Exam 2 CHM 112 Spring 2023

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.) Given the reaction 3 A(g) <--> B(g) + C(g), which way would the equilibrium shift if a catalyst was added? 1.) C

a.) toward reactants b.) toward products (c.) no shift

2.) Given the reaction 3 A(g) <--> B(g) + C(g), which way would the equilibrium shift if more of compound A was added to the flask? 2.) B

a.) toward reactants (b.) toward products c.) no shift

3.) Which process is most likely to be nonspontaneous? 3.) A

(a.) water freezing at 32°C b.) sugar dissolving in coffee

c.) a dead tree decomposing d.) helium escaping out of a hole in a balloon

4.) Given the reaction 3 A(g) <--> B(g) + C(g), which way would the equilibrium shift if the external pressure was increased? 4.) B

a.) toward reactants (b.) toward products c.) no shift

5.) Which response best describes equilibrium? 5.) D

a.) The concentrations of reactants and products are equal

b.) The reaction has reached the point where no more reactants or products are being formed

c.) The reaction has begun to form reactants and not products

(d.) The rate of the forward and reverse reactions are equal.

6.) Given the reaction 3 A(g) <--> B(g) + C(g), which way would the equilibrium shift if more of compound C was added? 6.) A

(a.) toward reactants b.) toward products c.) no shift

7.) If the value of K_{eq} for the reaction A (aq) + B (aq) <--> C (aq) is 2.45×10^3, what would be the value of K_{eq} for the reaction C (aq) <--> A (aq) + B (aq)? 7.) D

a.) 6.00×10^6 b.) 4.90×10^3 c.) 1.23×10^{-3} (d.) 4.08×10^{-4}

8.) Which of the following is most likely to result in an increase in entropy? 8.) C

a.) separating a mixture of fruits into bags containing only one kind of fruit

b.) neatly organizing your closet

(c.) dissolving table salt in water

d.) synthesizing one large molecule from five small molecules

9.) Given that the reaction 3 A(g) <--> B(g) + C(g), has an enthalpy of -22.7kJ/mol, which way would the equilibrium shift if the temperature was increased? 9.) A

(a.) toward reactants b.) toward products c.) no shift

10.) If the value of K_{eq} for the reaction A (aq) + B (aq) <--> C (aq) is 2.45×10^3, what would be the value of K_{eq} for the reaction [redacted] $3A_{(aq)} + 3B_{(aq)} \rightleftharpoons 3C_{(aq)}$ 10.) C

a.) 4.90×10^3 b.) 6.00×10^6 (c.) 1.47×10^{10} d.) 7.35×10^3

SHORT ANSWER (10 pts each): Completely answer all of the following questions. Read all questions carefully!!! SHOW ALL WORK. If your work is in a different location, you must make a note of this in the given work area for the problem in order for the work to be considered for partial credit. 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.

$+273.15 = 291.35$

1.) The reaction 2A(g) + B(g) ⟷ 3C(g) has ΔG° = 84.9kJ/mol at 18.2°C. What is the value of ΔG at 18.2°C when A = 1.84atm, B = 0.68atm, and C = 2.53atm?

$Q = \frac{[C]^3}{[A]^2[B]} = \frac{[2.53]^3}{[1.84]^2[0.68]} = 7.034237$ Answer: 89.6 kJ/mol

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

$\Delta G = 84.9\ kJ/mol + (8.314 \times 10^{-3}\ kJ/molK)(291.35K)(\ln(7.034237))$

$\Delta G = 84.9\ kJ/mol + (2.4222839\ kJ/mol)(1.950789)$

$\Delta G = 84.9\ kJ/mol + 4.725365\ kJ/mol$

$\Delta G = 89.625\ kJ/mol$

2.) If the enthalpy of vaporization of benzene (78.114g/mol) is 33.9kJ/mol, what would be the entropy in J/K if 31.5g of benzene was converted to a gas at its boiling point of 80.15°C?

$+273.15 = 353.30K$

$S = \frac{\Delta H}{T}$ Answer: 38.7 J/K

$31.5g\left(\frac{1mol}{78.114g}\right) = 0.403256178mol\left(\frac{33.9kJ}{1mol}\right)$

$= \frac{13.67044\ kJ}{353.30K} = 0.0386935\ \frac{kJ}{K}\left(\frac{1000J}{1kJ}\right) = 38.6935\ J/K$

3.) For the reaction 2A(aq) + 2B(aq) ⟷ 4C(aq) , the value of Kc = 2.62×10^{-3}.

a.) Write the equilibrium expression for this reaction.

$$K_c = \frac{[C]^4}{[A]^2[B]^2}$$

b.) If you start with 3.51M of compound C, what is the equilibrium concentration of each compound? Do not use the approximation method for this question - it is not needed.

	2A	+ 2B	⇌ 4C
I	0	0	3.51
C	+2x	+2x	−4x
E	2x	2x	3.51−4x

Compound A: 1.58 M

Compound B: 1.58 M

Compound C: 0.357 M

$$\sqrt[4]{2.62 \times 10^{-3}} = \frac{[3.51-4x]^4}{[2x]^2[2x]^2} = \sqrt[4]{\frac{[3.51-4x]^4}{16x^4}}$$

$$0.226243 = \frac{3.51-4x}{2x}$$

$$0.452486x = 3.51 - 4x$$

$$+4x \quad +4x$$

$$\frac{4.452486x}{4.452486} = \frac{3.51}{4.452486}$$

$$x = 0.788324$$

$[A] = [B] = 2x = 2(0.788324) = 1.577\,M$

$[C] = 3.51 - 4x = 3.51 - 4(0.788324)$

$= 0.356\,77\,M$

4.) If a given equilibrium process has ΔG° = 12.3 kJ/mol, what is the equilibrium constant for this process at 25.0°C?

$+273.15 = 298.151K$

Answer: 7.00×10^{-3}

$$\Delta G = -RT \ln K$$

$$12.3\ kJ/mol = -(8.314 \times 10^{-3}\ kJ/molK)(298.151K)(\ln K)$$

$$\frac{12.3\ kJ/mol}{-2.478819\ kJ/mol} = \frac{-(2.478819\ kJ/mol)(\ln K)}{-2.478819\ kJ/mol}$$

$$-4.96204 = \ln K$$

$$K = e^{-4.96204} = 6.9986 \times 10^{-3}$$

5.) Use the data in the table provided to calculate the requested values for the reaction below. Note that you may not need to use all values in the table. *Some values do not represent real data.

$K_2CO_3(s) \rightarrow 2K^+(aq) + CO_3^{2-}(aq)$

	$\Delta H°$ (kJ/mol)	$\Delta S°$ (J/molK)		$\Delta H°$ (kJ/mol)	$\Delta S°$ (J/molK)
Ag^+	105.9	73.9	Ag_2CO_3	-505.8	167.4
Cu^+	51.88	-26.4	Cu_2CO_3	-604.3	160.2
K^+	-251.2	102.5	K_2CO_3	-1150.18	155.44
Na^+	-239.66	60.25	Na_2CO_3	-1130.9	135.98
CO_3^{2-}	-676.3	-53.1			

a.) $\Delta H°_{rxn} = \Sigma\Delta H_{prod} - \Sigma\Delta H_{reac}$ Answer a: -28.52 kJ/mol

$[2(-251.2\ kJ/mol) + (-676.3\ kJ/mol)] - [-1150.18\ kJ/mol]$

$= -1178.7\ kJ/mol + 1150.18\ kJ/mol = -28.52\ kJ/mol$

b.) $\Delta S°_{rxn} = \Sigma\Delta S_{prod} - \Sigma\Delta S_{reac}$ Answer b: -3.54 J/molK

$[2(102.5\ J/molK) + (-53.1\ J/molK)] - [155.44\ J/molK]$

$151.9\ J/molK - 155.44\ J/molK = -3.54\ J/molK$

c.) $\Delta G°_{rxn}$ at 25.0°C Answer c: -27.46 kJ/mol

$\Delta G = \Delta H - T\Delta S = -28.52\ kJ/mol - [(298.15K)(-3.54 \times 10^{-3}\ kJ/molK)$

$= -28.52\ kJ/mol + 1.05545\ kJ/mol = -27.46\ kJ/mol$

d.) Is this reaction spontaneous at 25.0°C? Answer d: yes

e.) Briefly explain your answer to part d.

ΔG is negative

6.) For the reaction W (aq) + 3X (aq) ⟷ 2Y (l) + Z (aq), the equilibrium concentrations are 2.48M W, 1.69M X, 1.16mL Y, and 2.08M Z.

a.) Write the equilibrium expression for this reaction.

$K_{eq} = \dfrac{[Z]}{[W][X]^3}$ liquids not included!

b.) What is the value of K_{eq} for this reaction? Answer: 0.174

$K_{eq} = \dfrac{[2.08]}{[2.48][1.69]^3} = \dfrac{2.08}{11.970488} = 0.17376$

c.) If the concentrations of both compound X and compound Z were doubled, what would be the value of Q?

$Q = \dfrac{[2.08 \times 2]}{[2.48][1.69 \times 2]^3} = \dfrac{[4.16]}{[2.48][3.38]^3} = \dfrac{4.16}{95.76389} = 0.04344$ Answer: 0.0434

d.) If the concentrations of both compound X and compound Z were doubled as in part C, would the reaction shift toward the reactants or toward the products?

Answer: products

e.) Briefly explain your answer to part d.

$Q < K$ so the denominator is too large = too many reactants

7.) a.) The reaction $2X + 3Y \rightarrow Z$ has the overall rate law: Rate = $k[X]^2[Y]$. Which of the following options provides the best potential mechanism for this reaction?

Option A:
Step 1: $2X + Y \rightarrow M$ $k[X]^2[Y]$
Step 2: $M + 2Y \rightarrow Z$ $k[M][Y]^2$
$2X + 3Y \rightarrow Z$

Option B:
Step 1: $2X \rightarrow M$
Step 2: $M + 2Y \rightarrow Z$
$2X + 2Y \rightarrow Z$

Option C:
Step 1: $2X \rightarrow M$ $k[X]^2$
Step 2: $M + 3Y \rightarrow Z$
$2X + 3Y \rightarrow Z$

Option D:
Step 1: $2X + Y \rightarrow M$
Step 2: $M + Y \rightarrow Z$
$2X + 2Y \rightarrow Z$

Answer a: Option A

b.) Which step (1 or 2) is the rate limiting step? Answer b: Step 1

c.) Briefly explain your answer to part b.

Rate = $k[X]^2[Y]$; matches rate of overall reaction

d.) Does this reaction involve an intermediate? Answer d: yes

e.) Briefly explain your answer to part d.

M is formed in step 1 then used up in step 2. It is not a product or reactant in the overall reaction.