Name:

Instructions:

Write your name on every page.

In part A of the exam, please clearly fill in the single best answer to the multiple choice questions on this sheet (below).

In part B of the exam, please write legibly. Place your answer, including reasoning/calculations, inside the box provided where appropriate. Show your work to receive full marks.

Note 1: A periodic table and other potentially useful information are provided in the appendix. **This page may be removed**

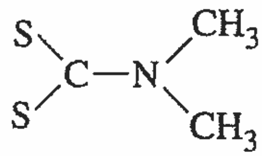
Note 2: Answers in pencil will not be re-marked

Multiple Choice Answers (Version 1)

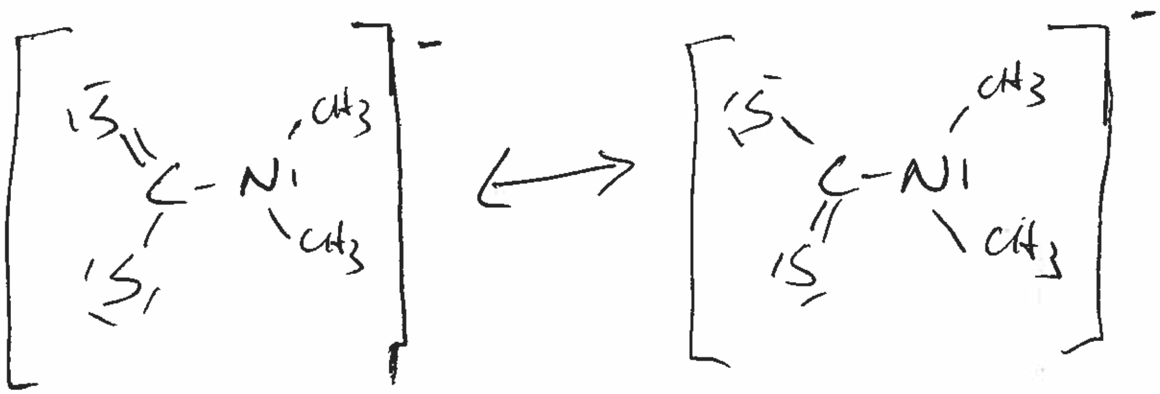
1. C
2. B
3. A
4. A
5. D
6. B
7. E
8. E
9. B
10. D
11. D
12. C

Part B

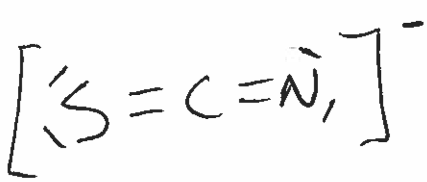
1. a) (10 marks) The dimethyldithiocarbamate ion $[S_2CN(CH_3)_2]^-$ has the following skeletal structure.



Draw the best Lewis structure for this ion, including any equivalent resonance structures.



b) (5 marks) Draw the best Lewis structure for the thiocyanate ion SCN^-, including any equivalent resonance structures



2. (5 marks) An emission is observed at a wavelength of 383.65 nm for the transition from an excited state of the hydrogen atom to the n = 2 state. Determine the principal quantum number (n) for this excited state.

$$E = \frac{hc}{\lambda} = \frac{(6.626\times10^{-34}\,\mathrm{J\,s})(2.998\times10^{8}\,\mathrm{m/s})}{(383.65\,\mathrm{nm})(\mathrm{m}/10^{9}\,\mathrm{nm})} = 5.178\times10^{-19}\,\mathrm{J}$$

$$E = R_H\left(\frac{1}{2^2}-\frac{1}{n_h{}^2}\right);\quad \frac{1}{n_h{}^2}=\frac{1}{4}-\frac{E}{R_H}\ \text{and}\ n_h=\left(\frac{1}{4}-\frac{E}{R_H}\right)^{-\frac{1}{2}}$$

$$n_h=\left(\frac{1}{4}-\frac{5.178\times10^{-19}J}{2.1787\times10^{-18}J}\right)^{-\frac{1}{2}}=9$$

3. The $4f_{z(x^2-y^2)}$ orbital for the hydrogen atom has the angular function (in cartesian coordinates) Y = (constant)$z(x^2-y^2)/r^3$

a) (4 marks) Determine the number of radial nodes and angular nodes for this orbital

no radial nodes (The number of radial nodes = $n - l - 1$. Since $n = 4$ and $l = 3$ for f orbitals, $n - l - 1 = 4 - 3 - 1 = 0$ radial nodes.)

3 angular nodes (The number of angular nodes = $l = 3$.)

a) (6 marks) Write equations to define the angular node surfaces

The angular nodes are solutions for $z(x^2-y^2) = 0$. These solutions are $z = 0$ (xy plane), and the planes where $x = y$ and $x = -y$, both perpendicular to the xy plane.

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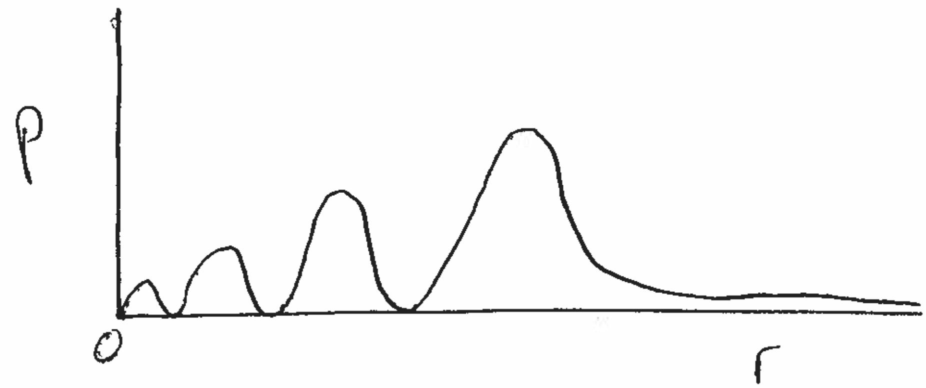
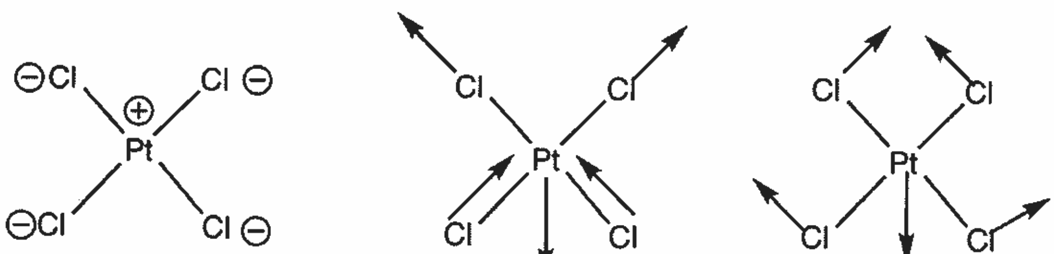
4. (5 marks) Sketch the radial probability distribution of a Hydrogen 4s orbital. Axes should be labeled but not scaled.



5. Shown below are three of the normal modes of vibration for $[PtCl_4]^{2-}$. Note that "+" and "–" indicate movement above and below the plane of the paper, respectively.



IR active IR active IR active

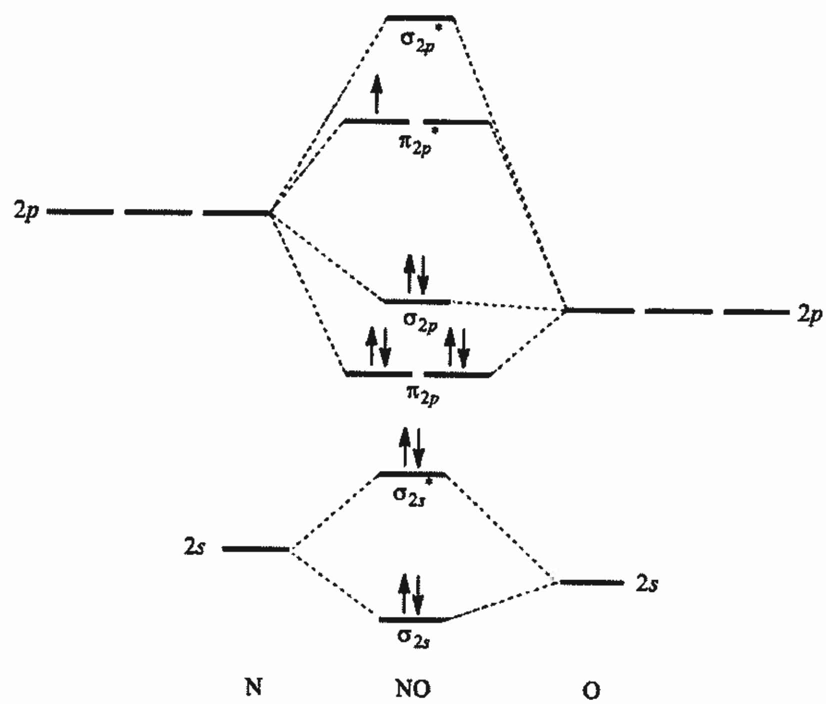
Dipole moment changes

a) (3 marks) For each vibration, indicate below the diagram whether you expect the vibration to be IR active or not and explain why.

b) (4 marks) How would you expect the frequency of the middle vibrational mode to compare to the same vibrational mode for $[PtBr_4]^{2-}$? Explain your reasoning

$\nu \propto \sqrt{\frac{K}{M_r}}$ Since M_r increases for $[PtBr_4]^{2-}$, the frequency for the Br^- complex would be lower than for the Cl^- complex.

6. a) (10 marks) Using molecular orbital theory, draw the energy level diagram (i.e. correlation diagram) for NO, assuming it follows the order of N_2. Show occupation of the orbitals by electrons in your diagram, and label both atomic and molecular orbitals.



b) (4 marks) Would you predict NO to be diamagnetic or paramagnetic? Explain.

Paramagentic – one unpaired electron

b) (6 marks) NO+ and NO- are also known. Arrange these (along with NO) in terms of bond strength and bond length and explain your reasoning.

NO^+ : bond order 3 (highest bond strength, shortest bond)
NO: bond order 2.5 (Intermediate bond strength, length)
NO^-: bond order 2 (lowest bond strength, longest bond)

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7\. a) (14 marks) Draw all the different isomers of $[Co(NH_3)_2(H_2O)_2BrCl]^+$. Indicate any enantiomeric pairs. Your drawings should depict the 3D geometry of the complex.