CHEM 1515.001 - 006
Exam IV
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Name _____

TA's Name _____

Section _____

INSTRUCTIONS:

1. This examination consists of a total of 9 different pages. The last three pages include a periodic table, a table of a solubility table, a table of equilibrium constants for acids and bases and a table of standard reduction potentials. All work should be done in this booklet.

2. PRINT your name, TA's name and your lab section number now in the space at the top of this sheet. DO NOT SEPARATE THESE PAGES.

3. Answer all questions that you can and whenever called for show your work clearly. Your method of solving problems should pattern the approach used in lecture. You do not have to show your work for the multiple choice or short answer questions.

4. No credit will be awarded if your work is not shown in 3, 4, and 5.

5. Point values are shown next to the problem number.

6. Budget your time for each of the questions. Some problems may have a low point value yet be very challenging. If you do not recognize the solution to a question quickly, skip it, and return to the question after completing the easier problems.

7. Look through the exam before beginning; plan your work; then begin.

8. Relax and do well.

	Page 2	Page 3	Page 4	Page 5	Page 6	TOTAL
SCORES	_____ (25)	_____ (24)	_____ (26)	_____ (16)	_____ (9)	_____ (100)

(9) 1. Write the chemical formula(s) of the product(s) and balance the following reactions. Identify all products phases as either (g)as, (l)iquid, (s)olid or (aq)ueous. Soluble ionic compounds should be written in the form of their component ions.

a) $\mathbf{2}HCl_{(aq)} + Zn_{(s)} \rightarrow\rightarrow \mathbf{H_2}_{(g)} + \mathbf{2Cl^-}_{(aq)} + \mathbf{3Zn^{2+}}_{(aq)}$

b) $Mg_{(s)} + Cu(NO_3)_{2(aq)} \rightarrow \mathbf{2Cu}_{(s)} + \mathbf{2NO_3^-}_{(aq)} + \mathbf{Mg^{2+}}_{(aq)}$

c) $HOCl_{(aq)} + KOH_{(aq)} \rightarrow \mathbf{H_2O}_{(l)} + \mathbf{OCl^-}_{(aq)} + \mathbf{2K^+}_{(aq)}$

(4) 2a. Write the ionic and net ionic chemical equation for 1a), 1b) or 1c).

Ionic equation

$$\mathbf{2NO_3^-}_{(aq)} + \mathbf{Cu^{2+}}_{(aq)} + \mathbf{Mg}_{(s)} \rightarrow \mathbf{Cu}_{(s)} + \mathbf{2NO_3^-}_{(aq)} + \mathbf{Mg^{2+}}_{(aq)}$$

Net Ionic equation

$$\mathbf{Cu^{2+}}_{(aq)} + \mathbf{Mg}_{(s)} \rightarrow \mathbf{Cu}_{(s)} + \mathbf{Mg^{2+}}_{(aq)}$$

(12) 3. A solution is prepared by mixing 100. mLs of 0.200 M $HC_3H_5O_2$ and 100. mLs of 0.220 M $NaC_3H_5O_2$.

a) Calculate the pH of the solution.

$\mathbf{0.200\ M\left(\frac{100\ mL}{200\ mL}\right) = 0.100\ M\ HC_3H_5O_2}$ $\mathbf{0.220\ M\left(\frac{100\ mL}{200\ mL}\right) = 0.110\ M\ NaC_3H_5O_2}$

	$HC_3H_5O_2 \rightleftarrows$	$H^+ +$	$C_3H_5O_2^-$	
I	0.100 M	~0	0.110	
C	-x	+x	+x	$x = [HC_3H_5O_2]_{diss}$
E	0.100-x	x	0.110+ x	

$$\mathbf{K_a = \frac{[H^+][C_3H_5O_2^-]}{[HC_3H_5O_2]}}$$

$$\mathbf{1.3 \times 10^{-5} = \frac{(x)(0.11+x)}{0.10 + x}} \qquad \mathbf{assume\ x << 0.1}$$

$$\mathbf{1.3 \times 10^{-5} = \frac{(x)(.11)}{0.1}}$$

$$\mathbf{1.18 \times 10^{-5}\ M = x = [H^+]}$$

$$\mathbf{pH = 4.93}$$

(24) 3. CONTINUED

b) Calculate the pH after adding 0.00400 mol of HCl to the solution in part a). (Assume no change in the volume of solution)

$$\mathbf{pH = 4.76}$$

c) Calculate the pH of the solution after adding 0.0200 mol of NaOH to the solution in part a). (Assume no change in the volume of solution)

$$\mathbf{pH = 9.10}$$

Buffer destroyed and the system is the salt of the weak acid $C_3H_5O_2^-$ at 0.21 M

(14) 4. Balance the following oxidation-reduction reaction using the half-reaction method.

a) $KMnO_{4(aq)} + H_2SO_{4(aq)} + NaCl_{(aq)} \rightarrow Cl_{2(aq)} + NaHSO_{4(aq)} + K_2SO_{4(aq)} + MnSO_{4(aq)}$
acidic solution

$KMnO_{4(aq)} + H_2SO_{4(aq)} \rightarrow K_2SO_{4(aq)} + MnSO_{4(aq)}$

$H_2SO_{4(aq)} + NaCl_{(aq)} \rightarrow Cl_{2(aq)} + NaHSO_{4(aq)}$

identify the oxidizing agent **$KMnO_4$** identify the reducing agent **NaCl**

(12) 5. Write the chemical formula(s) of the product(s) and balance the following spontaneous reactions.

a) $Sn^{2+}_{(aq)} + 2Ag^{+}_{(aq)} \rightarrow$ **$Sn^{4+}_{(aq)} + 2Ag_{(s)}$**

b) $Hg_{(l)} + MnO_4^{-}{}_{(aq)} + H^{+}_{(aq)} \rightarrow$ **$Hg^{2+}_{(aq)} + Mn^{2+}_{(aq)} + H_2O_{(l)}$**

c) $Al_{(s)} + H_2O_{(l)} \rightarrow$ **$Al^{3+}_{(aq)} + OH^{-}_{(aq)} + H_{2(l)}$**

(16) 6. Given the electrochemical cell shown in Figure I.

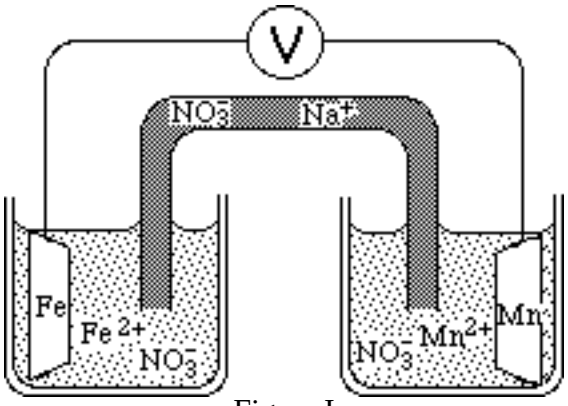

Figure I

a) Write the balanced net ionic equation for the spontaneous reaction that occurs as the cell operates.

$Mn_{(s)} + Fe^{2+}_{(aq)} \rightarrow \mathbf{Mn^{2+}_{(aq)}} + \mathbf{Fe_{(s)}}$

b) Determine the standard cell voltage, E°.

$E^{\circ} = +1.22$ v

c) Describe (use a diagram if you like) what is happening at the submicroscopic/atomic level on the surface of the anode in the cell.

d) Indicate the direction of flow of the ions in the salt bridge. (Be sure the anode and cathode compartments are identified.)

Anion towards the anode compartment (Mn electrode)and cations towards the cathode (Fe electrode)

(9) 7. Short answer.

a) The standard reduction potential for the reduction of RuO_4^- to RuO_4^{2-} is +0.59 volts. Which of the following substances can oxidize RuO_4^{2-} to RuO_4^- under standard condition?

$H_2SO_{4(aq)}$, $Pb^{2+}{}_{(aq)}$, **$Cr_2O_7^{2-}$ (in acidic solution)**

Write the balanced chemical equation to support your choice.

Periodic Table of the Elements

	IA	IIA	IIIB	IVB	VB	VIB	VIIB	VIII			IB	IIB	IIIA	IVA	VA	VIA	VIIA	VIIIA
1	1 **H** 1.008																	2 **He** 4.00
2	3 **Li** 6.94	4 **Be** 9.01											5 **B** 10.81	6 **C** 12.01	7 **N** 14.01	8 **O** 16.00	9 **F** 19.00	10 **Ne** 20.18
3	11 **Na** 22.99	12 **Mg** 24.30											13 **Al** 26.98	14 **Si** 28.09	15 **P** 30.97	16 **S** 32.06	17 **Cl** 35.45	18 **Ar** 39.95
4	19 **K** 39.10	20 **Ca** 40.08	21 **Sc** 44.96	22 **Ti** 47.88	23 **V** 50.94	24 **Cr** 52.00	25 **Mn** 54.94	26 **Fe** 55.85	27 **Co** 58.93	28 **Ni** 58.69	29 **Cu** 63.55	30 **Zn** 65.38	31 **Ga** 69.72	32 **Ge** 72.59	33 **As** 74.92	34 **Se** 78.96	35 **Br** 79.90	36 **Kr** 83.80
5	37 **Rb** 85.47	38 **Sr** 87.62	39 **Y** 88.91	40 **Zr** 91.22	41 **Nb** 92.91	42 **Mo** 95.94	43 **Tc** (98)	44 **Ru** 101.1	45 **Rh** 102.9	46 **Pd** 106.4	47 **Ag** 107.9	48 **Cd** 112.4	49 **In** 114.8	50 **Sn** 118.7	51 **Sb** 121.8	52 **Te** 127.6	53 **I** 126.9	54 **Xe** 131.3
6	55 **Cs** 132.9	56 **Ba** 137.3	57 **La** 138.9	72 **Hf** 178.5	73 **Ta** 180.9	74 **W** 183.8	75 **Re** 186.2	76 **Os** 190.2	77 **Ir** 192.2	78 **Pt** 195.1	79 **Au** 197.0	80 **Hg** 200.6	81 **Tl** 204.4	82 **Pb** 207.2	83 **Bi** 209.0	84 **Po** (209)	85 **At** (210)	86 **Rn** (222)
7	87 **Fr** (223)	88 **Ra** 226.0	89 **Ac** 227.0	104 (261)	105 (262)	106 (263)												

Lanthanides	58 **Ce** 140.1	59 **Pr** 140.9	60 **Nd** 144.2	61 **Pm** (145)	62 **Sm** 150.4	63 **Eu** 152.0	64 **Gd** 157.2	65 **Tb** 158.9	66 **Dy** 162.5	67 **Ho** 164.9	68 **Er** 167.3	69 **Tm** 168.9	70 **Yb** 173.0	71 **Lu** 175.0
Actinides	90 **Th** 232.0	91 **Pa** 231.0	92 **U** 238.0	93 **Np** 237.0	94 **Pu** (244)	95 **Am** (243)	96 **Cm** (247)	97 **Bk** (247)	98 **Cf** (251)	99 **Es** (252)	100 **Fm** (257)	101 **Md** (258)	102 **No** (259)	103 **Lr** (260)

Solubility Table

Ion	Solubility	Exceptions
NO_3^-	soluble	none
ClO_4^-	soluble	none
Cl^-	soluble	except Ag^+, Hg_2^{2+}, *Pb^{2+}
I^-	soluble	except Ag^+, Hg_2^{2+}, Pb^{2+}
SO_4^{2-}	soluble	except Ca^{2+}, Ba^{2+}, Sr^{2+}, Hg^{2+}, Pb^{2+}, Ag^+
CO_3^{2-}	insoluble	except Group IA and NH_4^+
PO_4^{3-}	insoluble	except Group IA and NH_4^+
^-OH	insoluble	except Group IA, *Ca^{2+}, Ba^{2+}, Sr^{2+}
S^{2-}	insoluble	except Group IA, IIA and NH_4^+
Na^+	soluble	none
NH_4^+	soluble	none
K^+	soluble	none

*slightly soluble

Name	Formula	K_{a1}	K_{a2}	K_{a3}
Acetic	$HC_2H_3O_2$	1.8×10^{-5}		
Ascorbic	$HC_6H_7O_6$	8.0×10^{-3}		
Arsenic	H_3AsO_4	5.6×10^{-3}	1.0×10^{-7}	3.0×10^{-12}
Arsenous	H_3AsO_3	6.0×10^{-10}		
Benzoic	$HC_7H_5O_2$	6.5×10^{-5}		
Boric	H_3BO_3	5.8×10^{-10}		
Butyric acid	$HC_4H_7O_2$	1.5×10^{-5}		
Carbonic	H_2CO_3	4.3×10^{-7}	5.6×10^{-11}	
Cyanic	HCNO	3.5×10^{-4}		
Citric	$H_3C_6H_5O_7$	7.4×10^{-4}	1.7×10^{-5}	4.0×10^{-7}
Formic	$HCHO_2$	1.8×10^{-4}		
Hydroazoic	HN_3	1.9×10^{-5}		
Hydrocyanic	HCN	4.9×10^{-10}		
Hydrofluoric	HF	7.2×10^{-4}		
Hydrogen chromate ion	$HCrO_4^-$	3.0×10^{-7}		
Hydrogen peroxide	H_2O_2	2.4×10^{-12}		
Hydrogen selenate ion	$HSeO_4^-$	2.2×10^{-2}		
Hydrogen sulfate ion	HSO_4^-	1.2×10^{-2}		
Hydrogen sulfide	H_2S	5.7×10^{-8}	1.3×10^{-13}	
Hypobromous	HBrO	2.0×10^{-9}		
Hypochlorous	HClO	3.0×10^{-8}		
Hypoiodus	HIO	2.0×10^{-11}		
Iodic	HIO_3	1.7×10^{-1}		
Lactic	$HC_3H_5O_3$	1.4×10^{-4}		
Malonic	$H_2C_3H_2O_4$	1.5×10^{-3}	2.0×10^{-6}	
Oxalic	$H_2C_2O_4$	5.9×10^{-2}	6.4×10^{-5}	
Nitrous	HNO_2	4.5×10^{-4}		
Phenol	HC_6H_5O	1.3×10^{-10}		
Phosphoric	H_3PO_4	7.5×10^{-3}	6.2×10^{-8}	4.2×10^{-13}
Paraperiodic	H_5IO_6	2.8×10^{-2}	5.3×10^{-9}	
Propionic	$HC_3H_5O_2$	1.3×10^{-5}		
Pyrophosphoric	H_4P_2O	3.0×10^{-2}	4.4×10^{-3}	
Selenous	H_2SeO_3	2.3×10^{-3}	5.3×10^{-9}	
Sulfuric	H_2SO_4	strong acid	1.2×10^{-2}	
Sulfurous	H_2SO_3	1.7×10^{-2}	6.4×10^{-8}	
Tartaric	$H_2C_4H_4O_6$	1.0×10^{-3}	4.6×10^{-5}	

E.2 DISSOCIATION CONSTANTS FOR BASES AT 25˚C

Name	Formula	K_b	Name	Formula	K_b
Ammonia	NH_3	1.8×10^{-5}	Hydroxylamine	$HONH_2$	1.1×10^{-8}
Aniline	$C_6H_5NH_2$	4.3×10^{-10}	Methylamine	CH_3NH_2	4.4×10^{-4}
Dimethylamine	$(CH_3)_2NH$	5.4×10^{-4}	Pyridine	C_5H_5N	1.7×10^{-9}
Ethylamine	$C_2H_5NH_2$	6.4×10^{-4}	Trimethylamine	$(CH_3)_3N$	6.4×10^{-5}
Hydrazine	H_2NNH_2	1.3×10^{-6}			

A. Acidic Solution	E^o(V)
$F_2(g) + 2H^+ + 2e^- \rightarrow 2HF(aq)$	3.06
$F_2(g) + 2e^- \rightarrow 2F^-$	2.87
$O_3(g) + 2H^+ + 2e^- \rightarrow O_2(g) + H_2O(l)$	2.07
$S_2O_8^{2-} + 2e^- \rightarrow 2SO_4^{2-}$	2.00
$H_2O_2(aq) + 2H^+ + 2e^- \rightarrow 2H_2O(l)$	1.776
$HClO_2(aq) + 2H^+ + 2e^- \rightarrow HClO(aq) + H_2O(l)$	1.645
$2HClO(aq) + 2H^+ + 2e^- \rightarrow Cl_2(g) + 2H_2O(l)$	1.63
$MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O(l)$	1.51
$Au^{3+} + 3e^- \rightarrow Au(s)$	1.498
$PbO_2(s) + 4H^+ + 2e^- \rightarrow Pb^{2+} + 2H_2O(l)$	1.455
$Cl_2(g) + 2e^- \rightarrow 2Cl^-$	1.360
$Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O(l)$	1.33
$2HNO_2(aq) + 4H^+ + 4e^- \rightarrow N_2O(g) + 3H_2O(l)$	1.29
$MnO_2(s) + 4H^+ + 2e^- \rightarrow Mn^{2+} + 2H_2O(l)$	1.23
$O_2(g) + 4H^+ + 4e^- \rightarrow 2H_2O(l)$	1.229
$ClO_3^- + 3H^+ + 2e^- \rightarrow HClO_2(aq) + H_2O(l)$	1.21
$Pt^{2+} + 2e^- \rightarrow Pt(s)$	~1.2
$2IO_3^- + 12H^+ + 10e^- \rightarrow I_2(s) + 6H_2O(l)$	1.195
$ClO_4^- + 2H^+ + 2e^- \rightarrow ClO_3^- + H_2O(l)$	1.19
$Br_2(aq) + 2e^- \rightarrow 2Br^-$	1.087
$Pd^{2+} + 2e^- \rightarrow Pd(s)$	0.987
$NO_3^- + 4H^+ + 3e^- \rightarrow NO(g) + 2H_2O(l)$	0.96
$NO_3^- + 3H^+ + 2e^- \rightarrow HNO_2(aq) + H_2O(l)$	0.942
$2Hg^{2+} + 2e^- \rightarrow Hg_2^{2+}$	0.920
$O_2(g) + 4H^+(pH = 7) + 4e^- \rightarrow 2H_2O(l)$	0.83
$2NO_3^- + 4H^+ + 2e^- \rightarrow N_2O_4(g) + 2H_2O(l)$	0.803
$Ag^+ + e^- \rightarrow Ag(s)$	0.799
$Hg^{2+} + 2e^- \rightarrow Hg(l)$	0.788
$Fe^{3+} + e^- \rightarrow Fe^{2+}$	0.771
$O_2(g) + 2H^+ + 2e^- \rightarrow H_2O_2(aq)$	0.682
$MnO_4^- + e^- \rightarrow MnO_4^{2-}$	0.564
$I_2(s) + 2e^- \rightarrow 2I^-$	0.536
$H_2SO_3(aq) + 4H^+ + 4e^- \rightarrow S(s) + 3H_2O(l)$	0.450
$SO_4^{2-} + 8H^+ + 6e^- \rightarrow S(s) + 4H_2O(l)$	0.357
$Cu^{2+} + 2e^- \rightarrow Cu(s)$	0.337
$AgCl(s) + e^- \rightarrow Ag(s) + Cl^-$	0.222
$SO_4^{2-} + 4H^+ + 2e^- \rightarrow H_2SO_3(aq) + H_2O(l)$	0.172
$Cu^{2+} + e^- \rightarrow Cu^+$	0.153
$Sb_2O_3(s) + 6H^+ + 6e^- \rightarrow 2Sb(s) + 3H_2O(l)$	0.152
$Sn^{4+} + 2e^- \rightarrow Sn^{2+}$	0.15
$S(s) + 2H^+ + 2e^- \rightarrow H_2S(aq)$	0.142
$2H^+ + 2e^- \rightarrow H_2(g)$	0.000
$Pb^{2+} + 2e^- \rightarrow Pb(s)$	−0.126
$Sn^{2+} + 2e^- \rightarrow Sn(s)$	−0.136
$Ni^{2+} + 2e^- \rightarrow Ni(s)$	−0.250
$PbCl_2(s) + 2e^- \rightarrow Pb(s) + 2Cl^-$	−0.268
$PbSO_4(s) + 2e^- \rightarrow Pb(s) + SO_4^{2-}$	−0.359
$Cd^{2+} + 2e^- \rightarrow Cd(s)$	−0.403
$Cr^{3+} + e^- \rightarrow Cr^{2+}$	−0.408
$Fe^{2+} + 2e^- \rightarrow Fe(s)$	−0.440
$Cr^{3+} + 3e^- \rightarrow Cr(s)$	−0.744
$Zn^{2+} + 2e^- \rightarrow Zn(s)$	−0.763
$Mn^{2+} + 2e^- \rightarrow Mn(s)$	−1.185
$Al^{3+} + 3e^- \rightarrow Al(s)$	−1.662
$H_2(g) + 2e^- \rightarrow 2H^-$	−2.25
$Mg^{2+} + 2e^- \rightarrow Mg(s)$	−2.363
$Na^+ + e^- \rightarrow Na(s)$	−2.714
$Ca^{2+} + 2e^- \rightarrow Ca(s)$	−2.866
$Sr^{2+} + 2e^- \rightarrow Sr(s)$	−2.888
$Ba^{2+} + 2e^- \rightarrow Ba(s)$	−2.906
$K^+ + e^- \rightarrow K(s)$	−2.925
$Li^+ + e^- \rightarrow Li(s)$	−3.045

B. Alkaline Solution	E^o(V)
$O_3(g) + H_2O(l) + 2e^- \rightarrow O_2(g) + 2OH^-$	1.24
$ClO^- + H_2O(l) + 2e^- \rightarrow Cl^- + 2OH^-$	0.89
$MnO_4^- + 2H_2O(l) + 3e^- \rightarrow MnO_2(s) + 4OH^-$	0.588
$NiO_2(s) + 2H_2O(l) + 2e^- \rightarrow Ni(OH)_2(s) + 2OH^-$	0.490
$O_2(g) + 2H_2O(l) + 4e^- \rightarrow 4OH^-$	0.401
$ClO_4^- + H_2O(l) + 2e^- \rightarrow ClO_3^- + 2OH^-$	0.36
$ClO_3^- + H_2O(l) + 2e^- \rightarrow ClO_2^- + 2OH^-$	0.33
$PbO_2(s) + H_2O(l) + 2e^- \rightarrow PbO(s) + 2OH^-$	0.247
$HgO(s) + H_2O(l) + 2e^- \rightarrow Hg(l) + 2OH^-$	0.098
$NO_3^- + H_2O(l) + 2e^- \rightarrow NO_2^- + 2OH^-$	0.01
$MnO_2(s) + 2H_2O(l) + 2e^- \rightarrow Mn(OH)_2(s) + 2OH^-$	−0.05
$CrO_4^{2-} + 4H_2O(l) + 3e^- \rightarrow Cr(OH)_3(s) + 5OH^-$	−0.13
$Cu_2O(s) + H_2O(l) + 2e^- \rightarrow 2Cu(s) + 2OH^-$	−0.358
$2S(s) + 2e^- \rightarrow S_2^{2-}$	−0.447
$Fe(OH)_3(s) + e^- \rightarrow Fe(OH)_2(s) + OH^-$	−0.56
$BrO_3^- + 3H_2O(l) + 6e^- \rightarrow Br^- + 6OH^-$	0.61
$Ni(OH)_2(s) + 2e^- \rightarrow Ni(s) + 2OH^-$	−0.72
$Cd(OH)_2(s) + 2e^- \rightarrow Cd(s) + 2OH^-$	−0.809
$2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-(pH = 7)$	−0.43
$2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-$	−0.828
$Fe(OH)_2(s) + 2e^- \rightarrow Fe(s) + 2OH^-$	−0.877
$Zn(OH)_2(s) + 2e^- \rightarrow Zn(s) + 2OH^-$	−1.245
$Al(OH)_3(s) + 3e^- \rightarrow Al(s) + 3OH^-$	−2.30
$Mg(OH)_2(s) + 2e^- \rightarrow Mg(s) + 2OH^-$	−2.690