Exam 3

# Part 1: Multiple Choice (2 points each)

## Directions: Please circle the *best* answer for each of the following questions.

1. Identify the location of reduction in an electrochemical cell.
2. the anode
3. the cathode
4. the electrode
5. the salt bridge
6. the socket
7. Which of the following pairs of coordination compounds or complex ions are examples of linkage isomers?
8. [Fe(CO)5NO2]2+ and [Fe(CO)5ONO]2+
9. [Fe(NH3)2(H2O)4]Cl2 and [Fe(NH3)2(H2O)4]Br2
10. [Fe(NH3)2(H2O)4]Cl2 and [Fe(NH3)4(H2O)2]Cl2
11. [Cu(CO)5Br]Cl and [Cu(CO)5Cl]Br
12. [MnCl3Br]2- and [MnClBr3]2-

1. Which of the following can function as a bidentate ligand?
2. CN-
3. SH-
4. H2O
5. H2NCH2CH2NH2
6. CO
7. An element with a strong tendency to gain electrons is also \_\_\_\_\_\_\_\_\_\_\_.
	1. easily oxidized
	2. a good oxidizing agent
	3. a good reducing agent
	4. a radioactive metal
	5. none of the above
8. For an octahedral complex what metal d orbitals are directly towards the ligand?
	1. dxy, dxz
	2. dxy, dxz, dyz
	3. $d\_{z^{2}}, d\_{x^{2}-y^{2}}$
	4. $d\_{z^{2}}, d\_{xz}, d\_{yz}$
	5. none of the above
9. What statement is not true about standard electrode potentials?
10. E°cell is positive for spontaneous reactions.
11. Electrons will flow from more negative to more positive electrode.
12. The electrode potential of the standard hydrogen electrode is exactly zero.
13. E°cell is the difference in voltage between the anode and the cathode.
14. The electrode in any half-cell with a greater tendency to undergo reduction is positively charged relative to the standard hydrogen electrode and therefore has a positive E°.
15. How many moles of aqueous ions will be produced from the dissolution of 2.0 mole of K3[FeCl6]?
16. 2
17. 4
18. 8
19. 16
20. 20
21. Which of the following species is diamagnetic?
	1. An isolated, gas-phase Cr3+ ion
	2. A high-spin octahedral Cr2+complex
	3. An isolated, gas-phase Cu2+ ion
	4. A low-spin octahedral Co3+ complex
	5. all of the above
22. Identify a component in the formation of rust.
23. Salt
24. Moisture
25. Acid
26. all of the above
27. none of the above
28. Which is most often used in the laboratory to measure pH?
	1. A standard hydrogen electrode
	2. A glass electrode
	3. A Daniell cell
	4. A conductivity cell
	5. none of the above

# Part 2: Short Answer

## Directions: Answer each of the following questions. Be sure to use complete sentences where appropriate. For full credit be sure to show all of your work.

1. Two different coordination compounds containing one cobalt(III) ion, five ammonia molecules, one bromide ion, and one sulfate ion exist. The dark violet form (A) gives a precipitate upon addition of aqueous barium chloride. No reaction is seen upon addition of aqueous barium chloride to the violet-red form (B). Suggest formula for these two compounds, name them, and write a chemical equation for the reaction of (A) with aqueous barium chloride (6 points).
2. [Co(NH3)5Br]SO4 pentaamminebromocobalt(III) sulfate
3. [Co(NH3)5SO4]Br pentaamminesulfatocobalt(III) bromide

[Co(NH3)5Br]SO4 (aq) + BaCl2 (aq) → [Co(NH3)5Br]Cl2 (aq) + BaSO4 (s)

1. The hexachlorochromate(III) ion has a maximum in its absorption spectrum at 735 nm (6 points).
	1. What is the formula of the ion? \_\_\_\_\_\_[CrCl6]3-
	2. Calculate the crystal field splitting energy (in kJ/mol) for this ion.

$∆=\frac{hc}{λ}=\frac{\left(6.626×10^{-34}J s\right)(3.00 ×10^{8}\frac{m}{s})}{(735 nm ion)}×\frac{10^{9} nm}{1m}×\frac{1 kJ}{1000 J}×\frac{6.022×10^{23} ions}{1 mol}=163\frac{kJ}{mol}$

1. Three beakers contain solution of [CoF6]3-, [Co(NH3)6]3+, and [Co(CN)6]3-. Match the solution with its color (3 points):
	1. Yellow \_\_\_\_\_\_[Co(CN)6]3-
	2. Blue \_\_\_\_\_\_[CoF6]3-
	3. Orange \_\_\_\_\_\_[Co(NH3)6]3+
2. Explain why compounds of Zn2+ are white, but compounds of Cu2+ are often blue or green (4 points).

Zn2+ has a filled d subshell, while Cu2+ has 9 d electrons. Since Zn2+ has this filled d subshell, the color of the compounds will be white. Cu2+ has an incomplete d subshell, so different ligands will cause a different crystal field splitting and the compounds will have color.

1. When a solution of platinum(II) chloride, PtCl2, is allowed to react with the ligand trimethylphosphine, P(CH­3)3, two compounds are produced. Both compounds give the same elemental analysis: 46.7% Pt; 17.0% Cl; 14.8% P; 17.2% C; 4.34% H (15 points).
	1. Determine the formula.

$$46.7 g Pt×\frac{1 mol Pt}{195.1 g Pt}=\frac{0.239644285 mol Pt}{0.239644285 mol Pt}=1$$

$$17.0 g Cl×\frac{1 mol Cl}{35.453 g Cl}=\frac{0.4795080811 mol Cl}{0.239644285 mol Pt}=2.000915987≈2$$

$$14.8 g P×\frac{1 mol P}{30.97 g P}=\frac{0.4778818211 mol P}{0.239644285 mol Pt}=1.994125144≈2$$

$$17.2 g C×\frac{1 mol C}{12.01 g C}=\frac{1.432139883 mol C}{0.239644285 mol Pt}=5.976106976≈6$$

$$4.34 g H×\frac{1 mol H}{1.008 g H}=\frac{4.305555555 mol H}{0.239644285 mol Pt}=17.9664437≈18$$

PtCl2P2C6H18 = PtCl2(P(CH3)3)2

* 1. Draw the structures and give the systematic names for both compounds.



1. Regarding the porous separator between the two halves of an electrochemical cell (4 points):
	1. Describe how it allows electrical charge to flow between the two-half cells.

The porous separator allows nonreactive ions to pass through the separator to maintain electrical neutrality.

* 1. Explain why a piece of wire could not perform the same function.

The wire would allow electrons to pass, but not other ions, and because electrons cannot travel through the solution, the wire would not complete the circuit.

1. A Downs cell operating at 77.0 A produces 31.0 kg of Na (10 points):

2 NaCl (s) → 2 Na (s) + Cl2 (g)

* 1. What volume of Cl2 (g) is produced at 1.0 atm and 540 °C?

$$31.0 kg Na×\frac{1000 g}{1 kg}×\frac{1 mol Na}{22.990 mol }×\frac{1 mol Cl\_{2}}{2 mol Na}=674.2061766 mol Cl\_{2}$$

$$PV=nRT⟹V=\frac{nRT}{P}=\frac{\left(674.2061766 mol \right)\left(0.08206 \frac{L atm}{mol K}\right)\left(540+273\right)}{1.0 atm}=4.5×10^{4} L$$

* 1. How many coulombs were passed through the cell?

$$674.2061766 mol Cl\_{2}×\frac{2 mol e^{-}}{1 mol Cl\_{2}}×\frac{96485 C}{mol e^{-}}=1.30×10^{8} C$$

Or

$$31.0 kg Na×\frac{1000 g}{1 kg}×\frac{1 mol Na}{22.990 mol }×\frac{1 mol e^{-}}{1 mol Na}×\frac{96485 C}{mol e^{-}}=1.30×10^{8} C$$

* 1. How long did it operate?

$$1.30×10^{8} C×\frac{s A}{1 C}×\frac{1}{77.0 A}=1.69×10^{6} s or 19.6 days $$

1. Permanganate ion can oxidize sulfite to sulfate in basic solution (10 points):

3 SO32- (aq) + H2O (l) + 2 MnO4- (aq) → 3 SO42- (aq) + 2 MnO2 (s) + 2 OH- (aq)  E° = 1.51 V

* 1. Determine the potential for the reaction at 298 K when the concentrations of the reactants and products are as follows: [MnO4-] = 0.150 M, [SO32-] = 0.356 M, [SO42-] = 0.178 M, and [OH-] = 0.0100 M.

$$E\_{cell}=E^{°}-\frac{RT}{nF}lnQ=E^{°}-\frac{RT}{nF}ln\left(\frac{[SO\_{4}^{2-}]^{3}[OH^{-}]^{2}}{[SO\_{3}^{2-}]^{3}[MnO\_{4}^{-}]^{2}}\right)$$

$$E\_{cell}=1.51 V-\frac{\left(8.3145\frac{J}{mol K}\right)\left(298 K\right)}{\left(6 mol e^{-}\right)\left(96485\frac{C}{mol e^{-}}\right)}ln\left(\frac{(0.178 M)^{3}(0.0100 M)^{2}}{(0.356 M)^{3}(0.150 M)^{2}}\right)$$

$$E\_{cell}=1.51 V--0.0318 V=1.54 V$$

* 1. Will the value of Erxn increase or decrease as the reaction proceeds?

Erxn will decrease as the reaction proceeds.

1. For the production of ammonia from the elements

N2 (g) + 3 H2 (g) $⇌$ 2 NH3 (g) E° = 0.057 V

find n and ΔGr° for the reaction (6 points).

Reduction: N2 + 6 e- → 2 N3-

Oxidation: **(**H2 → 2 H+ + 2 e-**) x 3**

 3 H2 → 6 H+ + 6 e-

 Therefore, n = 6

$$∆G^{°}=-nFE^{°}=-\left(6 mol e^{-}\right)\left(96485\frac{J}{ V mol e^{-}}\right)\left(0.057 V\right)×\frac{1 kJ}{1000 J}=-33 kJ$$

1. To electroplate all the Cu and Cd from a solution of CuSO4 and CdSO4 required 1.30 F of electricity (1 F = 1 mol e-). The mixture of Cu and Cd that was deposited had a mass of 50.36 g. What mass of CuSO4 was present in the original mixture (14 points)?

Let nCu = moles of e- from Cu Cu2+ (aq) + 2 e- → Cu (s)

 nCd = moles of e- from Cd Cd2+ (aq) + 2 e- → Cd (s)

nCu + nCd = 1.30 F = 1.30 mol e- $⇒$ nCd = 1.30 mol e- – nCu

mCu + mCd = 50.36 g

where $m\_{Cu}=n\_{Cu}×\frac{63.546 g Cu}{1 mol Cu}×\frac{1 mol Cu}{2 mol e^{-}}$

 $m\_{Cd}=n\_{Cd}×\frac{112.411 g Cd}{1 mol Cd}×\frac{1 mol Cd}{2 mol e^{-}}$

$$n\_{Cu}×\frac{63.546 g Cu}{1 mol Cu}×\frac{1 mol Cu}{2 mol e^{-}}+n\_{Cd}×\frac{112.411 g Cd}{1 mol Cd}×\frac{1 mol Cd}{2 mol e^{-}}=50.36 g$$

$n\_{Cu}×\frac{63.546 g Cu}{1 mol Cu}×\frac{1 mol Cu}{2 mol e^{-}}+(1.30 mol e^{-}-n\_{Cu})×\frac{112.411 g Cd}{1 mol Cd}×\frac{1 mol Cd}{2 mol e^{-}}=50.36 g$

$$n\_{Cu}×\frac{31.773 g Cu}{1 mol e^{-}}+(1.30 mol e^{-}-n\_{Cu})×\frac{56.2055 g Cd}{1 mol e^{-}}=50.36 g$$

$$n\_{Cu}×\frac{31.773 g Cu}{1 mol e^{-}}+73.06715 g Cd-n\_{Cu}×\frac{56.2055 g Cd}{1 mol e^{-}}=50.36 g$$

$$n\_{Cu}×\frac{-24.4325 g Cu}{1 mol e^{-}}=-22.70715 g$$

$n\_{Cu}=0.929382994 mol e^{-}×\frac{1 mol Cu^{2+}}{2 mol e^{-}}×\frac{1 mol CuSO\_{4}}{1 mol Cu^{2+}}×\frac{159.603 g CuSO\_{4}}{1 mol CuSO\_{4}}=74.2 g CuSO\_{4}$

Don’t forget to plug your answer into the original equation to check your work.