CHEM 1032
PRACTICE
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 !!!!

Dinitrogen tetraoxide (N_2O_4 – 92.010 g/mol) is used as rocket fuel because it can be stored as a liquid at room temperature and is explosive when mixed with certain reactants. One downside to the use of N_2O_4 is that in the gaseous form it can degrade into nitrogen dioxide (NO_2 – 46.006 g/mol) under standard conditions according to the equilibrium below.

$$\underset{\text{colorless}}{N_2O_4\,(g)} \rightleftharpoons \underset{\text{yellow}}{2\,NO_2\,(g)} \qquad K_C\ 0.0059 \text{ at } 298\text{ K}$$

Part I – Multiple Choice Questions (1 pt each)

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

C 1. How would you characterize the reaction?

K <<< 1 reactant favored

ΔG° +

A. Reactants favored with a negative $\Delta G°$.
B. Products favored with a negative $\Delta G°$.
C. Reactants favored with a positive $\Delta G°$.
D. Products favored with a positive $\Delta G°$.

$\Delta G° = -RT\ln K = -(8.314\,J/mol\,K \cdot 298\,K \cdot \ln 0.0059)$
$= +12.7\ kJ/mol$

C 2. If a closed vessel containing the reaction at equilibrium were expanded, causing an increase in volume, what would you expect to occur?

1 mole g $\rightleftharpoons$ 2 mole g $\longrightarrow$

$\uparrow V \ \downarrow P$

A. The reaction would shift forward since pressure increased.
B. The reaction would shift backwards since pressure increased.
C. The reaction would shift forward since pressure decreased.
D. The reaction would shift backwards since pressure decreased.

D 3. If the reaction were completed in reverse, what would be the value of K?

$\frac{1}{K} = \frac{1}{0.0059} = 169$

A. -0.0059
B. 0.0118
C. 3.5×10^{-5}
D. 169

A 4. The standard molar entropy (S°) of gaseous N_2O_4 is 304.4 J/mol K. What is true?

$S^\circ_s < S^\circ_l << S^\circ_g$

more disorder $\longrightarrow$

A. The S° for liquid N_2O_4 is smaller than the gas phase value.
B. The S° for liquid N_2O_4 is larger than the gas phase value.
C. The S° for solid N_2O_4 will be the same as the gas phase value.
D. There is not enough information to answer the question.

B 5. The enthalpy of the reaction above is 57.2 kJ/mol. If a sealed container of the reaction at equilibrium were put on ice, what would you expect to occur?

→ cold, lose heat

+57.2 kJ/mol = Endo = heat reactant

A. The reaction would become more yellow.
B. The reaction would become less yellow.
C. The reaction is at equilibrium, no shift will occur.
D. More information is needed.

$\text{heat} + \underset{\text{colorless}}{N_2O_{4(g)}} \rightleftharpoons \underset{\text{yellow}}{2\,NO_{2(g)}}$

$\downarrow \quad \longleftarrow$

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*

$$N_2O_4\,(g) \rightleftharpoons 2\,NO_2\,(g) \qquad K_C\ 0.0059 \text{ at } 298\text{ K}$$

6. Determine the concentration of N_2O_4 at equilibrium if its initial concentration is 0.540 M.

Show your work in this box.

	N_2O_4	$\rightleftharpoons$	$2\,NO_2$
I	0.540		0
C	$-x$		$+2x$
E	$0.540-x$		$+2x$

$$K = \frac{[NO_2]^2}{[N_2O_4]}$$

$$0.0059 = \frac{(2x)^2}{0.540-x}$$

$$0.003186 - 0.0059x = 4x^2$$

$$4x^2 + 0.0059x - 0.003186$$

$$\frac{-0.0059 \pm \sqrt{0.0059^2 - 4(4)(-0.003186)}}{2(4)}$$

$$\frac{-0.0059 \pm 0.2258}{8}$$

$$x = 0.0275$$

$$[N_2O_4] = 0.540 - 0.0275 = 0.513\text{ M}$$

ANSWER IN THIS BOX → *Write equilibrium concentration here….* 0.513 M

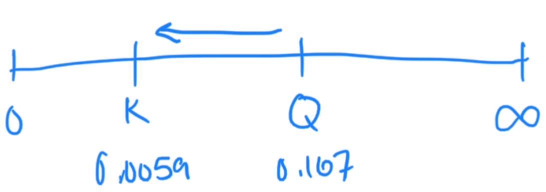
7. At some point in the reaction, the concentration of N_2O_4 is 0.234 M and NO_2 is 0.198 M. Is the reaction at equilibrium? Quantitatively prove your answer and explain which way the reaction will shift, if not at equilibrium.

Show your work in this box.

$$Q = \frac{[NO_2]^2}{[N_2O_4]}$$

$$Q = \frac{(0.198)^2}{0.234}$$

$$Q = 0.167$$



Reaction is not at equilibrium. The reaction quotient is 0.167, which is greater than K. This means there are more products present in this scenario than are present at equilibrium. The reaction needs to shift backwards in order to turn products into reactants.

CIRCLE ONE → *Is the reaction at equilibrium?*

YES *NO*

$N_2O_4\,(g) \rightleftharpoons 2\,NO_2\,(g)$ K_C 0.0059 at 298 K

8. The enthalpy of the reaction is 52.7 kJ/mol. The molar entropy of N_2O_4 (g) is 304.4 J/mol K. The molar entropy of NO_2 (g) is 240.1 J/mol K. Is the reaction always spontaneous? Always nonspontaneous? Or temperature dependent? Circle one and explain your answer.

Always Spontaneous	*Always Nonspontaneous*	*Spontaneous at High Temps*	*Spontaneous at Low Temps*

Explain your answer here….

$\Delta H^\circ_{rxn} = +52.7$ kJ/mol ← endothermic

$\Delta S^\circ_{rxn} = \Sigma$ products $- \Sigma$ reactants

$= (2 \cdot 240.1$ J/mol K$) - (304.4$ J/mol·K$)$

$= +175.8$ J/mol·K ← entropy increases

When $\Delta H^\circ(+)$ and $\Delta S^\circ(+)$ the reaction is spontaneous at high temps. This is because the $\Delta S(+)$ is already favored but ΔH being endothermic means it requires heat. At higher temps more heat is available.

9. Imagine you place only pure NO_2 (g) into a sealed container. Considering the reaction below, and the one at the top of this page, what do you expect to be the majority component(s) after equilibrium is reached? Circle one and explain your answer.

$N_2(g) + 2\,O_2(g) \rightleftharpoons 2\,NO_2(g)$ K_C 8.2×10^{-9} $1/8.2\times10^{-9}$

NO_2 (g)	*N_2O_4 (g)*	*N_2 (g) and O_2 (g)*

Explain your answer here….

If $NO_{2(g)}$ were put into container . . .

$2\,NO_{2(g)} \rightleftharpoons N_{2(g)} + 2\,O_{2(g)}$ $K_1 = 1.22\times10^8$

or

$2\,NO_{2(g)} \rightleftharpoons N_2O_{4(g)}$ $K_2 = 169$

The K of the first equation is much larger than K of second. The first K is also much greater than 1, so many products will form.

10. The enthalpy of the reaction is 52.7 kJ/mol. When will the entropy of the surroundings be the largest, at high temperature or low temperature? Explain your answer.

$$N_2O_4\,(g) \rightleftharpoons 2\,NO_2\,(g)$$

Explain here…

$\Delta H^{\circ}_{rxn} = 52.7\ kJ/mol$ Endothermic, will pull heat from surroundings, so ΔS_{surr} (−). This means it will always be negative. The change of $|\Delta S_{surr}|$ will be the largest (most negative) at low temps as the heat pulled will cause a larger decrease in S than at high temps.

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

$\Delta G° = \Delta H° - T\Delta S°$ $\quad$ $\Delta G_{rxn} = \Delta G^{o}_{rxn} + RT\ln Q$ $\quad$ $\Delta G^{o}_{rxn} = -RT\ln K$

USE THIS PAGE FOR SCRAP. IT WILL NOT BE GRADED.

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