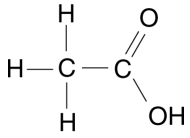
7.) How many glasses of water (200 mL) can be heated from 10 ^{o}C to 35 ^{o}C by the combustion of a mini-Snickers bar (40 Cal)?

A.) 1 **B.) 8** C.) 40 D.) 500 E.) 1000

8.) To the formation of which compound from the elements in standard states does the following process of bond-breaking → bond formation correspond?

2 C-C +2 H-H + ½ O=O → 3 C-H + C-O + O-H

A.) ethanol B.) formaldehyde **C.) methanol** D.) acetaldehyde E.) acetic acid

9.) Using the information on page 1, estimate ΔH^{o} for the process in question 8.

A.) 246 kJ/mol B.) 45 kJ/mol C.) 3 kJ/mol D.) -45 kJ/mol **E.) -246 kJ/mol**

10.) When you burn wood, energy is released. Which statement best describes where that energy comes from?

A.) The reaction breaks the chemical bonds in the wood, releasing their energy.

B.) Energy is released because wood and all organic materials have high energy bonds.

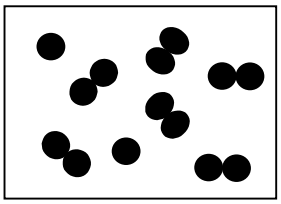
C.) When wood burns, its weak bonds break to combine with the stronger oxygen-oxygen double bonds, releasing energy.

D.) When you burn wood, the products are more stable than the reactants so energy is released.

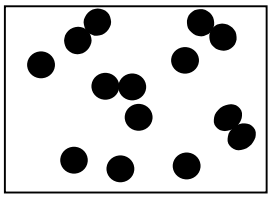
E.) When wood is a reactant, its high energy bonds release energy when they break.

 Name:_____

11.) Consider the dissociation reaction A_2 (g) $\rightleftharpoons$ 2 A (g). The following pictures represent one possible initial state and the equilibrium state for the system.



Initial State



Equilibrium State

Which of the following statements is true for this dissociation reaction?

A.) This reaction favors products at all temperatures because the number of A atoms increases and the number of A_2 molecules decreases.

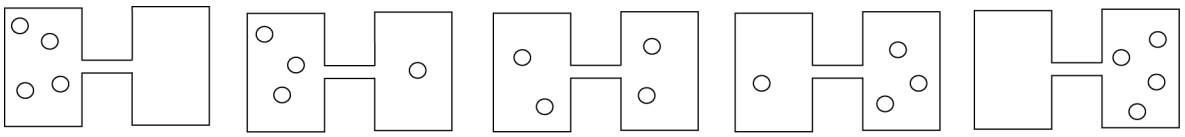
B.) This reaction favors reactants at all temperatures because the A_2 molecules have a bond which makes them more stable.

C.) This reaction favors reactants at lower temperatures because heat is absorbed.

D.) This reaction favors reactants at higher temperatures because heat is absorbed.

E.) This reaction doesn't favor products or reactants since the equilibrium constant equals 1.

12.) Which process is accompanied by the largest increase in entropy?



I **II** **III** **IV** **V**

A.) I→V **B.) I→II** C.) II→III

D.) III→IV E.) IV→V

 Name:_____

Part 2: Short Answer Problems (107 pts total)

Instructions: Enter answers for all questions in the boxes provided (or as otherwise instructed). Show your work. Where requested write explanations in fifteen words or less.

1.)
(60 pts)

Consider the following reaction: $CO_2(gas) + H_2(gas) \rightleftharpoons CO(gas) + H_2O(liquid)$
At equilibrium at 25 °C, $P_{CO_2} = P_{H_2} = 1.0$ atm ; $P_{CO} = 3.2 \times 10^{-4}$ atm .

a.) The volume is suddenly reduced by a factor of ½. What are Q and K?
How will the reaction proceed toward equilibrium?

$K = P_{CO} / P_{CO_2} P_{H_2} = 3.2 \times 10^{-4}$

After reduction in volume:
$P^*_{CO_2} = P^*_{H_2} = 2.0$ atm
$P^*_{CO} = 6.4 \times 10^{-4}$ atm

$Q = P^*_{CO} / P^*_{CO_2} P^*_{H_2} = 1.6 \times 10^{-4}$
$K = 3.2 \times 10^{-4}$ does not change.

Q: 1.6×10^{-4}
K: 3.2×10^{-4}

Short explanation of re-establishment of equilibrium:
After reduction in volume, Q<K. Products will be favored as equilibrium is re-established.

b.) What are the partial pressures of all the species in the reaction at the new equilibrium?

After reduction in volume:
$P^*_{CO_2} = P^*_{H_2} = 2.0$ atm
$P^*_{CO} = 6.4 \times 10^{-4}$ atm

When equilibrium is re-established:
$P^*_{CO_2} = P^*_{H_2} = 2.0$ atm - x
$P^*_{CO} = 6.4 \times 10^{-4}$ atm + x

$K = (6.4 \times 10^{-4} + x) / (2.0 - x)(2.0 - x)$

$\approx (6.4 \times 10^{-4} + x) / 4.0 = 3.2 \times 10^{-4}$

→ $x = 6.4 \times 10^{-4}$

P_{CO_2}: 2.0 atm
P_{H_2}: 2.0 atm
P_{CO}: 1.3×10^{-3} atm

 Name:_____

c.) Using the information on page 1, determine $\Delta H°$ for the reaction from $\Delta H_f°$'s and determine $\Delta S°$ for the reaction from S°'s. Explain the sign of $\Delta S°$.

$\Delta H° = \Delta H_f°(H_2O) + \Delta H_f°(CO) - \Delta H_f°(CO_2) - \Delta H_f°(H_2)$
$= -285.8\ kJ/mol - 110.5\ kJ/mol + 393.5\ kJ/mol + 0\ kJ/mol$

$\Delta S° = S°(H_2O) + S°(CO) - S°(CO_2) - S°(H_2)$
$= 70.0\ J/mol·K + 197.7\ J/mol·K - 213.6\ J/mol·K - 130.6\ J/mol·K$

$\Delta H°$: -2.8 kJ/mol

$\Delta S°$: -76.5 J/mol·K

Explanation: **$\Delta S < 0$ as more disordered reactants (all gas) are converted to more ordered products (both gas and liquid).**

d.) Determine $\Delta G°$ for the reaction at 25 °C.

$\Delta G° = \Delta H° - T\Delta S°$
$= (-2.8\ kJ/mol) - (298K)(-76.5\ J/mol·K)$

$\Delta G°$: 20.0 kJ/mol

e.) Below what temperature does the reaction become spontaneous?

Spontaneous for
$\Delta G° = \Delta H° - T\Delta H° < 0$

True when
$T < \Delta H° / \Delta S°$

T: 36.6 K

 Name:_____

(47 pts)
2.)

For questions **a – d** consider the following: Different hydrocarbon structural isomers burn differently in oxygen. This is the basis for the 'octane' rating of gasoline. Consider three structural isomers, X,Y and Z, of a certain hydrocarbon. The hydrocarbon isomers can react as follows at 298 K.

1) $X \rightleftharpoons Y$ $K_1 = 20.0$ $\Delta H° = -40.0$ kJ/mol $\Delta S° = -120$ J/K mol

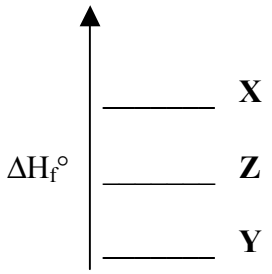
2) $Y \rightleftharpoons Z$ $K_2 = 0.4$ $\Delta H° = 20.0$ kJ/mol $\Delta S° = 60$ J/K mol

a.) What is the equilibrium constant for $X \rightleftharpoons Z$?

$K_{eq} = K_1 \bullet K_2$

K_{eq}: **8**

b.) Arrange the compounds X, Y, and Z on the relative enthalpy scale below?



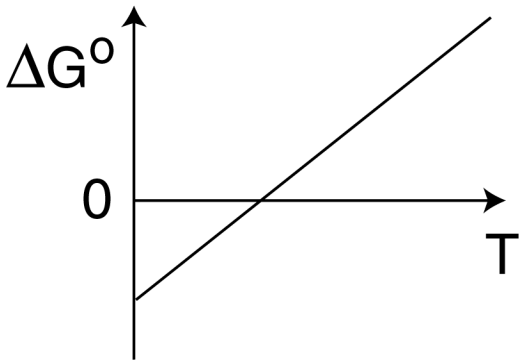
 Name:_____

c.) Upon combustion, which isomer, X or Z, burns hotter? Circle one and explain.

X Z Same

Explanation: **X is less stable as shown by its higher heat of formation.**

d.) Sketch a plot of ΔG° vs. T for the equilibrium X $\rightleftharpoons$ Z.



ΔH° < 0 and ΔS° < 0, so ΔG° is negative at low T and positive at high T.