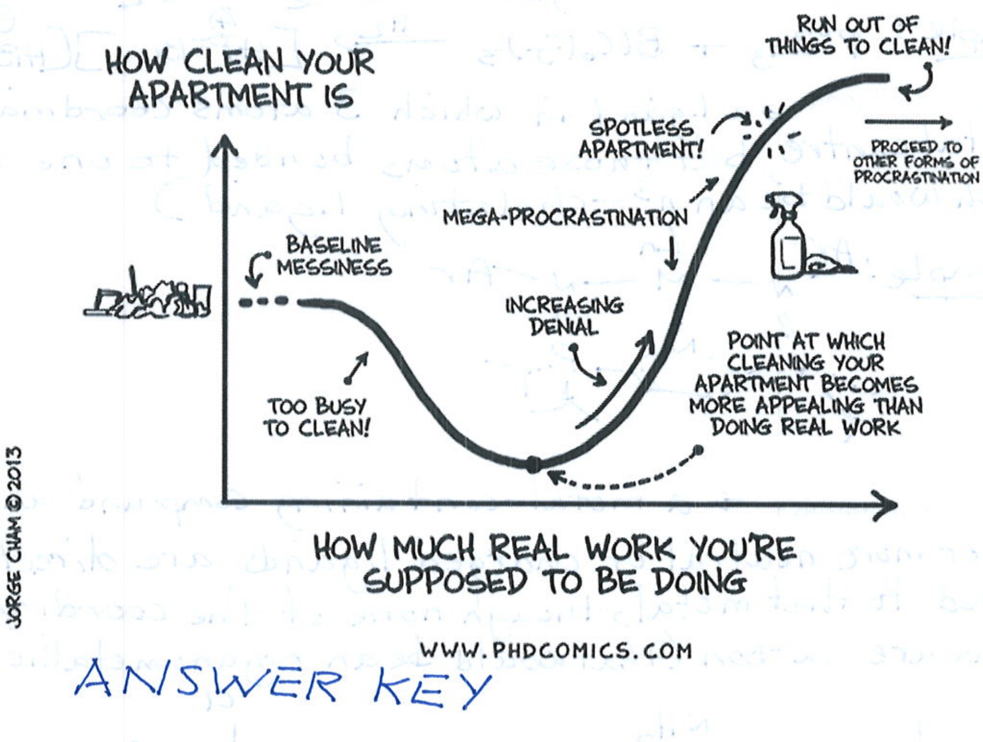
CHEMISTRY 3840: Inorganic Chemistry II
MIDTERM-1

Wednesday, February 11, 2026

INSTRUCTIONS

- This exam paper has 7 pages (including this page). Write all answers in the allotted spaces.
- The exam consists of 5 questions. You must complete all of them (unless otherwise noted).
- The exam is worth a total of 100 points. Most of these marks are for explanation/showing your work rather than for reaching the correct answer. Explain all of your answers fully, but it is not necessary to write in complete sentences (point form is acceptable).
- Remember to write your name and ID # on this page.
- This is an independent closed book exam – no material aids are permitted. Model kits are acceptable, but graphing calculators are not allowed.
- There is a 75 minute time limit.
- **Read the questions carefully**. Good luck.



ANSWER KEY

NAME: ______________________ **ID #:** ______________________

Chemistry 3840
Midterm Examination #1 (February 11, 2026)

1. Fully explain three of the following four terms/concepts. Use examples. (18 points)

a) tangential orbital → From a molecular orbital perspective for borohydride clusters, molecular orbitals are either "tangential" or "radial". Radial orbitals are "sp-like" which point to the centre of that cluster, and tangential orbitals are "p-like" orbitals that lie ⊥ to those radial orbitals.

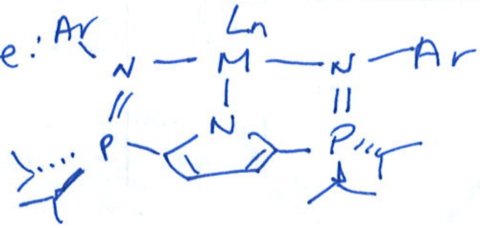
Example:

b) Frustrated Lewis Pair (FLP) → a combination of a sterically hindered Lewis acid and a sterically hindered Lewis base, which because of their bulk cannot form a "normal" Lewis acid-base adduct, and hence, retain their Lewis acidity and basicity even in the presence of one another. As a consequence FLP have been shown to cooperatively activate small molecules, such as H_2 and O_2

Example: $P^tBu_3 + B(C_6F_5)_3 \xrightarrow{H_2} [HP^{\oplus}{}^tBu_3][HB^{\ominus}(C_6F_5)_3]$

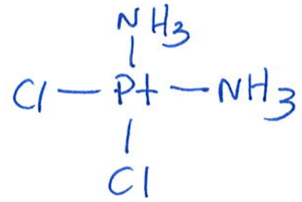
c) κ[3]-chelating ligand → a ligand in which 3 atoms coordinate to a metal centre, but those atoms bonded to one another. (which would be an η³-chelating ligand)

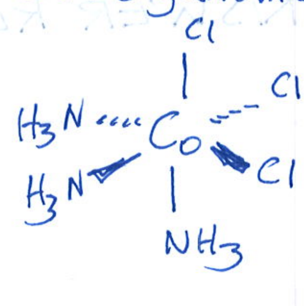
Example:



d) coordination complex → a metal-containing compound wherein one or more neutral or charged ligands are directly bonded to that metal, though none of the coordinating atoms are carbon (that would be an organometallic complex)

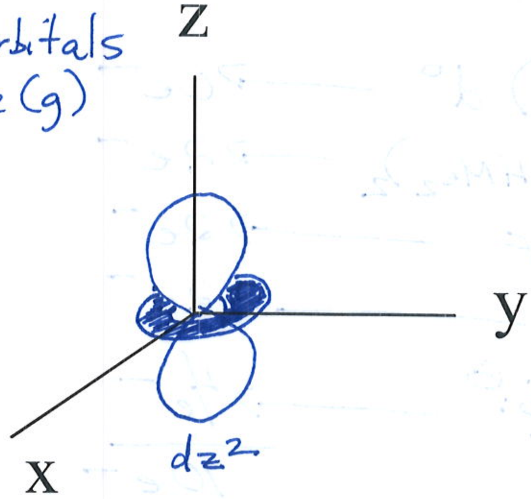
Example:

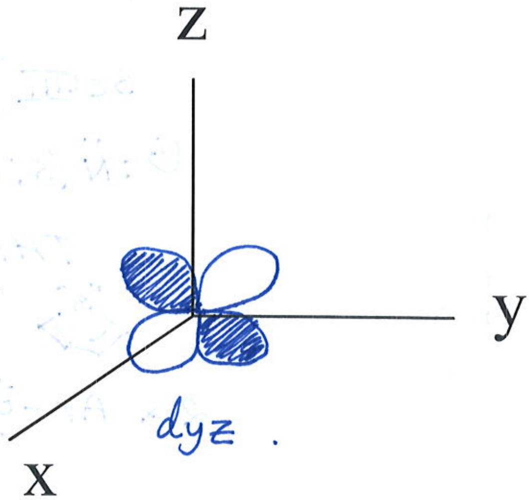


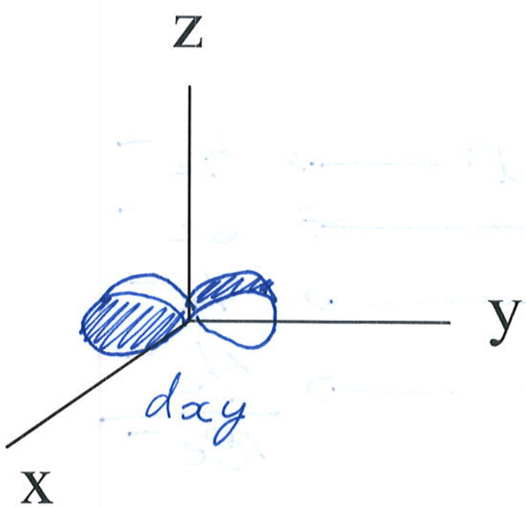


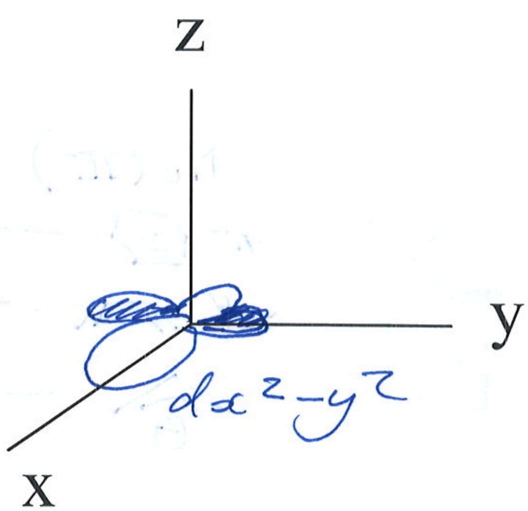
2. Draw and label the d-orbitals. Use the provided axes. Be sure to place signs on all lobes, label each orbital as gerade or ungerade. (10 points).

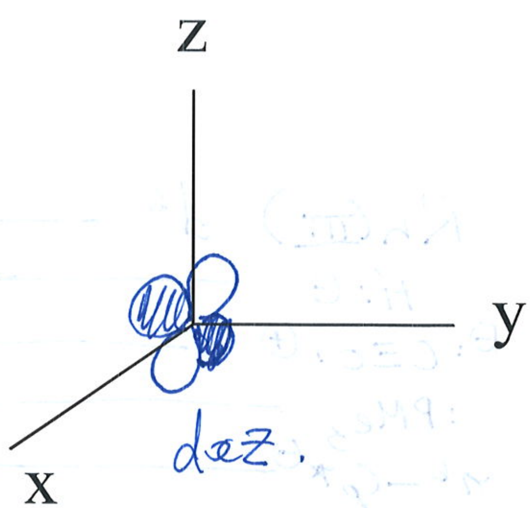
→ all 5 d-orbitals are gerade (g)





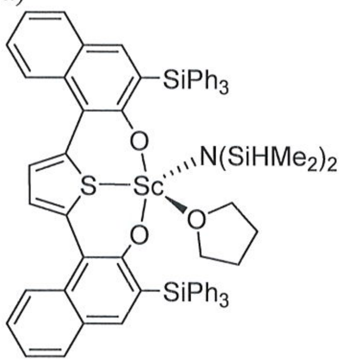






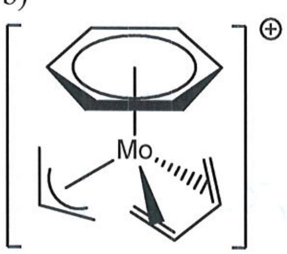
3. For ***any five*** of the following six molecules determine:
i) the oxidation state of the metal; ii) the d-electronic configuration of the metal; iii) the electron count at the metal centre. (40 points)

a)



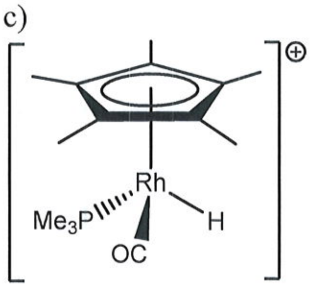
Sc(III) d^0 → $0e^-$
$\ominus$:N(SiHMe$_2$)$_2$ → $2e^-$
THF → $2e^-$
thiophene (:S:) → $2e^-$
2 × Ar–O:$^\ominus$ → $4e^-$
$10e^-$

b)



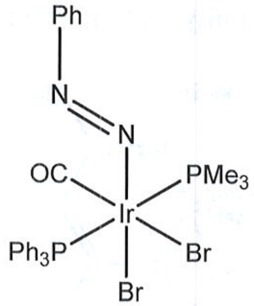
Mo(II) d^4 → $4e^-$
η^6 benzene → $6e^-$
η^4 diene → $4e^-$
allyl $\ominus$ → $4e^-$
$18e^-$

c)



Rh(III) d^6 → $6e^-$
H:$\ominus$ → $2e^-$
$\ominus$:C≡O:$\oplus$ → $2e^-$
:PMe$_3$ → $2e^-$
η^6–Cp*$^\ominus$ → $6e^-$
$18e^-$

3d)



Ir(III) d^6 ⟶ $6e^-$

$2\times$:Br:$^\ominus$ ⟶ $4e^-$

:PMe_3 ⟶ $2e^-$

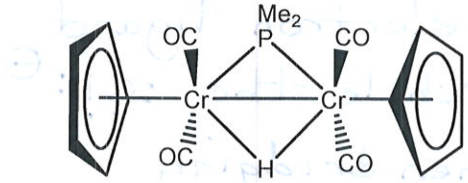
:PPh_3 ⟶ $2e^-$

$\ominus$:C≡O:$\oplus$ ⟶ $2e^-$

PhN=N:$^\ominus$ ⟶ $2e^-$

$18e^-$

e) Note: The Cr–Cr bond counts as 1 electron for each Cr when counting electrons at the metal centres, and has no impact on the oxidation state of either metal.



→ Both Cr centres are in identical environments w the same ligands bound in the same modes to each metal.

Cr(II) d^4 ⟶ $4e^-$

$2\times$ $^\ominus$:C≡O:$\oplus$ ⟶ $4e^-$

$\frac{1}{2}\times$ H:$^\ominus$ ⟶ $1e^-$

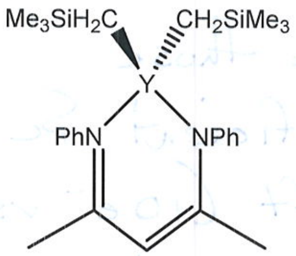
Cr–Cr ⟶ $1e^-$

$\frac{1}{2}$ $\ominus$:PMe_2 ⟶ $2e^-$

η^6–Cp$^\ominus$ ⟶ $6e^-$

$18e^-$

f)



Y(III) d^0 ⟶ $0e^-$

$2\times$ $^\ominus$:CH_2SiMe_3 ⟶ $4e^-$

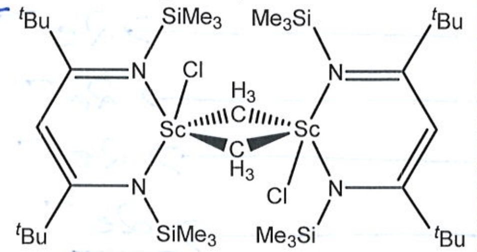
PhN: =CR_2 ⟶ $2e^-$

$\ominus$:NPh (–C(=CR_2)) ⟶ $2e^-$

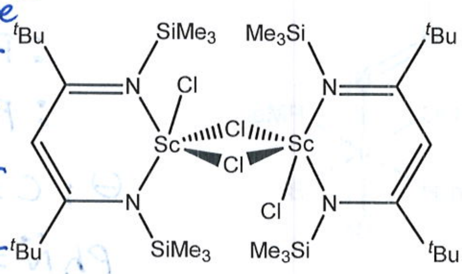
$8e^-$

4. Which of the following two complexes would you expect to be more likely for the ligand PMe_3 to coordinate to (assume that Cl and CH_3 are the same size)? Fully explain your choice. (20 points)

Sc(III) $d^0 \rightarrow 0e^-$
2^b $CH_3^{\ominus} \rightarrow 2e^-$
$Cl^{\ominus} \rightarrow 2e^-$
N N$^{\ominus} \rightarrow 4e^-$
$8e^-$



Sc(III) $d^0 \rightarrow 0e^-$
N N$^{\ominus} \rightarrow 4e^-$
^{t}$Cl^{\ominus} \rightarrow 2e^-$
2 ^{b}$Cl^{\ominus} \rightarrow 4e^-$
$10e^-$



→ Since $Cl^{\ominus}$ and $^{\ominus}CH_3$ are the same size, both compounds are identical from a steric perspective ∴ any difference in reactivity toward :PMe_3 must be solely based upon electronic differences

→ $^{\ominus}$:CH_3 is acting as a 3-centre-2-electron ligand when it bridges both Sc centres, while the :C̈l:$^{\ominus}$ is a 3-centre-4-electron ligand when bridging the two Sc centres. Hence, the e^- count for the Sc centres in the right compound is higher (by $2e^-$) than the one on the left.

↳ Since the complex on the right is more e^- rich (less e^- deficient) it is expected to be less likely that PMe_3 will coordinate to those Sc centres than the more e^- deficient Sc centres in the complex on the left ($10e^-$ vs. $8e^-$)

N.B. Both Sc complexes contain metal centres exclusively in the +3 oxidation state.

5. Use Wade's rules to classify $C_2B_7H_{13}$ as *nido*, *closo* or *arachno*. Show your work. (12 points)

$C_2B_7H_{13}$

$n = 2 + 7$

$n = 9$

$7\,BH \rightarrow 7 \times 2e^- \rightarrow 14e^-$

$2\,CH \rightarrow 2 \times 2e^- \rightarrow 4e^-$

$2\,Ce^- \rightarrow 2 \times 1e^- \rightarrow 2e^-$

$4\,H \rightarrow 4 \times 1e^- \rightarrow 4e^-$

$24e^- \rightarrow 12$ skeletal e^- pair

$\therefore n+3$ skeletal e^- pair

$\downarrow$

arachno structure.