CHEM 1032
Spring 2023
UNIT ASSESSMENT 2

SECTION: _____

NAME: KEY

TUID: | | | | | | | | | |

Before the Unit Assessment begins, read the rest of this page, and follow the instructions.

!!! Do not turn this page until given the signal to begin !!!

Put away everything besides pencil(s) and a scientific calculator.

- Non-programmable (scientific) calculators are permitted. Graphing calculators **are not permitted** (such as these models: TI-83, TI-84, TI-89, Casio FX-9750).
- Any other electronic devices - including cell phones, smart phones, and smart watches - **are not permitted**. If you are not sure what is permitted, ask *before* the exam begins.

When you are told to begin work, open the booklet and read the directions.

A periodic table and other useful information can be found on the next page.

Grading. Each question is graded by your instructor using the scale below.

1 - Excellent
- The student demonstrates a deep understanding of concepts and problem-solving techniques.
- Calculations are clear and legibly written.
- Any mistakes are minor or careless errors that do not indicate a major conceptual misunderstanding.

0.5 - Fair
- The student demonstrates a partial understanding of concepts and techniques.
- Calculations are clear and legibly written but contain errors.
  - The student may have started out correctly but gone on a tangent or not finished the problem.
  - The student may have used pattern matching to answer a different, more familiar question instead.

0 - Unsatisfactory/Incomplete
- The student did not demonstrate an understanding of the problem or has minimal understanding.
- Calculations are unclear, missing, or incomplete.
  - The student may have written some appropriate formulas or diagrams, but nothing further.
  - The student may have done something entirely wrong.
  - The student may have written almost nothing or nothing at all.

Unit Assessment Time: 50 minutes.
It is to your advantage to answer every question.

!!! Do not turn this page until given the signal to begin !!!

Units:

amu	*atomic mass unit*
atm	*atmosphere*
g	*gram*
h	*hour*
J	*joule*
K	*kelvin*
mmHg	*unit of pressure*
M	*molarity*
K	*kelvin*
L	*liter*
mol	*mole*
s	*second*

Symbols:

H	*enthalpy*
ν	*frequency*
M	*molar mass*
mol	*mole*
P	*pressure*
t	*time*
T	*temperature*
V	*volume*

Constants:

N_A	*Avogadro's number*
R	*ideal gas constant*

SI (Metric) Prefixes:

c	*centi-*
d	*deci-*
k	*kilo-*
m	*milli-*

1	2		3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 H 1.008																		2 He 4.0026
3 Li 6.94	4 Be 9.0122												5 B 10.81	6 C 12.011	7 N 14.007	8 O 15.999	9 F 18.998	10 Ne 20.180
11 Na 22.990	12 Mg 24.305												13 Al 26.982	14 Si 28.085	15 P 30.974	16 S 32.06	17 Cl 35.45	18 Ar 39.948
19 K 39.098	20 Ca 40.078(4)		21 Sc 44.956	22 Ti 47.867	23 V 50.942	24 Cr 51.996	25 Mn 54.938	26 Fe 55.845(2)	27 Co 58.933	28 Ni 58.693	29 Cu 63.546(3)	30 Zn 65.38(2)	31 Ga 69.723	32 Ge 72.630(8)	33 As 74.922	34 Se 78.971(8)	35 Br 79.904	36 Kr 83.798(2)
37 Rb 85.468	38 Sr 87.62		39 Y 88.906	40 Zr 91.224(2)	41 Nb 92.906(2)	42 Mo 95.95	43 Tc	44 Ru 101.07(2)	45 Rh 102.91	46 Pd 106.42	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.76	52 Te 127.60(3)	53 I 126.90	54 Xe 131.29
55 Cs 132.91	56 Ba 137.33	57-70 *	71 Lu 174.97	72 Hf 178.49(2)	73 Ta 180.95	74 W 183.84	75 Re 186.21	76 Os 190.23(2)	77 Ir 192.22	78 Pt 195.08	79 Au 196.97	80 Hg 200.59	81 Tl 204.38	82 Pb 207.2	83 Bi 208.98	84 Po	85 At	86 Rn
87 Fr	88 Ra	89-102 **	103 Lr	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Nh	114 Fl	115 Mc	116 Lv	117 Ts	118 Og

57 La 138.91	58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm [144.91]	62 Sm 150.36(2)	63 Eu 151.96	64 Gd 157.25(3)	65 Tb 158.93	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.05
89 Ac [227.03]	90 Th 232.04	91 Pa 231.04	92 U 238.03	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No

!!!! FOR CREDIT, BE CLEAR AND WRITE LEGIBLY !!!!

One of the most discussed molecules in the atmosphere is ozone (O_3), as it protects the Earth from high energy ultraviolet light. The molecular decomposition of ozone can occur either by reaction A or reaction B, shown below:

Reaction A: $2\ O_{3\ (g)} \rightleftharpoons 3\ O_{2\ (g)}$ $K_P = 1.64 \times 10^{57}$

Reaction B: $2\ O_{3\ (g)} + O_{(g)} \rightleftharpoons 3\ O_{2\ (g)}$ $\Delta G°_{rxn} = -402.8$ kJ/mol

Part I – Multiple Choice Questions (1 pt each)

Excellent Answer = 1 pt *Fair Answer = 0.5 pts* *Unsatisfactory Answer = 0 pts*

C 1. For Reaction A, what is the likely sign of $\Delta S°_{sys}$?

fewer moles gas → more moles gas

→ more dispersal

A. Negative, the products have a higher entropy than the reactants.
B. Negative, the reactants have a higher entropy than the products.
C. Positive, the products have a higher entropy than the reactants.
D. Positive, the reactants have a higher entropy than the products.

D 2. What is the equilibrium expression for Reaction B?

½ credit → A. $K_P = \frac{[O_2]^3}{[O_3]^2[O]}$ B. $K_P = \frac{(P_{O_3})^2(P_O)}{(P_{O_2})^3}$ C. $K_P = \frac{(P_{O_2})}{(P_{O_3})(P_O)}$ D. $K_P = \frac{(P_{O_2})^3}{(P_{O_3})^2(P_O)}$

B 3. Which reaction has a larger K value?

$-402.8\ kJ/mol \rightarrow 402800\ J/mol$

$\Delta G° = -RT\ln K$

$-402800\ J/mol \cdot K = -8.314 \cdot 298 \cdot \ln K$

$e^{+162.6} = \ln K$

$K = 4.04 \times 10^{70}$

A. Reaction A
B. Reaction B
C. Reaction A and B have equivalent K values.
D. There is not enough information.

C 4. If Reaction A were held in a container at equilibrium and the volume of the container were decreased to ¾ of its original value, what would you expect to occur?

V ↓ P ↑ ∴ need to decrease gas moles

2 mol gas ⇌ 3 mole gas ←

A. The reaction would shift forward to decrease pressure.
B. The reaction would shift forward to increase pressure.
C. The reaction would shift backward to decrease pressure.
D. The reaction would shift backward to increase pressure.

D 5. The $\Delta G°_f$ of $O_{3\ (g)}$ is 163.2 kJ/mol. What is the $\Delta G°_f$ of $O_{(g)}$?

$\Delta G°_{rxn} = \sum$ Products $- \sum$ Reactants

$-402.8\ kJ/mol = 0 - ((2 \cdot 163.2\ kJ/mol) + x))$

$x = +76.4\ kJ/mol$

A. -29.2 kJ/mol
B. 29.2 kJ/mol
½ credit → C. -76.4 kJ/mol
D. 76.4 kJ/mol

Part II – Open Answer Questions – *See Page 1 for full grading details*

Excellent Answer = 1 pt *Fair Answer = 0.5 pts* *Unsatisfactory Answer = 0 pts*

6. A container is found to contain 1.620 atm $O_{3\,(g)}$ and 1.620 atm $O_{2\,(g)}$. Using Reaction A, is the container at equilibrium? Quantitatively support your answer and **explain** if the reaction will shift forward or backward.

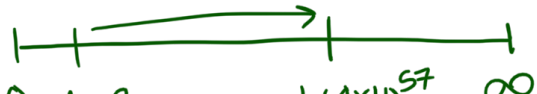
Show your work in this box.

$Q = \frac{[O_2]^3}{[O_3]^2}$

$Q = \frac{(1.620)^3}{(1.620)^2}$

$Q = 1.62$

$Q < K_p$



The reaction is not at equilibrium because the Q is significantly less than K. This indicates that the reaction has many more reactants present than what should be present at equilibrium. The reaction will need to shift forward to make more products to reach equilibrium.

CIRCLE ONE →	*Is the reaction at equilibrium?* *YES* (*NO*)	**CIRCLE ONE →**	*Shift?* (*FORWARD*) *BACKWARD*

7. Is Reaction B primarily controlled by entropy or enthalpy? Clearly explain your answer and include hypothesized signs of $\Delta S°_{rxn}$ and $\Delta H°_{rxn}$.

Explain your answer here…

Reaction B is $2O_{3\,(g)} + O_{(g)} \rightleftharpoons 3O_{2\,(g)}$.

The $\Delta G°_{rxn}$ is -402.8 ← spontaneous.

The spontaneous options are

	$\Delta H°_{rxn}$	$\Delta S°_{rxn}$
all T	−	+
at low T	−	−
at high T	+	+

→ $\Delta S°_{rxn}$ looks to be slightly (−) or no real change.

→ Thus $\Delta H°_{rxn}$ must be largely negative for reaction to be so (+) with $\Delta G°_{rxn}$.

→ Thus reaction is driven by Enthalpy

8. The molar entropies of $O_{3\,(g)}$ and $O_{2\,(g)}$ are similar in value. Explain why this is true and hypothesize which molar entropy would be larger and why?

Explain your answer here….

The molecules are both gases therefore they similiar S° values. This is because the gas phase has the most dispersial of all phases. The molecules have a lot of KE and are moving, thus there are many energy equivalent ways to distribute the system.

$S^\circ O_3 > S^\circ O_2$ because O_3 is a more structurally complex molecule.

9. A mixture combining O_3, O, and O_2 results in a reaction quotient for Reaction B of 3.0×10^{15}. Under these conditions, is the forward reaction spontaneous? Support your answer quantitatively by solving for a thermodynamic value.

Show your work in this box.

$-402.8\ kJ/mol\,K \rightarrow -402800\ J/mol\ K$

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

$\Delta G = -402800\ J/mol + (8.314\ J/mol \cdot K \cdot 298\ K \cdot \ln(3.0 \times 10^{15}))$

$\Delta G = -402800\ J/mol + 88294\ J/mol$

$\Delta G = -314505\ J/mol$

$\hookrightarrow -314.5\ kJ/mol$

Under these conditions the reaction is spontaneous in the forward direction.

ANSWER HERE → *Write value here…* $-314.5\ kJ/mol$

10. Another ozone decomposition reaction occurs with nitric oxide (NO). Using the reaction below determine the equilibrium concentration of $O_{2\,(g)}$ if the initial concentrations of the reactants are both 0.50 M.

$$NO_{(g)} + O_{3\,(g)} \rightleftharpoons NO_{2\,(g)} + O_{2\,(g)} \qquad K = 5.8 \times 10^{-34}$$

Show your work in this box.

	NO	O_3	$\rightleftharpoons$	NO_2	O_2
I	0.50	0.50		0	0
C	$-x$	$-x$		$+x$	$+x$
E	$0.50-x$	$0.50-x$		x	x

$$K = \frac{[NO_2][O_2]}{[NO_3][O_3]}$$

$$5.8\times10^{-34} = \frac{(x)(x)}{(0.50-x)(0.50-x)}$$

$$\sqrt{5.8\times10^{-34}} = \sqrt{\frac{(x)^2}{(0.50-x)^2}}$$

$$2.41\times10^{-17} = \frac{x}{0.50-x}$$

$$1.20\times10^{-17} - 2.41\times10^{-17}x = x$$

$$1.20\times10^{-17} = x$$

$[O_2]$ at eq $= x$

$= 1.20\times10^{-17}$ M

ANSWER HERE → *Write equilibrium O_2 M here…*

1.20×10^{-17} M

END OF EXAM
!!! DON'T FORGET TO CHECK YOUR WORK !!!!

Useful information:

$1\ atm = 760\ mmHg = 101.3\ kPa$ $\qquad R = 8.314\frac{J}{mol\cdot K} == 0.08206\ \frac{L\cdot atm}{mol\cdot K}$

0 ºC = 273 K

$\Delta G° = \Delta H° - T\Delta S°$ $\qquad \Delta G_{rxn} = \Delta G^{o}_{rxn} + RT\ln Q$ $\qquad \Delta G^{o}_{rxn} = -RT\ln K$ $\qquad K_P = K_C(RT)^{\Delta n}$

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