CHEM 310 Practice Exam 2B

Chemistry 310 **Name** _____

Practice Exam 2B

Access ID (PSU Email) _____

There are 9 questions on this exam. Check that you have done all parts of all of the problems. The maximum score on this exam is 100 points.

Exam policy:

- **Calculators with text-programmable memory are not allowed.**
- **No outside materials, resources or papers are allowed, including scratch paper.**
- **A data sheet is attached to this exam**, along with scratch paper and a periodic table.
- The answer key will be posted on Canvas after the exam is graded.
- You have 75 minutes to complete this exam.
- Put your name and access ID on all pages in case they become separated.
- You must turn in all exam materials including scratch paper and data sheets.

Advice:

- As you read the question, underline or circle key words to highlight them for yourself. Avoid errors from "mis-reading" the question.
- Pay attention to units and magnitudes (decimal places) of numbers obtained from calculations.
- There is no penalty for guessing.

PERIODIC TABLE of the ELEMENTS

MAIN GROUPS 1A (1)	2A (2)	3B (3)	4B (4)	5B (5)	6B (6)	7B (7)	8B (8)	8B (9)	8B (10)	1B (11)	2B (12)	3A (13)	4A (14)	5A (15)	6A (16)	MAIN GROUPS 7A (17)	8A (18)
1 **H** 1.008																	1 **H** 1.008
					TRANSITION METALS												2 **He** 4.003
3 **Li** 6.941	4 **Be** 9.012											5 **B** 10.811	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** 28.086	15 **P** 30.974	16 **S** 32.066	17 **Cl** 35.453	18 **Ar** 39.948
19 **K** 39.098	20 **Ca** 40.078	21 **Sc** 44.956	22 **Ti** 47.867	23 **V** 50.942	24 **Cr** 51.996	25 **Mn** 54.938	26 **Fe** 55.845	27 **Co** 58.933	28 **Ni** 58.693	29 **Cu** 63.546	30 **Zn** 65.39	31 **Ga** 69.723	32 **Ge** 72.61	33 **As** 74.992	34 **Se** 78.96	35 **Br** 79.904	36 **Kr** 83.80
37 **Rb** 85.468	38 **Sr** 87.62	39 **Y** 88.906	40 **Zr** 91.224	41 **Nb** 92.906	42 **Mo** 95.94	43 **Tc** [98]	44 **Ru** 101.07	45 **Rh** 102.90	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	53 **I** 126.90	54 **Xe** 131.29
55 **Cs** 132.91	56 **Ba** 137.33	57 **La*** 138.91	72 **Hf** 178.49	73 **Ta** 180.95	74 **W** 183.84	75 **Re** 186.21	76 **Os** 190.23	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** [209]	85 **At** [210]	86 **Rn** [222]
87 **Fr** [223]	88 **Ra** [226]	89 **Ac**** [227]	104 **Rf** [261]	105 **Db** [262]	106 **Sg** [266]	107 **Bh** [264]	108 **Hs** [265]	109 **Mt** [268]	110 **Ds** [271]	111 **Rg** [280]	112 **Cn** [285]	113 **Nh** [286]	114 **Fl** [289]	115 **Mc** [289]	116 **Lv** [293]	117 **Ts** [294]	118 **Og** [294]

* LANTHANOIDS	58 **Ce** 140.12	59 **Pr** 140.91	60 **Nd** 144.24	61 **Pm** [145]	62 **Sm** 150.36	63 **Eu** 151.96	64 **Gd** 157.25	65 **Tb** 158.92	66 **Dy** 162.50	67 **Ho** 164.93	68 **Er** 167.26	69 **Tm** 168.93	70 **Yb** 173.04	71 **Lu** 174.97
** ACTINOIDS	90 **Th** 232.04	91 **Pa** 231.04	92 **U** 238.03	93 **Np** [237]	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** [262]

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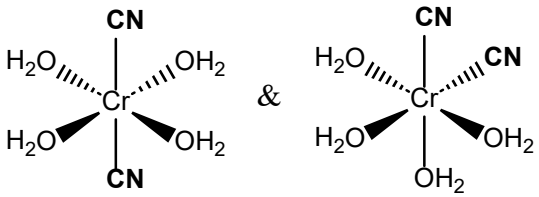
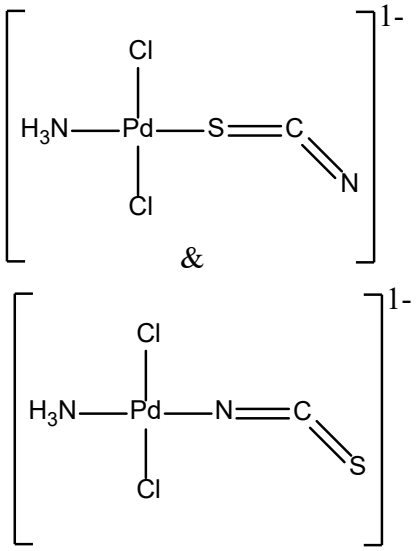
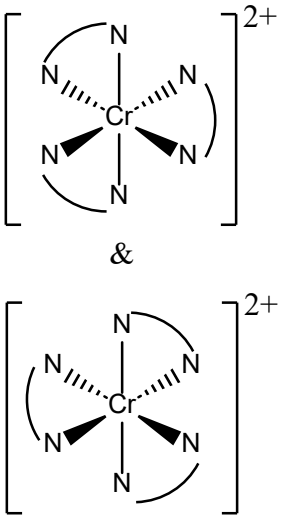
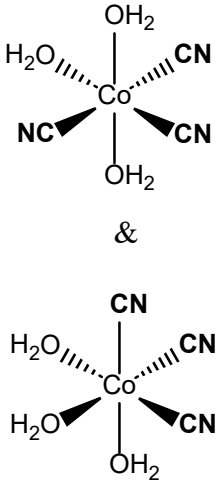
1. Given the complexes below, please assign each pair to the correct isomerization identity. (10 points)

Assign each isomer a letter corresponding to a pair of complexes. An example is provided.

Linkage Isomer	Coordination Isomer	Geometric Isomer *(cis/trans)*	Geometric Isomer *(fac/mer)*	Optical Isomer	EXAMPLE: Hydration Isomer
____	____	____	____	____	A

EXAMPLE: A	B	C
$[CrCl_2(H_2O)_4]Cl \bullet 2H_2O$ & $[Cr(H_2O)_6]Cl_3$	$[Co(en)_3][Cr(CN)_6]$ & $[Cr(en)_3][Co(CN)_6]$	

D	E	F
		

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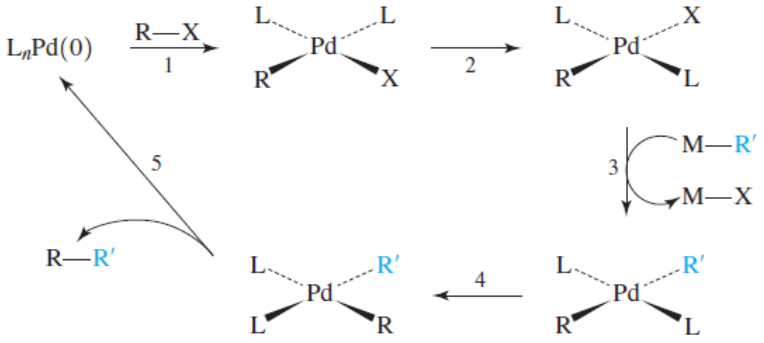
2. The catalytic cycle for Pd-Catalyzed Cross Coupling is shown below, with each reaction step labeled with a number. Give the name of the process represented by each number, using the exact wording of one of the choices below for each answer. You can use the same answer more than once for different steps. (10 points)

Word Bank

Orthometallation (*o*-LS)
Transmetallation (*trans*-LS)
Reductive Elimination (RE)
cis-trans Isomerization
Alkyl migration
Oxidative Addition (OA)
Migratory Insertion (1,2)

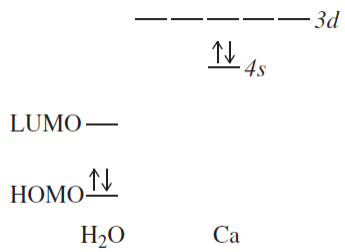


STEP 1	STEP 2	STEP 3	STEP 4	STEP 5

3. Given the 4 MO diagrams and reactions below, please classify water as a **Lewis acid**, **Lewis base**, **oxidizing agent**, or **reducing agent**. Briefly justify your answer. (8 points)

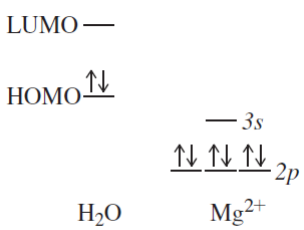
$2\,H_2O(l) + Ca(s) \longrightarrow Ca^{2+}(aq) + 2\,OH^-(aq) + H_2(g)$

Water is acting as _____.



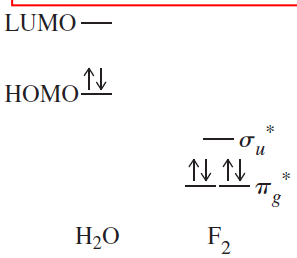
$6\,H_2O(l) + Mg^{2+} \longrightarrow [Mg(H_2O)_6]^{2+}(aq)$

Water is acting as _____.



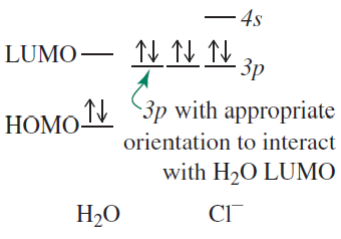
$2\,H_2O(l) + 2\,F_2(g) \longrightarrow 4\,F^-(aq) + 4\,H^+(aq) + O_2(g)$

Water is acting as _____.



$n\,H_2O(l) + Cl^- \longrightarrow [Cl(H_2O)_n]^-$

Water is acting as _____.



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3. Which of the following acids would be the strongest in water: HCl, $HClO_3$, or $HClO_4$? Please justify your answer. (5 points)

4. Based on the Latimer diagram below, please answer the following questions:

$$\overset{+4}{CuO^{2+}} \xrightarrow{+1.76\ V} \overset{+2}{Cu^{2+}} \xrightarrow{+0.159\ V} \overset{+1}{Cu^{+}} \xrightarrow{+0.520\ V} \overset{0}{Cu}$$

a) Write a balanced reaction for the reduction of CuO^{2+} to Cu(s) in acid. What is the coefficient for H^+ and e^-? Please circle your answer. (5 points)

H^+ coefficient	**e^- coefficient**
A. 1	A. 1
B. 2	B. 6
C. 6	C. 2
D. 0	D. 4

b) Please calculate the value of E° for the reduction of CuO^{2+} to Cu(s) in acid (the half reaction in the previous question). Show all work. (5 points)

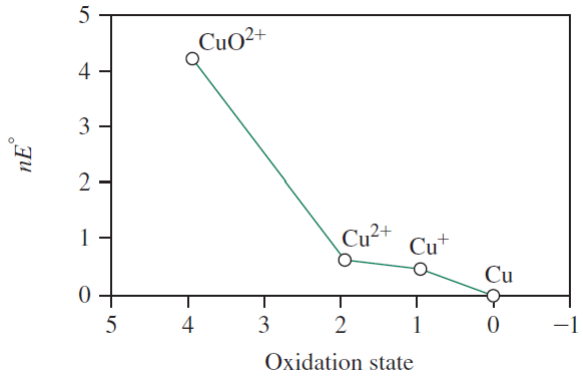
c) Given the Frost diagram, please circle which species are **thermodynamically stable** with respect to disproportionation in acid. (CIRCLE ALL CORRECT ANSWERS. THERE MAY BE MORE THAN ONE) (4 points)

A. CuO^{2+}

B. Cu^{2+}

C. Cu^+

D. Cu



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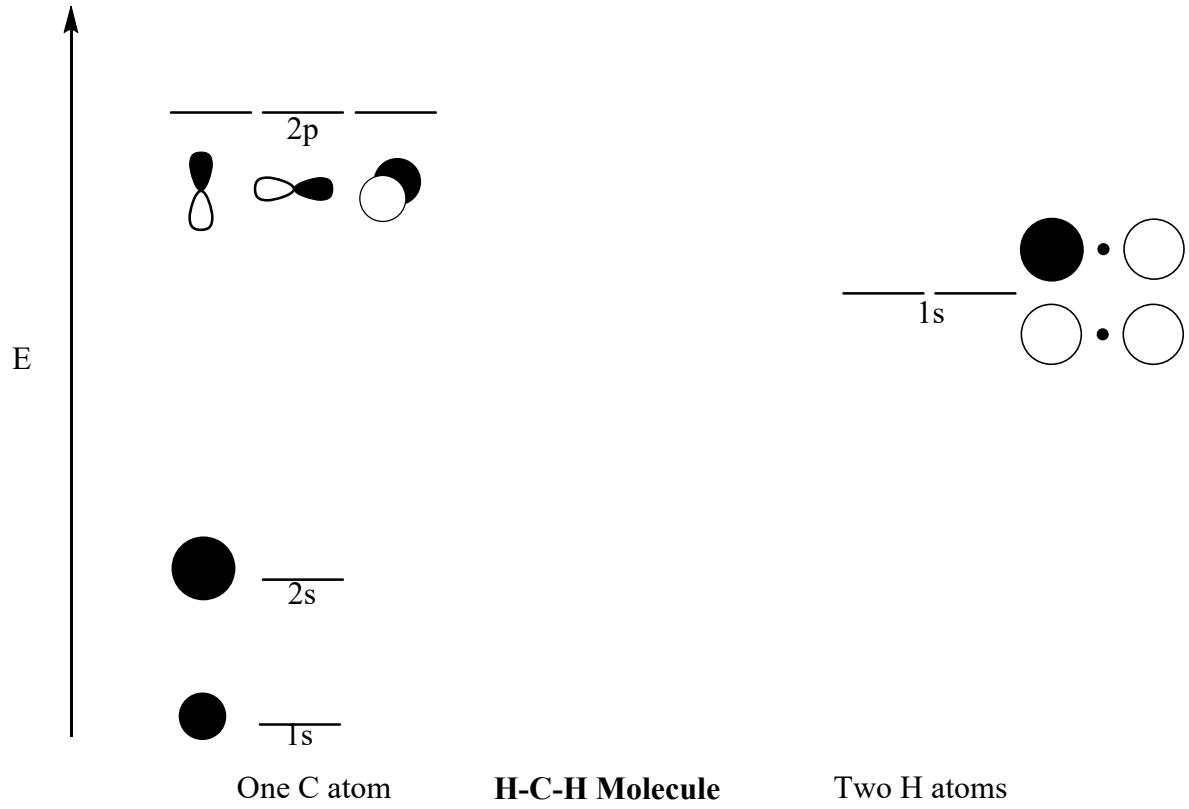
5. The C atomic orbitals and H · H group atomic orbitals and their approximate energies are shown below for the linear H-C-H molecule.

a. Construct a molecular orbital diagram for the H-C-H molecule. Use short lines to represent the molecular orbitals at their approximate energy levels relative to the atomic orbitals shown below. (4 points)

b. Label and draw the 3-dimensional shapes of all molecular orbitals, indicate which orbital line they belong to, and clearly indicate which molecular orbitals are sigma, pi, bonding, antibonding, and non-bonding. Use a dot to represent a node, similar to the one shown in the hydrogen group orbitals. (4 points)

c. Fill in the molecular orbital diagram you drew with the appropriate number of electrons at the correct locations. (4 points)

d. Calculate the bond order for H-C-H (methylene). (3 points)



BOND ORDER:

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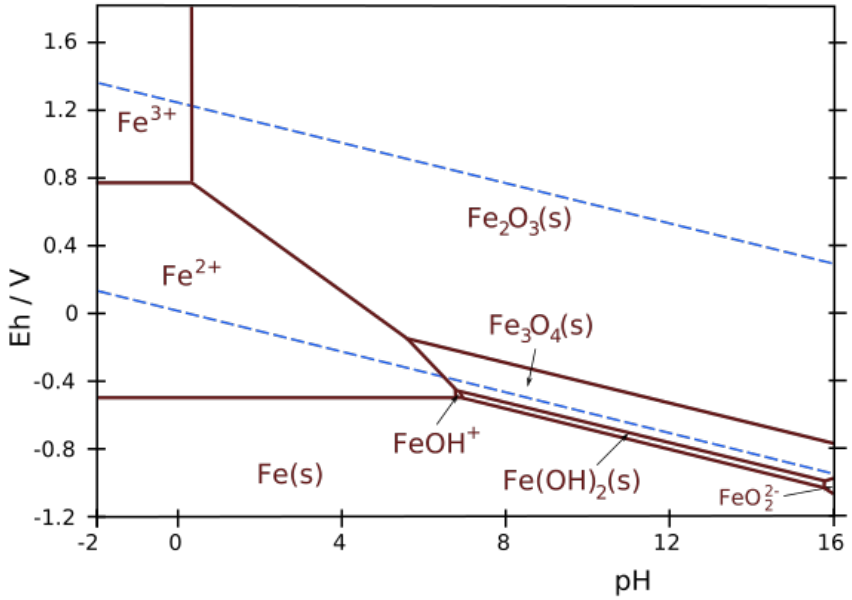
6. The Pourbaix diagram for iron is shown below. Please color/shade the region in which Fe_2O_3 (s) is stable in liquid water. (4 points)



7. Please answer the following questions regarding $[Cr(H_2O)_6]^{3+}$ and $[Cr(H_2O)_6]^{3+}$.

a) Calculate the CFSEs of each complex. (4 points)

b) Is $[Cr(H_2O)_6]^{3+}$ **kinetically inert** OR **labile**? (1 point)

c) Is $[Cr(H_2O)_6]^{2+}$ **kinetically inert** OR **labile**? (1 point)

8. Hexacyanoferrate(II) is a complex that is commonly used as an anticaking agent.

a) Calculate the Crystal Field Stabilization Energy of this complex. (2 points)

b) Do you expect the compound to be high or low spin? Justify your answer. (4 points)

c) Is Δ_o larger or smaller than the pairing energy? (1 point)

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9. For NO, NO^+, and NO^-:

a) Draw the energy diagrams (6 points)

b) Calculate the bond orders. (3 points)

c) Rank the molecules by strongest to weakest bond. Justify your answer. (4 points)

10. Answer the following questions regarding the reaction below:

$$[Pd(CN)_4]^{2-}(aq) + 4\,NH_3(aq) \rightleftharpoons [Pd(NH_3)_4]^{2+}(aq) + 4\,CN^-$$

a) Which way will the reaction above shift? Please justify your answer. (4 points)

b) What type of ligand is NH_3? Circle one (1 point)

π-donor **σ-donor** **π-acceptor**

c) Explain why CN^- is a strong field ligand. (3 points)

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CHEM 310 Data Sheet

Conversions and Constants

$1\ g = 6.02 \times 10^{23}\ amu$

$1\ \text{Å} = 1 \times 10^{-10}\ m$

$1\ eV = 96\ kJ\ mol^{-1}$

$for\ 1\ eV\ \lambda = 1240\ nm$

$1\ kcal = 4.184\ kJ$

$1\ J = C \cdot V = kg\ m^2 s^{-2}$

$1\ A = Cs^{-1}$

$c = 2.99792458 \times 10^{8}\ m\ s^{-1}$

$h = 6.63 \times 10^{-34}\ J\ s$

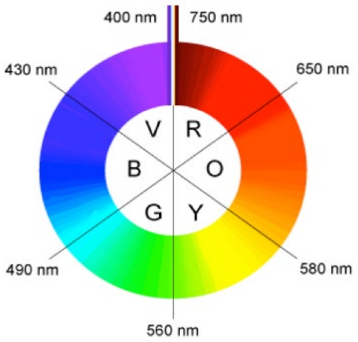
$F = 96485\ C\ mol^{-1}$

$N_A = 6.022 \times 10^{23}\ mol^{-1}$

$R = 8.314\ Jmol^{-1}K^{-1}$

$K_w = 1.0 \times 10^{-14}\ at\ 298\ K$

Color Wheel with λ Ranges



Equations

same group; 0.35
(*n*-1 group); 0.85
(lower *n* groups); 1.00

S for *nd/nf*
same group; 0.35
(groups to left); 1.00

$Z_{eff} = Z - S$

D(n) = D(m) – 0.6 log(n/m)

slope = 0.0592 V/pH

$-\Delta H = E_A E_B + C_A C_B + W$

$\mu_s = [n(n+2)]^{\frac{1}{2}}\ \mu_B$

$O_pE(OH)_q$ pK_a ~ 8 – 5p
add 5 units for q > 1

$\Delta G° = -nfE° = -RTlnK$

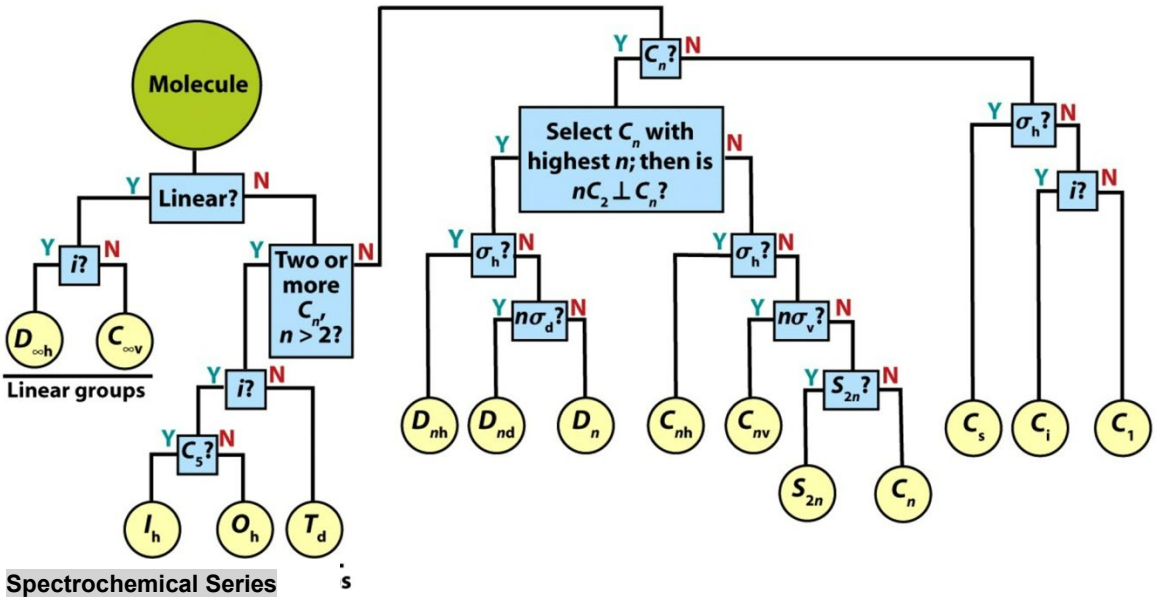
$E° = \frac{0.0592}{n} \log K\ (@298K)$

$E = E° - \frac{0.0592}{n} log\ Q(@298K)$

$E = h\nu = \frac{hc}{\lambda}$

$E_g(eV) = \frac{1240}{\lambda(nm)}$

Point Group Flow Chart



Spectrochemical Series

$I^- < Br^- < S^{2-} < \underline{S}CN^- < Cl^- < NO_2^- < N^{3-} < NO_3^- < F^- < OH^- < C_2O_4^{2-} < O^{2-} < H_2O <$
$\underline{N}CS^- < CH_3CN <$ pyridine $< NH_3 <$ en $<$ bipy $<$ phen $< NO_2^- < PPh_3 < CN^- < CO$

Trans-directing ligands

$F^-, H_2O, OH^- < NH_3 <$ py $< Cl^- < Br^- < I^-, SCN^-, NO_2^-, SC(NH_2)_2, Ph^- < SO_3^{2-} < PR_3,$
$AsR_3, SR_2, CH_3^- < H^-, NO, CO, CN^-, C_2H_4$