Inorganic Chemistry Cumulative Exam
February 6th, 2020
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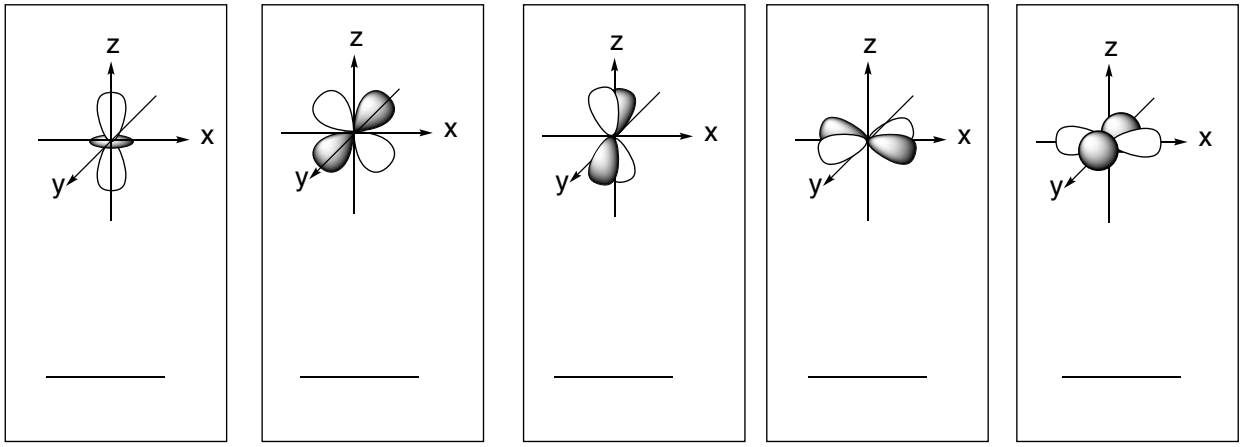
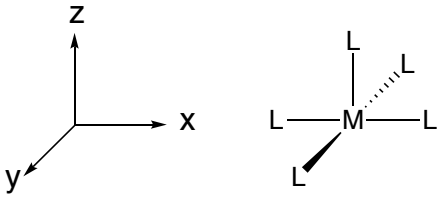
Note: *A periodic table is provided with this exam*
Note: *50/100 points correct to pass*

1. (20 points) Underneath the picture of each orbital, write its corresponding name.



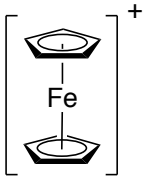
2. A **square-pyramidal ML_5** complex (L = arbitrary sigma-bonding ligand) is shown below. The Cartesian axes are shown for reference.



   a. (4 point) What is the point group of this molecule? _____

   b. (16 points) Draw the ligand field splitting diagram (only use meta *d* orbitals and ligand *s* orbital) and the associated molecular orbitals (including bonding, non-bonding, and anti-bonding interactions). *If a group of orbitals are the same energy, draw it clearly.*

3. Ferrocenium ion is shown below:



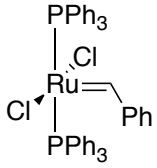
   a. (4 points) What is the formal oxidation state of Fe? _____

   b. (4 points) How many *d* electrons does Fe have in this oxidation state? _____

   c. (4 points) What is the electron-count of Fe in this complex? _____

   d. (4 points) What is the point group (as-drawn in *eclipsed* conformation)? _____

4. Grubb's catalyst is shown below:



   a. (4 points) What is the formal oxidation state of Ru? _____

   b. (4 points) How many *d* electrons does Ru have in this oxidation state? _____

   c. (4 points) What is the electron-count of Ru in this complex? _____

   d. (4 points) What is the point group? _____

5. Consider a d^5 **octahedral metal ion**.

   a. (8 points) Fill in the crystal field splitting diagrams for low- and high-spin configurations.

High-spin	*Low-spin*
— — e_g	— — e_g
— — — t_{2g}	— — — t_{2g}

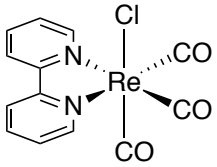
   b. (4 points) What is the spin value, *S*, of the high-spin state? _____

   c. (4 points) What is the spin value, *S*, of the low-spin state? _____

6. (6 points) Octahedral complexes of Co^{+3} are exceptionally slow at exchanging their bound ligands for other ligands, often being referred to as inert complexes. Explain, using ligand field arguments.

7. (6 points) Despite possessing identical electron counts and oxidation states, $[NiCl_4]^{2-}$ and $[PtCl_4]^{2-}$ have very different molecular geometries, with the former being tetrahedral and the latter being square-planar. Explain, using ligand field diagrams and steric arguments.

8. **Extra Credit (10 points, no partial credit)**. If you have a sample that you believe to be $Re(CO)_3$(2,2'-bipyridine)Cl (see structure below), besides crystallography, explain what combination of techniques you could use to identify its composition and structure? *An acceptable answer must address how the elemental composition, ligand identities, and symmetry are measured, and how the interpretation of these data converge onto a single structure.*



hydrogen 1 **H** 1.0079												boron 5 **B** 10.811	carbon 6 **C** 12.011	nitrogen 7 **N** 14.007	oxygen 8 **O** 15.999	fluorine 9 **F** 18.998	helium 2 **He** 4.0026
lithium 3 **Li** 6.941	beryllium 4 **Be** 9.0122																neon 10 **Ne** 20.180
sodium 11 **Na** 22.990	magnesium 12 **Mg** 24.305											aluminium 13 **Al** 26.982	silicon 14 **Si** 28.086	phosphorus 15 **P** 30.974	sulfur 16 **S** 32.065	chlorine 17 **Cl** 35.453	argon 18 **Ar** 39.948
potassium 19 **K** 39.098	calcium 20 **Ca** 40.078		scandium 21 **Sc** 44.956	titanium 22 **Ti** 47.867	vanadium 23 **V** 50.942	chromium 24 **Cr** 51.996	manganese 25 **Mn** 54.938	iron 26 **Fe** 55.845	cobalt 27 **Co** 58.933	nickel 28 **Ni** 58.693	copper 29 **Cu** 63.546	zinc 30 **Zn** 65.39	gallium 31 **Ga** 69.723	germanium 32 **Ge** 72.61	arsenic 33 **As** 74.922	selenium 34 **Se** 78.96	bromine 35 **Br** 79.904	krypton 36 **Kr** 83.80
rubidium 37 **Rb** 85.468	strontium 38 **Sr** 87.62		yttrium 39 **Y** 88.906	zirconium 40 **Zr** 91.224	niobium 41 **Nb** 92.906	molybdenum 42 **Mo** 95.94	technetium 43 **Tc** [98]	ruthenium 44 **Ru** 101.07	rhodium 45 **Rh** 102.91	palladium 46 **Pd** 106.42	silver 47 **Ag** 107.87	cadmium 48 **Cd** 112.41	indium 49 **In** 114.82	tin 50 **Sn** 118.71	antimony 51 **Sb** 121.76	tellurium 52 **Te** 127.60	iodine 53 **I** 126.90	xenon 54 **Xe** 131.29
caesium 55 **Cs** 132.91	barium 56 **Ba** 137.33	57-70 *	lutetium 71 **Lu** 174.97	hafnium 72 **Hf** 178.49	tantalum 73 **Ta** 180.95	tungsten 74 **W** 183.84	rhenium 75 **Re** 186.21	osmium 76 **Os** 190.23	iridium 77 **Ir** 192.22	platinum 78 **Pt** 195.08	gold 79 **Au** 196.97	mercury 80 **Hg** 200.59	thallium 81 **Tl** 204.38	lead 82 **Pb** 207.2	bismuth 83 **Bi** 208.98	polonium 84 **Po** [209]	astatine 85 **At** [210]	radon 86 **Rn** [222]
francium 87 **Fr** [223]	radium 88 **Ra** [226]	89-102 **	lawrencium 103 **Lr** [262]	rutherfordium 104 **Rf** [261]	dubnium 105 **Db** [262]	seaborgium 106 **Sg** [266]	bohrium 107 **Bh** [264]	hassium 108 **Hs** [269]	meitnerium 109 **Mt** [268]	ununnilium 110 **Uun** [271]	ununnium 111 **Uuu** [272]	unubium 112 **Uub** [277]		ununquadium 114 **Uuq** [289]				

*Lanthanide series	lanthanum 57 **La** 138.91	cerium 58 **Ce** 140.12	praseodymium 59 **Pr** 140.91	neodymium 60 **Nd** 144.24	promethium 61 **Pm** [145]	samarium 62 **Sm** 150.36	europium 63 **Eu** 151.96	gadolinium 64 **Gd** 157.25	terbium 65 **Tb** 158.93	dysprosium 66 **Dy** 162.50	holmium 67 **Ho** 164.93	erbium 68 **Er** 167.26	thulium 69 **Tm** 168.93	ytterbium 70 **Yb** 173.04
**Actinide series	actinium 89 **Ac** [227]	thorium 90 **Th** 232.04	protactinium 91 **Pa** 231.04	uranium 92 **U** 238.03	neptunium 93 **Np** [237]	plutonium 94 **Pu** [244]	americium 95 **Am** [243]	curium 96 **Cm** [247]	berkelium 97 **Bk** [247]	californium 98 **Cf** [251]	einsteinium 99 **Es** [252]	fermium 100 **Fm** [257]	mendelevium 101 **Md** [258]	nobelium 102 **No** [259]