UNIVERSITY OF TORONTO

FACULTY OF APPLIED SCIENCE AND ENGINEERING

MIDTERM EXAMINATION

TUESDAY FEBRUARY 25, 2014

Time: 9:00am-11:00am

Place: EX100

First Year – Engineering Science

MSE 160H1F – Molecules and Materials

Examiner –E. D. Sone

Only approved scientific calculators and rulers are allowed

Name (Last Name, First Name):
Student Number:
Tutorial Day/Time:
Teaching Assistant:

Part A: _____/24

Part B: _____/76

TOTAL: _____/100

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

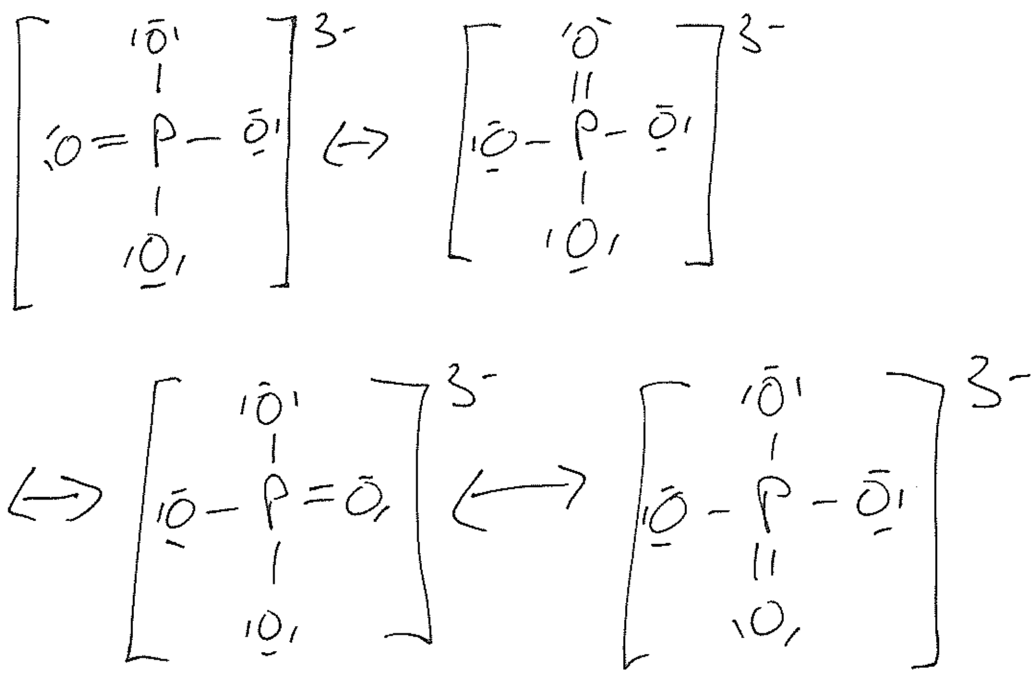
Multiple Choice Answers (Version 2)

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

Name:

Part B

1. a) (10 marks) Draw the best Lewis structure (based on formal charge considerations) and any equivalent resonance structures for the phosphate ion, PO_4^{3-}.



b) (2 marks) What is the average bond order of the PO bonds?

5/4

Name:

2. (5 marks) Consider a universe where the spin quantum number can take the values +1/2, -1/2, +3/2, -3/2 while all the other quantum numbers are the same as in our universe. Assuming the Pauli's exclusion principle still holds,

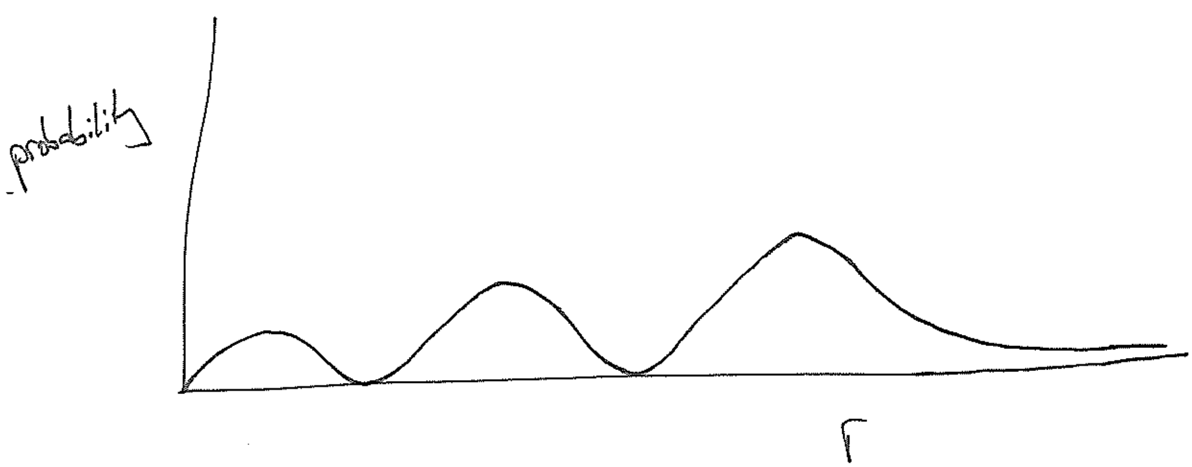
a) What would be the atomic numbers of the first three noble (inert) gases?

4, 20, 36

b) How many elements would there be in the first row of transition elements?

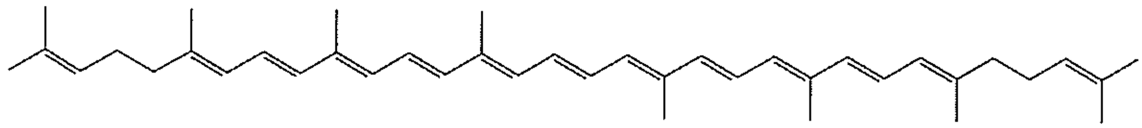
20

3. (5 marks) Sketch the expected radial distribution of a Hydrogen 3s orbital. Axes should be labeled but not scaled.

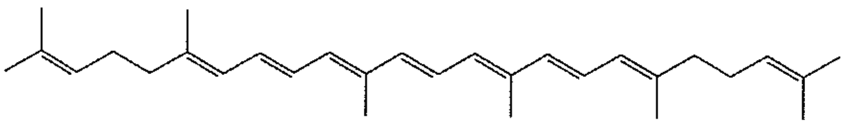


4. (8 marks) Molecules X and Y have the following structures:

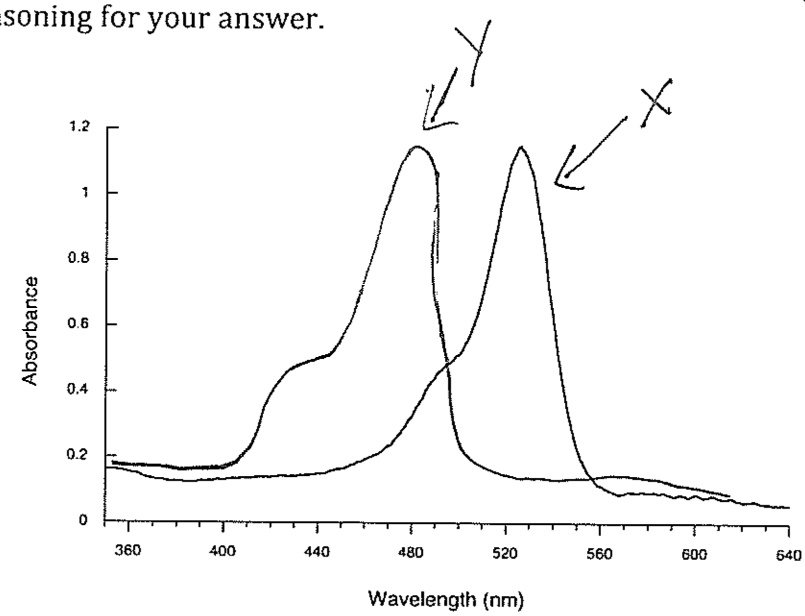
X:



Y:



The absorption spectrum of X is shown in the figure below. On the same figure, sketch the absorption spectrum you would expect for Y. Briefly explain the reasoning for your answer.



Explanation:

The spectrum is shifted to lower wavelength (higher energy) because the $\pi \rightarrow \pi^*$ transition in Y would require more energy than in X. X has a more extensively conjugated system of alternating double bonds, so the electrons in the delocalized π orbital can be thought of as confined to a longer box, ∴ smaller difference in energy levels

Name:

5. a) (10 marks) Using molecular orbital theory, draw the energy level diagram (i.e. correlation diagram) for N_2, showing occupation of the orbitals by electrons. Be sure to label both atomic and molecular orbitals.

See text p. 444/445

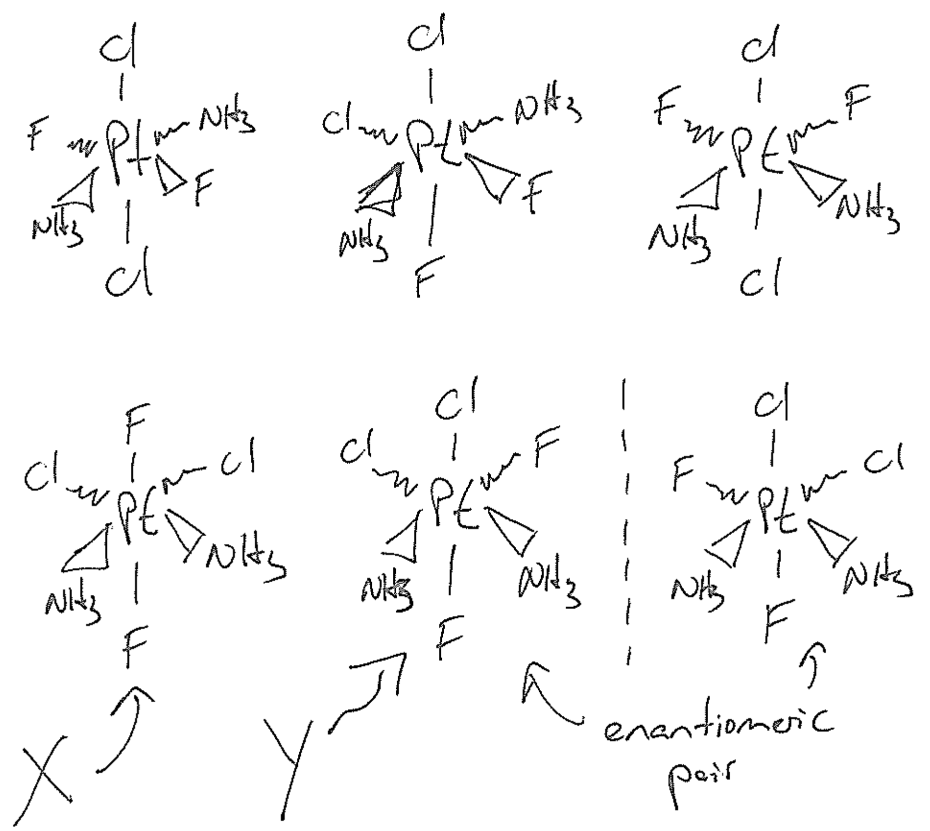
b) (6 marks) Consider that N_2 absorbs a photon with energy corresponding to the difference between its highest occupied molecular orbital and its lowest unoccupied molecular orbital. How would the bond energy, length, and vibrational frequency of the excited state compare to that of the ground state ion? Briefly explain why for each.

An electron would be promoted from the $\sigma 2p_z$ MO to the $\pi^* 2p$ MO, leading to a decrease in bond order (from 3 to 2).

Therefore, bond energy would decrease
bond length would increase
vibrational frequency would decrease ($\propto \sqrt{\frac{k}{m}}$)

Name:

6. a) (10 marks) Draw all the different isomers of [$PtCl_2F_2(NH_3)_2$]. Indicate any enantiomeric pairs. Your drawings should depict the 3D geometry of the molecule.



b) (5 marks) Pick any two of the isomers you drew in part (a) and label them X and Y, respectively. Describe an experiment you could do to determine whether a given vial contains a solution of X or Y.

Y is a chiral compound, therefore a solution of Y should rotate plane-polarized light.
X is not chiral, ∴ it will not rotate plane-polarized light.

Name:

7) (15 marks) For each of the following pairs, briefly describe a how you could distinguish which sample corresponds to which material (i.e. a test, observation, measurement, or reasoning). Be practical (and safe).

a) X is a green solid; Y is a violet solid. One is $[Ni(NH_3)_6]Cl_2$; the other is $K_4[NiCl_6]$

Since NH_3 is a stronger field ligand than Cl^-, Δ for $[Ni(NH_3)_6]Cl_2$ will be greater, and it will absorb light of shorter wavelength

X is green ∴ absorbs red

Y is violet, ∴ absorbs yellow ← shorter wavelength

∴ Y must be $[Ni(NH_3)_6]Cl_2$

b) X and Y are both colourless liquids with similar boiling points. One is water, the other is heptane (C_7H_{16}). You have no sense of smell.

Since water is polar and heptane is not, water should dissolve NaCl, but heptane will not dissolve NaCl.

c) X and Y are both coloured solids, but you are completely colour blind. One is $K_4[FeCl_6]$ and the other is $K_4[Fe(CN)_6]$.

CN^- is a very strong field ligand, while Cl^- is weak.

Therefore $K_4[FeCl_6]$ should be high spin ↳ paramagnetic

$K_4[Fe(CN)_6]$ should be low spin ↳ diamagnetic