Exam 2

MULTIPLE CHOICE (3pts each): Write the ONE letter corresponding to the correct answer on the line next to each question. The LETTER ASSOCIATED WITH THE CORRECT ANSWER MUST BE WRITTEN ON THE LINE NEXT TO THE QUESTION in order to receive full credit.

1.) For the reaction $2A(g) \leftrightarrow B(g)$, $K_p = 0.874$. If the pressures of A & B are A = 2.45atm   1.) __D__
and B = 4.87atm $Q = \frac{[B]}{[A]^2} = \frac{(4.87)}{(2.45)^2} = \frac{4.87}{6.00 A5} = 0.8113$
  a.) the reaction has stopped   b.) the reverse reaction is favored
  c.) the reaction is at equilibrium   d.) the forward reaction is favored

  $Q < K_p$

2.) An equilibrium reaction has a free energy of +18.6kJ/mol at 25°C. What is the   2.) __A__ $\ln K = -7.5036$
equilibrium constant for this process?
  a.) 5.51x10^-4   b.) 1.01   c.) 1.37x10^-39   d.) 1.81x10^3 $K = e^{-7.5036}$
  $\Delta G = -RT \ln K$ $18.6 kJ/mol = -(8.314 \times 10^{-3} kJ/mol K)(298.15) \ln K$ $= 5.51 \times 10^{-4}$

3.) Which response best describes equilibrium?   3.) __C__
  a.) The concentrations of reactants and products are equal.
  b.) The reaction has reached a point where no more products or reactants are being formed.
  c.) The rate of the forward and reverse reactions are equal.
  d.) The reaction has begun to form reactants and not products.

4.) Which of the following molecules would have the greatest entropy? (Assume all   4.) __C__
are liquids.)
  a.) C_6H_{14} b.) C_5H_{12} c.) C_7H_{16} d.) C_4H_{10}

5.) For a given reaction, $\Delta H = -34.2$kJ/mol and $\Delta S = -284$J/molK. At 300K, this   5.) __B__
reaction is
  a.) spontaneous   b.) nonspontaneous   c.) at equilibrium   d.) at completion
  $\Delta G = -34.2 kJ/mol - (300K \times -0.284 kJ/mol K) = +51 kJ/mol$

6.) Which of the following K_{eq} values describes the process in which the reverse   6.) __D__
reaction is the most highly favored?
  a.) 4.96x10^5   b.) 2.65x10^-2   c.) 1.87x10^3   d.) 7.86x10^-4 ← smallest, the forward is the least favored, reverse

7.) When the reaction $2A(g) + B(g) \rightarrow 3C(g)$ occurs, the entropy of the system   7.) __C__
  a.) increases   b.) decreases   c.) stays the same
  same # particles on each side, all gases

8.) For the reaction $2A + B \leftrightarrow C$, $K_{eq} = 1.45$. What is K_{eq} for $4A + 2B \leftrightarrow 2C$?   8.) __D__
  a.) 0.690   b.) 3.05   c.) 2.90   d.) 2.10
  $(1.45)^2 = 2.1025$

9.) Which response best describes how a catalyst works: 9.) __B__
  a.) by shifting the equilibrium toward the products
  b.) by lowering the activation energy
  c.) by acting as an additional reactant
  d.) all responses are correct

10.) Which of the following processes is most likely to be spontaneous?   10.) __A__
  a.) nitrogen & oxygen gas mixing together when two gas tanks are connected
  b.) water boiling at 80°C under atmospheric pressure
  c.) carbon dioxide and water forming a tree
  d.) sodium chloride precipitating out of an **unsaturated** solution

SHORT ANSWER (10 pts each): Completely answer all of the following questions. Read all questions carefully!!! SHOW ALL WORK. Make sure to include units and report all mathematical answers to the correct number of significant figures. Write final answers in designated locations when indicated.

1. Given the following reaction, indicate how each of the listed stresses would impact the equilibrium. Use toward reactants/products, not left/right.

$$2\ SO_3\ (g) \longleftrightarrow 2\ SO_2\ (g) + O_2\ (g) \qquad \Delta H = +198\ kJ/mol$$
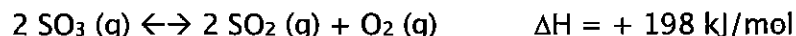
a.) Add SO_3 Answer: <u>toward products</u>
   ↖ reactant

b.) Add a catalyst   Answer: <u>no change</u>

c.) Increase temperature   Answer: <u>toward products</u>
   ↳ endothermic

d.) Increase pressure   Answer: <u>toward reactants</u>
   fewer mol of gas particles

e.) Briefly describe one method (not including any of the stresses mentioned above or their opposites) that you could use to increase the amount of SO_2.

   Remove SO_2 or O_2

2. The reaction $3A\ (aq) \longleftrightarrow 2B\ (aq) + C\ (aq)$ has an equilibrium constant of 0.876. If you start with a flask containing 0.987M A, what are the equilibrium concentrations of all components? (Hint: You do not need the approximation method.)

[A] : <u>0.351 M</u>

[B] : <u>0.424 M</u>

[C] : <u>0.212 M</u>

$$3A \rightleftharpoons 2B + C$$

0.987	0	0
$-3x$	$+2x$	$+x$
$0.987-3x$	$2x$	x
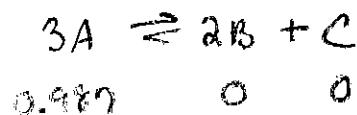
$$\sqrt[3]{0.876} = \frac{[2x]^2[x]}{[0.987-3x]^3} = \frac{(4x^2)(x)}{(0.987-3x)^3} \qquad \sqrt[3]{\frac{4x^3}{(0.987-3x)^3}}$$

$$0.95683 = \frac{1.5874\ x}{0.987-3x}$$

$$0.94439 - 2.87049x = 1.5874x$$
$$+2.87049x \quad +2.87049x$$

$[A] = 0.987 - 3(0.21185) = 0.35145$

$[B] = 2(0.21185) = 0.4237$

$[C] = 0.21185$

$$\frac{0.94439}{4.45789} = \frac{4.45789x}{4.45789} \qquad x = 0.21185$$

3. The molar enthalpy of vaporization for a compound with a molar mass of 56.948g/mol is 37.6 kJ/mol at 68.2°C. What is the change in entropy, in J/K, when 19.5g of this compound moves from the liquid to the gas phase at this temperature?
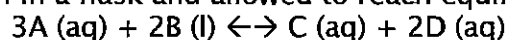
$$19.5g \left(\frac{1mol}{56.948g}\right) = 0.34242\,mol \left(\frac{37.6kJ}{mol}\right)$$

Answer: __ 37.7 J/K __

$$= \frac{12.87492\,kJ}{341.35K}$$

$$= 0.0377176\ kJ/K$$

$$= 37.7176\ J/K$$

4. The following reaction is run in a flask and allowed to reach equilibrium:

3A (aq) + 2B (l) ←→ C (aq) + 2D (aq)

After being allowed to reach equilibrium, the flask contains 0.25M A, 0.97g B, 0.56M C and 0.30M D.

a.) Write the equilibrium expression for this reaction.

$$K_{eq} = \frac{[C][D]^2}{[A]^3}$$

Answer: _____

b.) Calculate the value of K_{eq}.   Answer: __ 3.23 __

$$K_{eq} = \frac{[0.56]\,[0.30]^2}{[0.25]^3} = 3.2266$$

(above: 0.04, 0.015625)

c.) What is the value of K_{eq} for the reverse reaction? Answer: __ 0.310 __
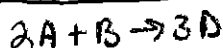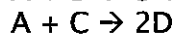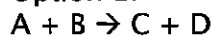
$$\frac{1}{3.2266} = 0.3100198$$

5. Given the reaction A + 2B → 3C, where the rate law is Rate = k[B]^2
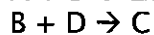
a.) Which option provides the most likely mechanism for this reaction?
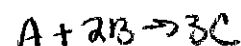
Answer: _Option 3_

Option 1:
A + B → C + D
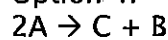A + C → 2D
_____
2A + B → 3D

Option 2:
A + B → 2C + D   no step
B + D → C   has Rate = k[B]^2
_____
A + 2B → 3C

Option 3: ✔
2B → A + D   Rate = k[B]^2
2A + D → 3C
_____
A + 2B → 3C
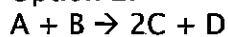
Option 4:
2A → C + B
2B + C → 3D
_____
2A + B → 3D

b.) BRIEFLY describe two reasons why you chose your option for part a.

Steps add up to A + 2B → 3C

Step 1 has Rate = k[B]^2

6. For the reaction 2A(g) ←→ B(g), ΔG° = +26.3 kJ/mol. If [A] = 0.94M and [B] = 0.56M:

a.) What is the value of Q?   Answer: _0.634_

$$Q = \frac{[B]}{[A]^2} = \frac{[0.56]}{[0.94]^2} = 0.6337\eta$$

b.) What is the value of ΔG at 298K?

$$\Delta G = \Delta G° + RT \ln Q$$

Answer: _+25.2 kJ/mol_

$$= +26.3 \text{ kJ/mol} + \left[(8.314 \times 10^{-3} \text{ kJ/mol·K})(298K)(\ln 0.6337\eta)\right]$$
$$(-0.456064)$$

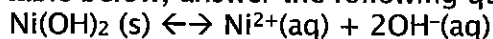$$= +26.3 \text{ kJ/mol} - 1.129944 \text{ kJ/mol} = +25.17 \text{ kJ/mol}$$

c.) Is the reaction spontaneous at these concentrations?   Answer: _no !_

d.) BRIEFLY explain your answer to part c.

ΔG is positive

7. Given the information in the table below, answer the following questions about the reaction
$Ni(OH)_2 (s) \leftrightarrow Ni^{2+}(aq) + 2OH^-(aq)$
Note that the table contains information for all versions of the exam. You will not use all values. Include signs with all numerical answers.

	ΔH (kJ/mol)	ΔS (J/molK)
OH⁻	−229.94	−10.5
Al³⁺	−524.7	−313.38
Al(OH)₃	−179.91	216.43
Cu²⁺	64.39	−99.6
Cu(OH)₂	−450.37	108.43
Mn²⁺	−218.8	−83.68
Mn(OH)₂	700.0	94.9
Ni²⁺	−64.0	−159.4
Ni(OH)₂	−538.06	79.5

a.) What is the value of ΔS_{rxn}?

Answer: -0.2599 kJ/mol K
-259.9 J/mol K

$[-159.4 + 2(-10.5)] - [79.5]$

$= -259.9$ J/mol K

b.) What is the value of ΔH_{rxn}?

Answer: $+14.18$ kJ/mol

$(-64.0 + 2(-229.94)] - (-538.06)$

$= +14.18$ kJ/mol

c.) What is the value of ΔG_{rxn} at 50.0°C?

Answer: $+98.17$ kJ/mol

$+273.15$
323.15 K

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

$= 14.18$ kJ/mol $- [(323.15 K)(-0.2599$ kJ/mol K$) = +98.167$ kJ/mol

d.) Is this reaction spontaneous at 50.0°C?

Answer: no

e.) BRIEFLY explain your answer to part d.

ΔG is positive