

**CHEM 1423 - Final Exam – May 9, 2017**

**Name** \_\_\_\_\_

**If you wish to have your final exam and course grade posted on the Web site, please provide me with a four (4) digit number which will be the ID number for your grade.**

\_\_\_\_\_

**Four (4) digit number for posting**

Please turn in:

1. Your Scantron with your name written in + bubbled answers. You don't have to bubble in your name.
2. This signature sheet. Please put your name on top. You are welcome to supply a 4 digit number of your choice if you would like your course results posted anonymously on the course web site.

You can keep the test (below) and use it to compare results with the answer key.

Conversions: 1 atm. = 760 torr

Constants: R = 0.082 L·atm/mol·K

R = 8.31 J/mol·K

R = 8.31x10<sup>-3</sup> kJ/mol·K

N<sub>A</sub> = 6.02x10<sup>23</sup> mol<sup>-1</sup>

F = 96,500 Coul/mol e<sup>-</sup>

c = 3.00x10<sup>8</sup> m/s (speed of light)

Molar Masses: Given with each question: [M=xx]

PERIODIC TABLE OF THE ELEMENTS

Key		Atomic Number		Symbol		Atomic Mass	
1	H	1	H	1.008	1.008	1.008	1.008
1 IA	2 He	2	He	4.003	4.003	4.003	4.003
2	3 Li	3	Li	6.941	6.941	6.941	6.941
	4 Be	4	Be	9.012	9.012	9.012	9.012
3	11 Na	11	Na	23.00	23.00	23.00	23.00
	12 Mg	12	Mg	24.30	24.30	24.30	24.30
4	19 K	19	K	39.10	39.10	39.10	39.10
	20 Ca	20	Ca	40.08	40.08	40.08	40.08
5	37 Rb	37	Rb	85.47	85.47	85.47	85.47
	38 Sr	38	Sr	87.62	87.62	87.62	87.62
6	55 Cs	55	Cs	132.9	132.9	132.9	132.9
	56 Ba	56	Ba	137.3	137.3	137.3	137.3
7	87 Fr	87	Fr	(223)	(223)	(223)	(223)
	88 Ra	88	Ra	(226)	(226)	(226)	(226)
	103 Lr	103	Lr	(260)	(260)	(260)	(260)
	104 Rf	104	Rf	(261)	(261)	(261)	(261)
	105 Db	105	Db	(262)	(262)	(262)	(262)
	106 Sg	106	Sg	(263)	(263)	(263)	(263)
	107 Bh	107	Bh	(264)	(264)	(264)	(264)
	108 Hs	108	Hs	(265)	(265)	(265)	(265)
	109 Mt	109	Mt	(266)	(266)	(266)	(266)
	110 Ds	110	Ds	(267)	(267)	(267)	(267)
	111 Rg	111	Rg	(268)	(268)	(268)	(268)
	112 Cn	112	Cn	(269)	(269)	(269)	(269)
	113 Nh	113	Nh	(270)	(270)	(270)	(270)
	114 Fl	114	Fl	(271)	(271)	(271)	(271)
	115 Mc	115	Mc	(272)	(272)	(272)	(272)
	116 Lv	116	Lv	(273)	(273)	(273)	(273)
	117 Ts	117	Ts	(274)	(274)	(274)	(274)
	118 Og	118	Og	(275)	(275)	(275)	(275)
	119 Uue	119	Uue	(276)	(276)	(276)	(276)
	120 Uub	120	Uub	(277)	(277)	(277)	(277)
	121 Uuq	121	Uuq	(278)	(278)	(278)	(278)
	122 Uuq	122	Uuq	(279)	(279)	(279)	(279)
	123 Uub	123	Uub	(280)	(280)	(280)	(280)
	124 Uuq	124	Uuq	(281)	(281)	(281)	(281)
	125 Uuq	125	Uuq	(282)	(282)	(282)	(282)
	126 Uuq	126	Uuq	(283)	(283)	(283)	(283)
	127 Uuq	127	Uuq	(284)	(284)	(284)	(284)
	128 Uuq	128	Uuq	(285)	(285)	(285)	(285)
	129 Uuq	129	Uuq	(286)	(286)	(286)	(286)
	130 Uuq	130	Uuq	(287)	(287)	(287)	(287)
	131 Uuq	131	Uuq	(288)	(288)	(288)	(288)
	132 Uuq	132	Uuq	(289)	(289)	(289)	(289)
	133 Uuq	133	Uuq	(290)	(290)	(290)	(290)
	134 Uuq	134	Uuq	(291)	(291)	(291)	(291)
	135 Uuq	135	Uuq	(292)	(292)	(292)	(292)
	136 Uuq	136	Uuq	(293)	(293)	(293)	(293)
	137 Uuq	137	Uuq	(294)	(294)	(294)	(294)
	138 Uuq	138	Uuq	(295)	(295)	(295)	(295)
	139 Uuq	139	Uuq	(296)	(296)	(296)	(296)
	140 Uuq	140	Uuq	(297)	(297)	(297)	(297)
	141 Uuq	141	Uuq	(298)	(298)	(298)	(298)
	142 Uuq	142	Uuq	(299)	(299)	(299)	(299)
	143 Uuq	143	Uuq	(300)	(300)	(300)	(300)
	144 Uuq	144	Uuq	(301)	(301)	(301)	(301)
	145 Uuq	145	Uuq	(302)	(302)	(302)	(302)
	146 Uuq	146	Uuq	(303)	(303)	(303)	(303)
	147 Uuq	147	Uuq	(304)	(304)	(304)	(304)
	148 Uuq	148	Uuq	(305)	(305)	(305)	(305)
	149 Uuq	149	Uuq	(306)	(306)	(306)	(306)
	150 Uuq	150	Uuq	(307)	(307)	(307)	(307)
	151 Uuq	151	Uuq	(308)	(308)	(308)	(308)
	152 Uuq	152	Uuq	(309)	(309)	(309)	(309)
	153 Uuq	153	Uuq	(310)	(310)	(310)	(310)
	154 Uuq	154	Uuq	(311)	(311)	(311)	(311)
	155 Uuq	155	Uuq	(312)	(312)	(312)	(312)
	156 Uuq	156	Uuq	(313)	(313)	(313)	(313)
	157 Uuq	157	Uuq	(314)	(314)	(314)	(314)
	158 Uuq	158	Uuq	(315)	(315)	(315)	(315)
	159 Uuq	159	Uuq	(316)	(316)	(316)	(316)
	160 Uuq	160	Uuq	(317)	(317)	(317)	(317)
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	164 Uuq	164	Uuq	(321)	(321)	(321)	(321)
	165 Uuq	165	Uuq	(322)	(322)	(322)	(322)
	166 Uuq	166	Uuq	(323)	(323)	(323)	(323)
	167 Uuq	167	Uuq	(324)	(324)	(324)	(324)
	168 Uuq	168	Uuq	(325)	(325)	(325)	(325)
	169 Uuq	169	Uuq	(326)	(326)	(326)	(326)
	170 Uuq	170	Uuq	(327)	(327)	(327)	(327)
	171 Uuq	171	Uuq	(328)	(328)	(328)	(328)
	172 Uuq	172	Uuq	(329)	(329)	(329)	(329)
	173 Uuq	173	Uuq	(330)	(330)	(330)	(330)
	174 Uuq	174	Uuq	(331)	(331)	(331)	(331)
	175 Uuq	175	Uuq	(332)	(332)	(332)	(332)
	176 Uuq	176	Uuq	(333)	(333)	(333)	(333)
	177 Uuq	177	Uuq	(334)	(334)	(334)	(334)
	178 Uuq	178	Uuq	(335)	(335)	(335)	(335)
	179 Uuq	179	Uuq	(336)	(336)	(336)	(336)
	180 Uuq	180	Uuq	(337)	(337)	(337)	(337)
	181 Uuq	181	Uuq	(338)	(338)	(338)	(338)
	182 Uuq	182	Uuq	(339)	(339)	(339)	(339)
	183 Uuq	183	Uuq	(340)	(340)	(340)	(340)
	184 Uuq	184	Uuq	(341)	(341)	(341)	(341)
	185 Uuq	185	Uuq	(342)	(342)	(342)	(342)
	186 Uuq	186	Uuq	(343)	(343)	(343)	(343)
	187 Uuq	187	Uuq	(344)	(344)	(344)	(344)
	188 Uuq	188	Uuq	(345)	(345)	(345)	(345)
	189 Uuq	189	Uuq	(346)	(346)	(346)	(346)
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	194 Uuq	194	Uuq	(351)	(351)	(351)	(351)
	195 Uuq	195	Uuq	(352)	(352)	(352)	(352)
	196 Uuq	196	Uuq	(353)	(353)	(353)	(353)
	197 Uuq	197	Uuq	(354)	(354)	(354)	(354)
	198 Uuq	198	Uuq	(355)	(355)	(355)	(355)
	199 Uuq	199	Uuq	(356)	(356)	(356)	(356)
	200 Uuq	200	Uuq	(357)	(357)	(357)	(357)
	201 Uuq	201	Uuq	(358)	(358)	(358)	(358)
	202 Uuq	202	Uuq	(359)	(359)	(359)	(359)
	203 Uuq	203	Uuq	(360)	(360)	(360)	(360)
	204 Uuq	204	Uuq	(361)	(361)	(361)	(361)
	205 Uuq	205	Uuq	(362)	(362)	(362)	(362)
	206 Uuq	206	Uuq	(363)	(363)	(363)	(363)
	207 Uuq	207	Uuq	(364)	(364)	(364)	(364)
	208 Uuq	208	Uuq	(365)	(365)	(365)	(365)
	209 Uuq	209	Uuq	(366)	(366)	(366)	(366)
	210 Uuq	210	Uuq	(367)	(367)	(367)	(367)
	211 Uuq	211	Uuq	(368)	(368)	(368)	(368)
	212 Uuq	212	Uuq	(369)	(369)	(369)	(369)
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	214 Uuq	214	Uuq	(371)	(371)	(371)	(371)
	215 Uuq	215	Uuq	(372)	(372)	(372)	(372)
	216 Uuq	216	Uuq	(373)	(373)	(373)	(373)
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	218 Uuq	218	Uuq	(375)	(375)	(375)	(375)
	219 Uuq	219	Uuq	(376)	(376)	(376)	(376)
	220 Uuq	220	Uuq	(377)	(377)	(377)	(377)
	221 Uuq	221	Uuq	(378)	(378)	(378)	(378)
	222 Uuq	222	Uuq	(379)	(379)	(379)	(379)
	223 Uuq	223	Uuq	(380)	(380)	(380)	(380)
	224 Uuq	224	Uuq	(381)	(381)	(381)	(381)
	225 Uuq	225	Uuq	(382)	(382)	(382)	(382)
	226 Uuq	226	Uuq	(383)	(383)	(383)	(383)
	227 Uuq	227	Uuq	(384)	(384)	(384)	(384)
	228 Uuq	228	Uuq	(385)	(385)	(385)	(385)
	229 Uuq	229	Uuq	(386)	(386)	(386)	(386)
	230 Uuq	230	Uuq	(387)	(387)	(387)	(387)
	231 Uuq	231	Uuq	(388)	(388)	(388)	(388)
	232 Uuq	232	Uuq	(389)	(389)	(389)	(389)
	233 Uuq	233	Uuq	(390)	(390)	(390)	(390)
	234 Uuq	234	Uuq	(391)	(391)	(391)	(391)
	235 Uuq	235	Uuq	(392)	(392)	(392)	(392)
	236 Uuq	236	Uuq	(393)	(393)	(393)	(393)
	237 Uuq	237	Uuq	(394)	(394)	(394)	(394)
	238 Uuq	238	Uuq	(395)	(395)	(395)	(395)
	239 Uuq	239	Uuq	(396)	(396)	(396)	(396)
	240 Uuq	240	Uuq	(397)	(397)	(397)	(3

## ELECTROCHEMISTRY INFORMATION

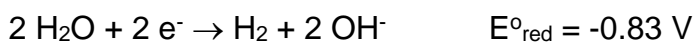
**Table 1: Standard Reduction Potentials**

### Reduction Half-Reactions $E^\circ$ (V)

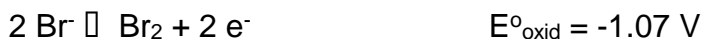
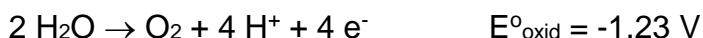
$F_2 + 2 e^- \rightarrow 2 F^-$	+2.87
$Au^{3+} + 3 e^- \rightarrow Au$	+1.50
$Cl_2 + 2 e^- \rightarrow 2 Cl^-$	+1.36
$Br_2 + 2 e^- \rightarrow 2 Br^-$	+1.07
$Hg^{2+} + 2 e^- \rightarrow Hg$	+0.86
$Ag^+ + 1 e^- \rightarrow Ag$	+0.80
$I_2 + 2 e^- \rightarrow 2 I^-$	+0.54
$Cu^{2+} + 2 e^- \rightarrow Cu$	+0.34
$Sn^{2+} + 2 e^- \rightarrow Sn$	-0.14
$Fe^{3+} + 3 e^- \rightarrow Fe$	-0.04
$Ni^{2+} + 2 e^- \rightarrow Ni$	-0.25
$Fe^{2+} + 2 e^- \rightarrow Fe$	-0.44
$Zn^{2+} + 2 e^- \rightarrow Zn$	-0.76
$Mn^{2+} + 2 e^- \rightarrow Mn$	-1.18
$Al^{3+} + 3 e^- \rightarrow Al$	-1.66
$Mg^{2+} + 2 e^- \rightarrow Mg$	-2.37
$K^+ + 1 e^- \rightarrow K$	-2.93
$Li^+ + 1 e^- \rightarrow Li$	-3.05

**Table 2: Some Reduction and Oxidation Potentials in Aqueous Solution**

**Reduction Potentials**



**Oxidation Potentials**



**Some Electrochemical Equations**

$F = 96,500 \text{ C/mol e}^-$  (Coulombs per mole of electrons)

$1 \text{ J} = 1 \text{ CxV}$  [i.e. 1 Joule = 1 Coulomb x Volt]

$$\Delta G^\circ = -nFE^\circ$$

$$E = E^\circ - \frac{0.0592}{n} \cdot \log(Q)$$

$Q = i \times t$  i.e. Charge (in Coul) = Current (in Amps = Coul/sec) x time (in sec)]

$E = Q \times V$  i.e. Energy (in J) = Charge (in Coulombs) x Voltage (in Volts)  
(note: 1 Coulomb-Volt = 1 Joule)

(60) **60 QUESTIONS (Mark the one correct answer to each question on your scantron)**

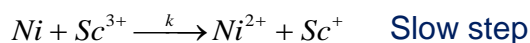
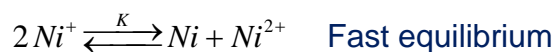
**Each Question is worth 1 point. Your score will be converted to percent by: Score = XX/60 x 100 (where XX is the number of correct answers)**

1. For the reaction,  $A + B \rightarrow \text{Products}$ , the rate law is:  $\text{Rate} = k \frac{[C]^2}{[B]}$  The units of the rate constant are:
- (A)  $s^{-1}$                       (B)  $M^2s^{-1}$                       (C)  $M^{-2}s^{-1}$                       (D)  $M^{-1}s^{-1}$
2. The rate of the chemical reaction involving two substances, A and B, is measured. It is found that if the initial concentration of A used is tripled, keeping the B concentration the same, the rate increases by a factor of 9 (relative to the first experiment). If the concentrations of both A and B are doubled, the rate increases by a factor of 32 (relative to the first experiment). The rate law for this reaction is: Rate =
- (A)  $k[A]^2[B]^2$                       (B)  $k[A][B]$                       (C)  $k[A]^2[B]^3$                       (D)  $k[A][B]^2$
3. Consider a reaction which is zeroth order; i.e.  $d[A]/dt = -k[A]^0 = -k$  For this reaction, a plot of \_\_\_\_ vs. time is a straight line with a \_\_\_\_ slope.
- (A)  $\ln([A]_t)$ , negative                      (B)  $[A]_t$ , negative  
(C)  $[A]_t$ , positive                      (D)  $1/[A]_t$ , positive
4. The reaction,  $A \rightarrow \text{Products}$ , is of order "n" with respect to [A]; i.e.  $\text{Rate} = k[A]^n$ . When the initial concentration of A is 0.20 M, the initial rate is  $1.5 \text{ Ms}^{-1}$ . When the initial concentration of A is 0.60 M, the initial rate is  $40.5 \text{ Ms}^{-1}$ . The order of this reaction, n, is:
- (A) -2                      (B) +1                      (C) +2                      (D) +3

**For #5 - #6:** Consider a **second** order reaction,  $A \rightarrow \text{Products}$ . The rate constant for this reaction is  $0.02 \text{ M}^{-1}\text{s}^{-1}$ . The initial concentration of A is 0.75 M

5. Approximately how long will it take for the reactant concentration to decrease to 0.20 M?
- (A) 45 s                      (B) 100 s                      (C) 180 s                      (D) 80 s
6. What will be the concentration of A 60 s after the start of the reaction?
- (A) 0.39 M                      (B) 0.23 M                      (C) 0.47 M                      (D) 0.56 M

7. For the reaction,  $\text{Sc}^{3+}(\text{aq}) + 2 \text{Ni}^+(\text{aq}) \rightarrow \text{Sc}^+(\text{aq}) + 2 \text{Ni}^{2+}(\text{aq})$ , the reaction mechanism is:



The overall rate equation for this reaction is:

- (A)  $\text{Rate} = k' \frac{[\text{Ni}^{2+}][\text{Sc}^{3+}]}{[\text{Ni}^+]^2}$       (B)  $\text{Rate} = k' \frac{[\text{Ni}^+][\text{Sc}^{3+}]}{[\text{Ni}^{2+}]}$   
 (C)  $\text{Rate} = k' \frac{[\text{Ni}^+]^2[\text{Sc}^{3+}]}{[\text{Ni}^{2+}]}$       (D)  $\text{Rate} = k'[\text{Ni}][\text{Sc}^{3+}]$

8. The gas phase equilibrium,  $2 \text{A}(\text{g}) \rightleftharpoons 3 \text{B}(\text{g}) + \text{C}(\text{g})$ . The equilibrium constant is  $K_c = 1 \times 10^{-4}$ . If one puts an initial concentration of 2.0 M of A into a flask, what is the approximate concentration of B at equilibrium? [NOTE: You may assume that very little A reacts]

- (A) 0.16 M      (B) 0.19 M      (C) 0.28 M      (D) 0.06 M

9. Consider the gas phase equilibrium reaction,  $2 \text{A}(\text{g}) \rightleftharpoons \text{B}(\text{g})$ . If one initially fills a container with A at a concentration of 3.0 M, and then allows it to come to equilibrium, it is found that the equilibrium concentration of B is 1.2 M. Therefore, the value of the equilibrium constant,  $K_c$  is approximately:

- (A) 3.3      (B) 2.0      (C) 0.67      (D) 0.37

10. The equilibrium constant for the reaction,  $\text{N}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2 \text{NO}(\text{g})$  is  $1.7 \times 10^{-3}$  (at 2300 K). What is the equilibrium constant for the reaction,  $6 \text{NO}(\text{g}) \rightleftharpoons 3 \text{N}_2(\text{g}) + 3 \text{O}_2(\text{g})$  ?

- (A)  $4.9 \times 10^{-9}$       (B) 8.4      (C)  $1.7 \times 10^3$       (D)  $2.0 \times 10^8$

**For #11 - #13:** Consider the gas phase equilibrium,  $4 \text{NO}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2 \text{N}_2\text{O}_5(\text{g})$ . This is an Exothermic reaction.

11. For the above reaction, if  $\text{O}_2(\text{g})$  is added to the mixture, then the ratio,  $[\text{NO}_2]/[\text{N}_2\text{O}_5]$  will \_\_\_\_\_ and  $K_c$  will \_\_\_\_\_

- (A) decrease, Increase      (B) increase, decrease  
 (C) decrease, remain constant      (D) increase, remain constant

12. For the above reaction, if Ne(g) is added to the mixture in a container at fixed **total pressure**, the ratio,  $[\text{NO}_2]/[\text{N}_2\text{O}_5]$  will \_\_\_\_\_ and  $K_c$  will \_\_\_\_\_
- (A) decrease, Increase                      (B) increase, decrease  
(C) decrease, remain constant              (D) increase, remain constant
13. For the above reaction, if the temperature is **decreased**,
- (A) the equilibrium will move to the left and K will decrease  
(B) the equilibrium will move to the right and K will increase  
(C) the equilibrium will move to the left and K will remain constant  
(D) the equilibrium will move to the right and K will remain constant
14. The weight percent of Thallium in a sample of water is  $3 \times 10^{-11} \%$ . Therefore, the concentration of Thallium, in parts per trillion (ppt) is:
- (A) 0.30 ppt      (B)  $3 \times 10^{-2}$  ppt      (C)  $3 \times 10^{-4}$  ppt      (D) 3.0 ppt
15. What is the molality of a solution prepared by adding 138 grams of Glycerol ( $\text{C}_3\text{H}_8\text{O}_3$ ,  $M=92$ .) to 600 grams of water?
- (A) 2.033 molal                      (B) 3.75 molal                      (C) 2.5 molal  
(D) Determination of the molality requires the density of the solution
16. The density of a solution prepared by adding 93 grams of Ethylene Glycol ( $\text{C}_2\text{H}_6\text{O}_2$ ,  $M=62$ ) to 400 grams of water is 1.30 g/mL. What is the approximate Molarity of this solution?
- (A) 3.95 Molar      (B) 3.75 Molar      (C) 4.95 Molar      (D) 3.45 Molar
17. Which of the following aqueous solutions has the **lowest boiling** point?
- (A) 0.20 m  $\text{K}_3\text{PO}_4$                       (B) 0.30 m  $\text{Ca}(\text{NO}_3)_2$   
(C) 0.70 m  $\text{C}_6\text{H}_{12}\text{O}_6$                       (D) 0.32 m NaBr
18. When a sample of the strong electrolyte, aluminum nitrate,  $\text{Al}(\text{NO}_3)_3$ , is dissolved in 600 mL of aqueous solution, the osmotic pressure at 25 °C is 350 torr. Approximately how many moles of  $\text{Al}(\text{NO}_3)_3$  are dissolved in the 600 mL?
- (A)  $1.1 \times 10^{-2}$  mol      (B)  $2.8 \times 10^{-3}$  mol      (C)  $7.9 \times 10^{-3}$  mol      (D)  $3.9 \times 10^{-3}$  mol
19. The normal boiling point of pure  $\text{CCl}_4(\text{l})$  is 77.0 °C and the boiling point elevation constant is 5.0 °C/m. When 80. grams of an unknown compound is placed in 750 grams of  $\text{CCl}_4$ , the boiling point of the solution is 80.5 °C. The Molar Mass of the unknown compound is approximately:
- (A) 86 g/mol                      (B) 69 g/mol                      (C) 152 g/mol                      (D) 114 g/mol

20. A 300. L sample of nitric acid ( $\text{HNO}_3$ ,  $M=63$ ) has a **pOH** of 11.5. Approximately how many grams of nitric acid are contained in the sample?
- (A) 60. grams      (B) 0.20 grams      (C) 0.62 grams      (D) 23. grams
21. Which of the following aqueous solutions is/are basic ( $\text{pH} > 7$ )?
- (i) Potassium Lactate (KLac)  
(ii) Sodium Nitrate ( $\text{NaNO}_3$ )  
(iii) Pyridinium Bromide (PyrHBr)  
(iv) Sodium Propanoate (NaProp)
- (A) i & iv      (B) ii & iii      (C) i & ii & iv      (D) iv only
22. The pH of a 0.10 M solution of hydrocyanic acid, HCN, is 5.10. Therefore, the acid dissociation constant,  $K_a$ , for this acid is:
- (A)  $6.8 \times 10^{-12}$       (B)  $7.9 \times 10^{-5}$       (C)  $6.3 \times 10^{-10}$       (D)  $4.8 \times 10^{-7}$
23. For the weak acid, Hypobromous acid, HBrO, the acid ionization constant is  $2.0 \times 10^{-9}$ . What is the approximate pH of a 0.05 M solution of this acid?
- (A) 9.0      (B) 5.0      (C) 3.4      (D) 4.6
24. The weak base, aniline (Anil), has a base equilibrium constant,  $K_b = 4.3 \times 10^{-10}$ . What is the pH of a 0.05 M aqueous solution of anilinium chloride (AnilHCl)?
- (A) 11.0      (B) 8.7      (C) 5.3      (D) 3.0
25. If added to 2 L of 0.40 M  $\text{HNO}_3$ , which of the following would form a buffer?
- (1) 0.6 mol of potassium lactate (KLac)  
(2) 0.6 mol of sodium carbonate ( $\text{Na}_2\text{CO}_3$ )  
(3) 1.2 mol of sodium acetate (NaAc)  
(4) 1.2 mol of ammonium bromide ( $\text{NH}_4\text{Br}$ )
- (A) 1 & 2 & 3      (B) 2 & 3 & 4      (C) 3 only      (D) 2 & 3

**For #26 - #30:** Consider Carbonic acid,  $\text{H}_2\text{CO}_3$ , which is a diprotic acid with acid dissociation constants,  $K_a' = 4.2 \times 10^{-7}$  and  $K_a'' = 4.8 \times 10^{-11}$ .

26. What is the approximate pH of a 0.05 M solution of sodium carbonate,  $\text{Na}_2\text{CO}_3$  ?
- (A) 5.8      (B) 11.5      (C) 10.2      (D) 8.2
27. What is the approximate pH of a solution containing 0.25 M  $\text{K}_2\text{CO}_3$  and 0.40 M  $\text{NaHCO}_3$  ?
- (A) 10.5      (B) 9.4      (C) 10.1      (D) 6.6



28. What is the approximate pH of a solution prepared by adding 0.70 mol of  $\text{HNO}_3$  to 4 L of 0.40 M  $\text{Na}_2\text{CO}_3$ ?
- (A) 10.4                      (B) 10.2                      (C) 5.5                      (D) 10.7
29. What is the approximate pH of a solution prepared by adding 2.40 mol of  $\text{NaOH}$  to 5 L of 0.40 M  $\text{H}_2\text{CO}_3$  ?
- (A) 5.9                      (B) 10.9                      (C) 9.0                      (D) 9.7
30. What is the approximate ratio of concentrations,  $[\text{H}_2\text{CO}_3]/[\text{HCO}_3^-]$ , of a buffer solution with  $\text{pH} = 6.80$ ?
- (A) 2.7                      (B) 1.5                      (C) 0.4                      (D) 0.7
31. 600 mL of 0.40 M  $\text{NaOH}(\text{aq})$  is needed to completely neutralize a sample of aqueous  $\text{H}_3\text{PO}_4(\text{aq})$ . Approximately how many grams of  $\text{H}_3\text{PO}_4$  ( $M=98 \text{ g/mol}$ ) were in the sample?
- (A) 70.6 g                      (B) 7.8 g                      (C) 23.5 g  
(D) Cannot be determined without the volume of the  $\text{H}_3\text{PO}_4$  sample
32. Consider the slightly soluble salt,  $\text{AB}_3$ . The solubility product constant for  $\text{AB}_3$  is  $K_{\text{sp}} = 6.0 \times 10^{-23}$ . What is the solubility of  $\text{AB}_3$  in a solution containing 0.05 M  $\text{NaB}(\text{aq})$  (which is a strong electrolyte)?
- (A)  $1.8 \times 10^{-20} \text{ M}$       (B)  $7.4 \times 10^{-12} \text{ M}$       (C)  $4.8 \times 10^{-19} \text{ M}$       (D)  $1.2 \times 10^{-21} \text{ M}$
33. The enthalpy of vaporization of toluene is 39.2 kJ/mol and the normal boiling point is 111 °C.. What is the entropy change of the **system** when **2 (two) moles** of toluene gas condenses at 111 °C?
- (A) -204 J/K                      (B) -102 J/K                      (C) -706 J/K                      (D) +102 J/K
34. The enthalpy of vaporization of liquid benzene,  $\text{C}_6\text{H}_6(\text{l})$ , is +30.7 kJ/mol. What is the entropy change of the **surroundings** for the condensation of 0.50 mol of benzene gas at the boiling point, 80 °C?
- (A) -43.5. J/K                      (B) -87 J/K                      (C) +87. J/K                      (D) +43.5 J/K
35. For the reaction,  $\text{CH}_3\text{OH}(\text{g}) \rightleftharpoons \text{CO}(\text{g}) + 2\text{H}_2(\text{g})$ ,  $\Delta H^\circ = +91 \text{ kJ}$  and  $\Delta S^\circ = +221 \text{ J/K}$ . What is the entropy change of the **surroundings**,  $\Delta S_{\text{surr}}$ , for the related reaction,  $2\text{CO}(\text{g}) + 4\text{H}_2(\text{g}) \rightleftharpoons 2\text{CH}_3\text{OH}(\text{g})$ , at 25 °C?
- (A) +611 J/K                      (B) -442 J/K                      (C) -611 J/K                      (D) +442 J/K

36. For the hypothetical reaction,  $A \rightleftharpoons B$ ,  $\Delta S^\circ = -70 \text{ J/K}$  (independent of temperature). The equilibrium constant for the reaction at  $150^\circ\text{C}$  is  $2.0 \times 10^{-3}$ . What is the enthalpy change,  $\Delta H^\circ$  for this reaction?
- (A) +51.5 kJ      (B) -7.8 kJ      (C) -37.3 kJ      (D) -51.5 kJ
37. The reaction,  $A \rightarrow B$ , is **exergonic** at  $25^\circ\text{C}$  and the entropy change is  $-20 \text{ J/K}$ . What can be concluded about the enthalpy change for this reaction?
- (A)  $\Delta H < -18 \text{ kJ}$       (B)  $\Delta H > +6 \text{ kJ}$       (C)  $\Delta H < -6 \text{ kJ}$   
 (D) No conclusion can be made about  $\Delta H$
38. The equilibrium constant for the reaction,  $4 \text{ N}_2\text{O}_5 \rightleftharpoons 4 \text{ N}_2(\text{g}) + 10 \text{ O}_2(\text{g})$ , is  $5.8 \times 10^{82}$  at  $25^\circ\text{C}$ . What is the approximate value of the Gibbs Free Energy of Formation of  $\text{N}_2\text{O}_5(\text{g})$ ?
- (A) +120. kJ/mol      (B) +240. kJ/mol      (C) -120 kJ/mol  
 (D) Insufficient data is given to determine  $\Delta G_f^\circ(\text{N}_2\text{O}_5)$

**For #39 - #40:** The Enthalpy of Vaporization of  $\text{Cl}_2(\text{liq})$  is  $10.2 \text{ kJ/mol}$ . The Entropy of Vaporization of  $\text{Cl}_2(\text{liq})$  is  $42.9 \text{ J/mol-K}$ .

39. The Entropy change of the universe,  $\Delta S_{\text{univ}}$ , when **3 (three)** moles of  $\text{Cl}_2(\text{liq})$  **vaporizes** to  $\text{Cl}_2(\text{gas})$  at  $-60^\circ\text{C}$  is approximately:
- (A) +5.0 J/mol-K      (B) -15.0 J/mol-K      (C) -5.0 J/mol-K  
 (D) None of the above
40. The Gibbs Energy Change,  $\Delta G^\circ$ , when **3 (three)** moles of  $\text{Cl}_2(\text{gas})$  **condenses** to  $\text{Cl}_2(\text{liq})$  at  $-60^\circ\text{C}$  is approximately:
- (A) +1.8 kJ/mol      (B) +3.2 kJ/mol      (C) -1.0 kJ/mol      (D) -3.2 kJ/mol
41. Regarding the reaction,  $\text{Br}_2\text{O}_5(\text{s}) + 5 \text{ CO}(\text{g}) \rightarrow \text{Br}_2(\text{l}) + 5 \text{ CO}_2(\text{g})$ , which of the following statements is/are true?
- (1)  $\text{Br}_2\text{O}_5$  is the reducing agent      (2)  $\text{Br}_2$  is oxidized  
 (3) CO is oxidized      (4)  $\text{Br}_2\text{O}_5$  is reduced
- (A) 1 & 2      (B) 3 & 4      (C) 2 & 3 & 4      (D) 1 & 2 & 4

42. For the electrochemical cell given by  $\text{Al}|\text{Al}^{3+}||\text{Cu}^{2+}|\text{Cu}$ , which of the following statements is/are correct?
- (1) The cathode reaction is  $\text{Cu} \rightarrow \text{Cu}^{2+} + 2\text{e}^-$
  - (2) Electrons flow from the Al electrode to the Cu electrode through an external circuit
  - (3) The anode reaction is  $\text{Al} \rightarrow \text{Al}^{3+} + 3\text{e}^-$
  - (4) If the half-cells are separated by a  $\text{K}_2\text{SO}_4$  salt bridge,  $\text{SO}_4^{2-}$  ions flow towards the Cu electrode
- (A) 2 & 3      (B) 1 & 3 & 4      (C) 1 & 2 & 3      (D) 1 & 4

**For #43 - #50: Use Table 1 (Standard Reduction Potentials) as needed.**

43. Which of the following reactions are **reactant** favored?
- (1)  $\text{Cl}^-|\text{Cl}_2||\text{Hg}^{2+}|\text{Hg}$
  - (2)  $\text{I}^-|\text{I}_2||\text{Ag}^+|\text{Ag}$
  - (3)  $\text{Fe}|\text{Fe}^{2+}||\text{Ni}^{2+}|\text{Ni}$
  - (4)  $\text{Ag}|\text{Ag}^+||\text{Cu}^{2+}|\text{Cu}$
- (A) 2 & 3      (B) 1 & 3 & 4      (C) 3 only      (D) 1 & 4
44. For the electrochemical cell given by  $\text{Hg}|\text{Hg}^{2+}||\text{Be}^{2+}|\text{Be}$ , the cell potential is  $E^\circ_{\text{cell}} = -2.71 \text{ V}$ . What is the **reduction potential** of  $\text{Be}^{2+}$ ?
- (A)  $-1.85 \text{ V}$       (B)  $+3.57 \text{ V}$       (C)  $-3.57 \text{ V}$       (D)  $+1.85 \text{ V}$
45. For the redox reaction given by  $\text{Fe}|\text{Fe}^{3+}||\text{Cu}^{2+}|\text{Cu}$ , the cell potential is:  $E^\circ_{\text{cell}} = +0.38 \text{ V}$ . What is the equilibrium constant,  $K$ , for this reaction?
- (A)  $6.9 \times 10^{+12}$       (B)  $3.3 \times 10^{+38}$       (C)  $5.3 \times 10^{+16}$       (D)  $3.1 \times 10^{-39}$
46. What is the standard Gibbs Free Energy change for the electrochemical reaction,  $\text{Ni}^{2+} + 2 \text{I}^- \rightarrow \text{Ni} + \text{I}_2$ ?
- (A)  $-56 \text{ kJ}$       (B)  $+56 \text{ kJ}$       (C)  $+152 \text{ kJ}$       (D)  $+76 \text{ kJ}$
47. Consider the following electrochemical cell reaction (values in parentheses indicate Molar Concentrations):  $\text{Al}(\text{s})|\text{Al}^{3+}(1.50 \text{ M})||\text{Mn}^{2+}(0.002 \text{ M})|\text{Mn}(\text{s})$ . Under standard conditions, the cell potential is  $E^\circ_{\text{cell}} = +0.48 \text{ V}$ . What is the approximate cell potential,  $E_{\text{cell}}$ , at the concentrations shown in the reaction?
- (A)  $-0.40 \text{ V}$       (B)  $+0.56 \text{ V}$       (C)  $+0.73 \text{ V}$       (D)  $+0.40 \text{ V}$

48. Consider a concentration cell, containing 0.10 M  $H^+$  in the reference compartment (the cathode) and a solution containing  $H^+$  in the sample cell (the anode) with  $pH = 3.50$ . (**Note:  $n = 1$  for this cell**)

In cell notation, this can be written as:  $H_2(g)|H^+(pH=3.50)||H^+(0.10 M)|H_2(g)$ .  
The cell potential,  $E_{cell}$  is approximately:

- (A) +0.15 V      (B) +0.34 V      (C) -0.15 V      (D) -0.21 V

49. The concentration of Arsenic [As,  $M=74.9$ ] in drinking water was determined using a concentration cell with 0.40 M Arsenic(III) nitrate,  $As(NO_3)_3$ , in the reference cell (the cathode) and a sample of water with an unknown concentration of  $As^{3+}(xx)$  in the sample cell (the anode).

In cell notation, this can be written as:  $As(s)|As^{3+}(xx)||As^{3+}(0.40 M)|As(s)$ .

The cell potential in the above concentration cell was measured to be +0.115 V. Therefore, the concentration of Arsenic in the sample, in **micrograms per Liter ( $\mu g/L$ )** is approximately:

- (A) 280  $\mu g/L$       (B) 3,900  $\mu g/L$       (C) 45  $\mu g/L$       (D) 111  $\mu g/L$

50. The solubility product of  $Li_3PO_4$  is  $K_{sp} = 3.2 \times 10^{-9}$ . A Saturated solution of  $Li_3PO_4$  is placed in the sample compartment (anode) of an electrochemical cell and a standard 2.00 M solution of  $LiCl$  (a strong electrolyte) is placed in the reference compartment (cathode). In cell notation, this can be written as:  
 $Li(s) | Li^+(Saturated Solution) || Li^+(2.00 M) | Li(s)$ .

What will be the cell voltage,  $E_{cell}$  ?

- (A) -0.052 V      (B) +0.136 V      (C) +0.052 V      (D) +0.068 V

**For #51 - #52: Use Table 2 (Some Reduction and Oxidation Potentials in Aqueous Solution) near the top of the test.**

51. If aqueous Zn(II) Fluoride,  $ZnF_2(aq)$  is placed in an electrolysis cell, and a voltage is applied, what will be the principal products of the electrolysis?

- (A) Zn ,  $F_2$       (B)  $F_2$  ,  $H_2$  ,  $OH^-$   
(C)  $H_2$  ,  $OH^-$  ,  $O_2$  ,  $H^+$       (D) Zn ,  $O_2$  ,  $H^+$

52. If aqueous Aluminum Iodide,  $AlI_3(aq)$  is placed in an electrolysis cell, and a voltage is applied, what will be the principal products of the electrolysis?

- (A) Al ,  $I_2$       (B)  $I_2$  ,  $H_2$  ,  $OH^-$   
(C)  $H_2$  ,  $OH^-$  ,  $O_2$  ,  $H^+$       (D) Al ,  $O_2$  , H (C)

53. A current of 0.80 Amps (Coul/sec) is passed through a solution of Aluminum Nitrate,  $\text{Al}(\text{NO}_3)_3(\text{aq})$ , for 7. hours. Approximately what mass of solid Aluminum,  $\text{Al}(\text{s})$  [ $M=27$ ], will be deposited at the cathode?
- (A) 1.9 g                      (B) 1.3 g                      (C) 16.9 g                      (D) 5.6 g
54. Approximately how much energy (in kJ) is needed to plate out 90. grams of  $\text{Sn}(\text{s})$  [ $M=118.7$ ] by electrolysis from a solution containing  $\text{Sn}(\text{NO}_3)_2(\text{aq})$ ? Assume that the voltage is 9. Volts.
- (A) 660 kJ                      (B) 2,050 kJ                      (C) 330 kJ                      (D) 1,320 kJ
55. The type of nuclides with the highest number of stable isotopes have a(n) \_\_\_\_\_ number of protons and \_\_\_\_\_ number of neutrons
- (A) even , odd                      (B) odd , even                      (C) even , even                      (D) odd , odd
56. What nuclide will undergo positron emission to form Ar-38 ?
- (A) Ca-42                      (B) Cl-38                      (C) Cl-40                      (D) K-38
57. Which of the following is a likely decay path for Ne-19. Stable isotopes in this range typically have  $N/Z = 1.0$ .
- (A)  ${}_{10}^{19}\text{Ne} \rightarrow {}_{-1}^0e + {}_{11}^{19}\text{Na}$                       (B)  ${}_{10}^{19}\text{Ne} \rightarrow {}_2^4\text{He} + {}_8^{15}\text{O}$
- (C)  ${}_{10}^{19}\text{Ne} \rightarrow {}_{+1}^0e + {}_9^{19}\text{F}$                       (D)  ${}_{10}^{19}\text{Ne} \rightarrow {}_1^1\text{H} + {}_9^{18}\text{F}$
58. Californium-252 ( $\text{Cf-252}$ ) combines with an alpha particle to form a neutron and a new element. The new element is:
- (A) Md-255                      (B) Cm-249                      (C) Md-256                      (D) Fm-255

**The last 2 questions are on the following page**

59. Typical values of  $N/Z$  for stable nuclei rise with increasing atomic numbers because:
- (A) More neutrons are required to form attractive interactions with the protons
  - (C) More long-range neutron-neutron attractions are required to counter the increasing short-range proton-proton repulsions
  - (B) Increased numbers of neutrons shield the short range proton-proton repulsions
  - (D) More short-range neutron-neutron attractions are required to counter the increasing long-range proton-proton repulsions.
60. Use the Molar Masses below to calculate the approximate Binding Energy per Nucleon ( $E_b/N$ ) of Kr-92.
- $m({}_1^1\text{H}) = 1.008 \text{ g/mol}$  ,  $m({}_0^1\text{n}) = 1.009 \text{ g/mol}$  ,  $m({}_{36}^{92}\text{Kr}) = 91.926 \text{ g/mol}$
- (A)  $4.7 \times 10^8 \text{ kJ/mol}$
  - (B)  $8.5 \times 10^8 \text{ kJ/mol}$
  - (C)  $8.5 \times 10^{11} \text{ kJ/mol}$
  - (D)  $7.8 \times 10^{10} \text{ kJ/mol}$