Chemistry 112-2014, Vining NAME: **Answer Key**

Exam #3 **Take Home Version**

1. When the reversible reaction, $N_2 + O_2 \rightleftarrows 2\ NO$, has reached a state of dynamic equilibrium, which statement below is true?

(a) Both the forward and reverse reactions stop completely and no more NO, N_2 or O_2 are produced.

(b) The rate of the forward reaction equals the rate of the reverse reaction.

(c) The rate constant of the forward reaction equals the rate constant of the reverse reaction.

2. For the reaction $2\ SO_2Cl_2(g) \rightleftarrows 2\ SO_2(g) + Cl_2(g)$, the expression for K_{eq} is

(a) $K_{eq} = \frac{[SO_2]^2[Cl_2]^2}{[SO_2Cl_2]^2}$

(d) $K_{eq} = \frac{[SO_2]^2[Cl_2]}{[SO_2Cl_2]}$

(b) $K_{eq} = \frac{[SO_2]^2[Cl_2]}{[SO_2Cl_2]^2}$

(e) $K_{eq} = \frac{[SO_2Cl_2]^2}{[SO_2]^2[Cl_2]}$

(c) $K_{eq} = \frac{2[SO_2]^2[Cl_2]}{2[SO_2Cl_2]^2}$

3. The equilibrium $2\ SO_2Cl_2(g) \rightleftarrows 2\ SO_2(g) + Cl_2(g)$ has an equilibrium constant of K = 22.6. What is the value of K for the equilibrium written as: $SO_2(g) + ½\ Cl_2(g) \rightleftarrows SO_2Cl_2(g)$?

(a) 22.6 (b) 0.0442 (c) 511 (d) 0.00196 **(e) 0.210**

Reaction is reversed and multiplied by 1/2. Reversing the reaction leads to the inverse. Multiplying by a constant, raise K to the power of that constant. So, $K_2 = 1/K_1^{0.5} = 0.210$.

4. Consider the system, $2\ CH_2Cl_2(g) \rightleftarrows CH_4(g) + CCl_4(g)$, which has an equilibrium constant of K = 2.4. If a system has:

$[CH_2Cl_2] = 0.22$ M
$[CH_4] = 1.64$ M
$[CCl_4] = 0.58$ M

then, (a) the system is at equilibrium

(b) the system is not at equilibrium and will react to form more CH_2Cl_2

(c) the system is not at equilibrium and will react to form more CH_4 and CCl_4

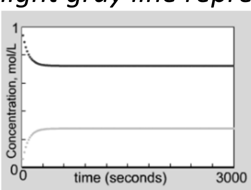
$Q = \frac{[CH_4][CCl_4]}{[CH_2Cl_2]^2} = \frac{1.64 \times 0.58}{0.22^2} = 19.7 > K$ Because Q>K, not at equilibrium, shifts left

5. The following system is at equilibrium $CH_4(g) + CCl_4(g) \rightleftarrows 2\ CH_2Cl_2(g)$.

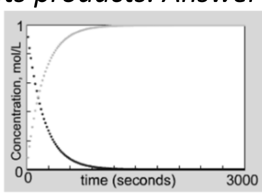
If CCl_4 is added to the sample, what will then happen to the concentrations of CH_4 and of CH_2Cl_2?

(a) both $[CH_4]$ and $[CH_2Cl_2]$ will increase
(b) both $[CH_4]$ and $[CH_2Cl_2]$ will decrease
(c) $[CH_4]$ will decrease and $[CH_2Cl_2]$ will increase--- reaction shift right, using CH_4, making CH_2Cl_2
(d) $[CH_4]$ will increase and $[CH_2Cl_2]$ will decrease
(e) $[CH_4]$ will remain constant and $[CH_2Cl_2]$ will increase

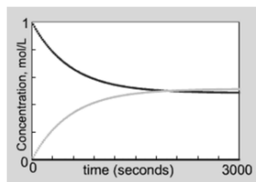
Questions 6-7 use the following concentration-time plots. The black line represents reactants and the light gray line represents products. Answer with the correct letter.



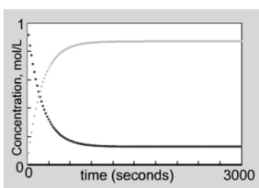
a.



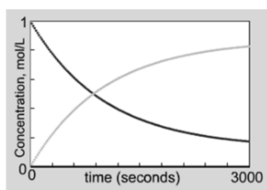
b.



c.



d.



e.

6. Which reaction goes to completion? ***(b)--- reactant concentration drops to zero***

7. Which reaction has the smallest equilibrium constant? ***(a) --- smallest [products]***

8. What is the conjugate base of $HC_2O_4^-$? ***Remove an H^+***

(a) $H_2C_2O_4$ (b) $H_3C_2O_4^+$ (c) $2\ CO_2$ ***(d) $C_2O_4^{2-}$***

9. What is the pH of a 0.000483 M solution of NaOH?
This is a strong base, so [OH-] = 0.000483
pOH = -log(0.000483) = 3.31; pH = 14.00 – 3.31 = 10.68

(a) 4.83×10^{-4} (b) 2.07×10^{-11} (c) 3.31 ***(d) 10.68*** (e) 7.00

10. What are $[H_3O^+]$ and $[OH^-]$ for a solution that has a pH of 9.0?

(a) $[H_3O^+] = 9$ M and $[OH^-] = 5$ M

(b) $[H_3O^+] = 5$ M and $[OH^-] = 9$ M

(c) $[H_3O^+] = 1 \times 10^9$ M and $[OH^-] = 1 \times 10^5$ M

(d) $[H_3O^+] = 1 \times 10^{-5}$ M and $[OH^-] = 1 \times 10^{-9}$ M

(e) $[H_3O^+] = 1 \times 10^{-9}$ M and $[OH^-] = 1 \times 10^{-5}$ M

11. Which of the following are the pH ranges expected for solutions of NH_4NO_3 and KCN?

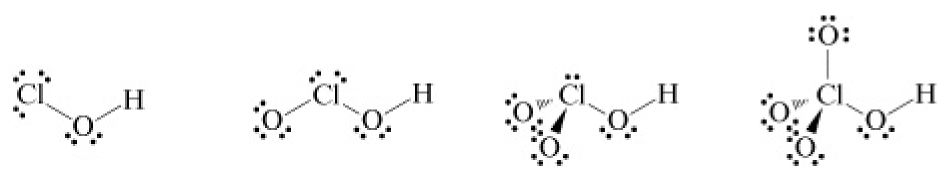
a) NH_4NO_3 is acidic and KCN is basic

b) NH_4NO_3 is acidic and KCN is neutral

c) NH_4NO_3 is basic and KCN is basic

d) NH_4NO_3 is neutral and KCN is acidic

12. Which of the following acids has the largest K_a value? ***(d) has the most electronegative O atoms***



(a) (b) (c) (d)

13. Consult the table of K_a values provided. Is it possible for a solution of hydrofluoric acid to have a higher pH than a solution of formic acid? That's all the information you are given- don't ask for more.

(a) yes (b) no (c) it is impossible to answer

Although HF is a stronger acid, pH depends on both Ka and the acid concentration.

14. A chemical system has an equilibrium constant of 1.4×10^{-6}. This means:

(a) ΔG^o is positive and the system is reactant-favored

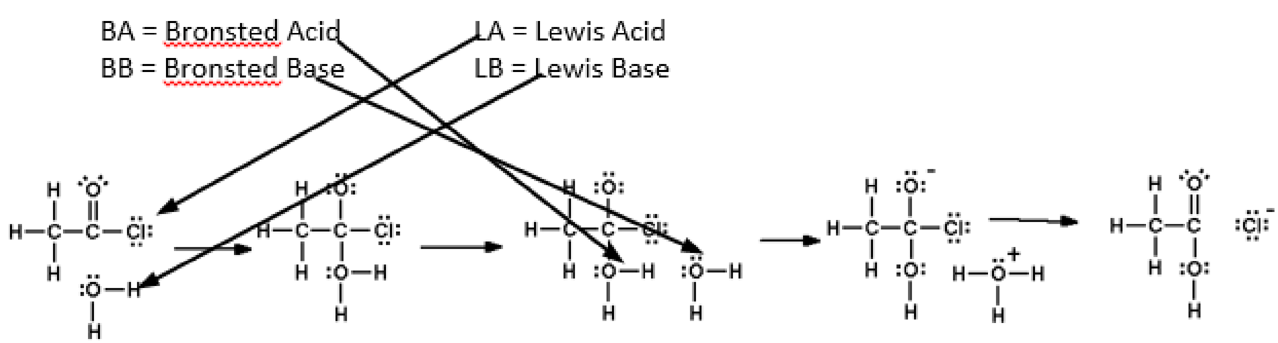
Exam **#3B:** ANSWER SHEET Name: ______________________

1.	a	b	c	d	e	8.	a	b	c	d	e
2.	a	b	c	d	e	9.	a	b	c	d	e
3.	a	b	c	d	e	10.	a	b	c	d	e
4.	a	b	c	d	e	11.	a	b	c	d	e
5.	a	b	c	d	e	12.	a	b	c	d	e
6.	a	b	c	d	e	13.	a	b	c	d	e
7.	a	b	c	d	e	14.	a	b	c	d	e

15. Write the net-ionic equation for the acid-base reaction occurring between HClO and KOH.

HClO is a weak acid: $\boldsymbol{HClO(aq) + HO^{-}(aq) \rightarrow H_2O(l) + ClO^{-}(aq)}$

16. Consider the following set of reaction steps. Add the following labels to the species they represent. Point to the species and add the label. You label four things in total. If something is both Lewis and Bronsted, label it Bronsted. For example, find something that is acting as a Lewis Acid and draw and arrow to it labeled with "LA."



17. For each of the following, circle the one that will have the higher pH (or circle they are the same):

a. 0.1 M CH_3CO_2H	or	***0.1 M $NaCH_3CO_2$***	or	same
b. 0.1 M HCl	or	***0.1 NaOH***	or	same
c. 0.1 M HCl	or	0.1 M HNO_3	or	***same***

18. A student ran the following reaction in the laboratory at **450** K: $\mathbf{PCl_5}(g) \rightleftarrows \mathbf{PCl_3}(g) + \mathbf{Cl_2}(g)$
When she introduced **0.789** moles of $\mathbf{PCl_5}(g)$ into a 1.00 liter container, she found the equilibrium concentration of $\mathbf{Cl_2}(g)$ to be **0.0312** M. Calculate the equilibrium constant, K_c.

	$\mathbf{PCl_5}(g)$	$\rightleftarrows$	$\mathbf{PCl_3}(g)$	+	$\mathbf{Cl_2}(g)$
I	**0.789**		**0**		**0**
C	**-x**		**+x**		**+x**
E	**0.789-x**		**x**		**0.0312**

X = 0.0312
[PCl5]eq = 0.789 – 0.0312 = 0.7578 M
[PCl3]eq = [Cl2] = x = 0.0312 M

$$K = \frac{[\mathrm{PCl_3}][\mathrm{Cl_2}]}{[\mathrm{PCl_5}]} = \frac{x \cdot x}{0.789 - x} = \frac{(0.0312)^2}{0.7578} = 0.00128$$

19. Butene isomerizes to form cyclobutane.

butene $\rightleftarrows$ cyclobutane K = 6.0

If a sample of 1.00 M butene is placed in a flask and allowed to react, what will [cyclobutane] be once equilibrium is established?

	butene	$\rightleftarrows$	cyclobutane
I	**1.00**		**0**
C	**-x**		**+x**
E	**1.00 – x**		**x**

K = 6.0 = x/(1-x)
6 – 6x = x
6 = 7x
X = 6/7 = 0.857 M = [cyclobutane]

20 in-class version. What is the pH of a 0.30 M solution of CH_3CO_2H?

CH_3CO_2H is a weak acid.

	$CH_3CO_2H + H_2O$	$\rightleftarrows$ H_3O^+	+ $CH_3CO_2^-$
I	0.30	0	0
C	-x	+x	+x
E	0.30 – x	x	x

$K_a = 1.8 \times 10^{-5} = x^2/(0.30\text{-}x) \approx x^2/0.30$ $\quad x = (1.8 \times 10^{-5} \cdot 0.30)^{1/2} = 0.00232M = [H_3O^+]$

The above estimation is allowed because 0.30 is more than 100x greater than K_a.

$pH = -\log[H_3O^+] = 2.63$

20 take-home version. What is the pH of a 0.0030 M solution of HF?

HF is a weak acid.

	$HF + H_2O$	$\rightleftarrows$ H_3O^+	+ F^-
I	0.30	0	0
C	-x	+x	+x
E	0.30 – x	x	x

$K_a = 7.4 \times 10^{-4} = x^2/(0.0030\text{-}x)$

The estimation that $0.0030 - x \approx x^2/0.0030$ is not allowed. X must be found using the quadratic.

$x = \ = 0.001165 = [H_3O^+]$

$pH = -\log[H_3O^+] = 2.93$

21. A 0.100 M solution of a weak acid, HA, has pH = 3.88 at 25 °C and pH = 3.10 at 55 °C. What are ΔH^o and ΔS^o for the weak acid ionization reaction?

Pathway:

1. for each temperature, pH → $[H_3O^+]$ → K → ΔG^o
2. compare ΔG^o at different temperatures to find ΔS^o
3. use ΔG^o and ΔS^o at one temperature to find ΔH^o

25 °C = 298 K $[H_3O^+] = 10^{-3.88} = 1.32e^{-4}$ M

$K_a = (1.32e\text{-}4)^2/(0.1000 - 1.32e^{-4}) = 1.745e^{-7}$

$\Delta G^o(298) = -RT \ln K = -8.314$ J/K mol x 298 K x $\ln(1.745e^{-7}) = +38{,}554$ J

55 °C = 328 K $[H_3O^+] = 10^{-3.10} = 7.94e^{-4}$ M

$K_a = (7.94e\text{-}4)^2/(0.1000 - 7.94e^{-4}) = 6.360e^{-6}$

$\Delta G^o(298) = -RT \ln K = -8.314$ J/K mol x 328 K x $\ln(6.360e^{-6}) = +32{,}630$ J

$$\begin{aligned} 38554\ \text{J} &= \Delta H^o - 298\ \text{K}\ \Delta S^o \\ -[33630\ \text{J} &= \Delta H^o - 328\ \text{K}\ \Delta S^o] \\ \hline 5924\ \text{J} &= +30\ \text{K}\ \Delta S^o \end{aligned}$$

$\Delta S^o = 5924/30$ J/K = 197 J/K

$\Delta H^o = 38554$ J + 298 K ΔS^o = 38554 J + 298 K (197 J/K) = +97,400 J = 97.4 kJ

Alternate to steps 2 and 3:

$$\ln\frac{K_2}{K_1} = \frac{\Delta H^o}{R}\left[\frac{1}{T_2} - \frac{1}{T_1}\right]$$ insert K and T values and solve for ΔH^o = 97400 J

use ΔG^o and ΔH^o at one temperature to find ΔS^o.

Useful Information

$pH = -\log[H_3O^+]$ $pOH = -\log[OH^-]$ $K_w = 1.0 \times 10^{-14}$ at 25 °C

$[H_3O^+] = 10^{-pH}$ $[OH^-] = 10^{-pOH}$ $\Delta G^o = -RT \ln K$ $\Delta G = \Delta G^o + RT \ln Q$

K_a and K_b Values					
Name of Acid	**Acid**	**K_a**	**Name of Base**	**Base**	**K_b**
Hydrogen sulfate ion	HSO_4^-	1.2×10^{-2}	sulfate ion	SO_4^{2-}	8.3×10^{-13}
Phosphoric acid	H_3PO_4	7.5×10^{-3}	dihydrogen phosphate ion	$H_2PO_4^-$	1.3×10^{-12}
Hexaaquairon(III) ion	$Fe(H_2O)_6^{3+}$	6.3×10^{-3}	pentaaquahydroxoiron(III) ion	$Fe(H_2O)_5OH^{2+}$	1.6×10^{-12}
Hydrofluoric acid	HF	7.4×10^{-4}	fluoride ion	F^-	1.4×10^{-11}
Formic acid	HCO_2H	1.8×10^{-4}	formate ion	HCO_2^-	5.6×10^{-11}
Benzoic acid	$C_6H_5CO_2H$	6.3×10^{-5}	benzoate ion	$C_6H_5CO_2^-$	1.6×10^{-10}
Acetic acid	CH_3CO_2H	1.8×10^{-5}	acetate ion	$CH_3CO_2^-$	5.6×10^{-10}
Hexaaquaaluminum ion	$Al(H_2O)_6^{3+}$	7.9×10^{-6}	pentaaquahydroxoaluminum ion	$Al(H_2O)_5OH^{2+}$	1.3×10^{-9}
Carbonic acid	H_2CO_3	4.2×10^{-7}	hydrogen carbonate ion	HCO_3^-	2.4×10^{-8}
Hydrogen sulfide	H_2S	1×10^{-7}	hydrogen sulfide ion	HS^-	1×10^{-7}
Dihydrogen phosphate ion	$H_2PO_4^-$	6.2×10^{-8}	hydrogen phosphate ion	HPO_4^{2-}	1.6×10^{-7}
Hypochlorous acid	$HClO$	3.5×10^{-8}	hypochlorite ion	ClO^-	2.9×10^{-7}
Ammonium ion	NH_4^+	5.6×10^{-10}	ammonia	NH_3	1.8×10^{-5}
Hydrocyanic acid	HCN	4.0×10^{-10}	cyanide ion	CN^-	2.5×10^{-5}
Hexaaquairon(II) ion	$Fe(H_2O)_6^{2+}$	3.2×10^{-10}	pentaaquahydroxoiron(II) ion	$Fe(H_2O)_5OH^+$	3.1×10^{-5}
Hydrogen carbonate ion	HCO_3^-	4.8×10^{-11}	carbonate ion	CO_3^{2-}	2.1×10^{-4}
Hydrogen phosphate ion	HPO_4^{2-}	3.6×10^{-13}	phosphate ion	PO_4^{3-}	2.8×10^{-2}

	1 IA	2 IIA	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8 VIIIB	9 VIIIB	10 VIIIB	11 IB	12 IIB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA
1	1 1.0079 H HYDROGEN																	2 4.0026 He HELIUM
2	3 6.941 Li LITHIUM	4 9.0122 Be BERYLLIUM											5 10.811 B BORON	6 12.011 C CARBON	7 14.007 N NITROGEN	8 15.999 O OXYGEN	9 18.998 F FLUORINE	10 20.180 Ne NEON
3	11 22.990 Na SODIUM	12 24.305 Mg MAGNESIUM											13 26.982 Al ALUMINIUM	14 28.086 Si SILICON	15 30.974 P PHOSPHORUS	16 32.065 S SULPHUR	17 35.453 Cl CHLORINE	18 39.948 Ar ARGON
4	19 39.098 K POTASSIUM	20 40.078 Ca CALCIUM	21 44.956 Sc SCANDIUM	22 47.867 Ti TITANIUM	23 50.942 V VANADIUM	24 51.996 Cr CHROMIUM	25 54.938 Mn MANGANESE	26 55.845 Fe IRON	27 58.933 Co COBALT	28 58.693 Ni NICKEL	29 63.546 Cu COPPER	30 65.39 Zn ZINC	31 69.723 Ga GALLIUM	32 72.64 Ge GERMANIUM	33 74.922 As ARSENIC	34 78.96 Se SELENIUM	35 79.904 Br BROMINE	36 83.80 Kr KRYPTON
5	37 85.468 Rb RUBIDIUM	38 87.62 Sr STRONTIUM	39 88.906 Y YTTRIUM	40 91.224 Zr ZIRCONIUM	41 92.906 Nb NIOBIUM	42 95.94 Mo MOLYBDENUM	43 (98) Tc TECHNETIUM	44 101.07 Ru RUTHENIUM	45 102.91 Rh RHODIUM	46 106.42 Pd PALLADIUM	47 107.87 Ag SILVER	48 112.41 Cd CADMIUM	49 114.82 In INDIUM	50 118.71 Sn TIN	51 121.76 Sb ANTIMONY	52 127.60 Te TELLURIUM	53 126.90 I IODINE	54 131.29 Xe XENON
6	55 132.91 Cs CAESIUM	56 137.33 Ba BARIUM	57-71 La-Lu Lanthanide	72 178.49 Hf HAFNIUM	73 180.95 Ta TANTALUM	74 183.84 W TUNGSTEN	75 186.21 Re RHENIUM	76 190.23 Os OSMIUM	77 192.22 Ir IRIDIUM	78 195.08 Pt PLATINUM	79 196.97 Au GOLD	80 200.59 Hg MERCURY	81 204.38 Tl THALLIUM	82 207.2 Pb LEAD	83 208.98 Bi BISMUTH	84 (209) Po POLONIUM	85 (210) At ASTATINE	86 (222) Rn RADON