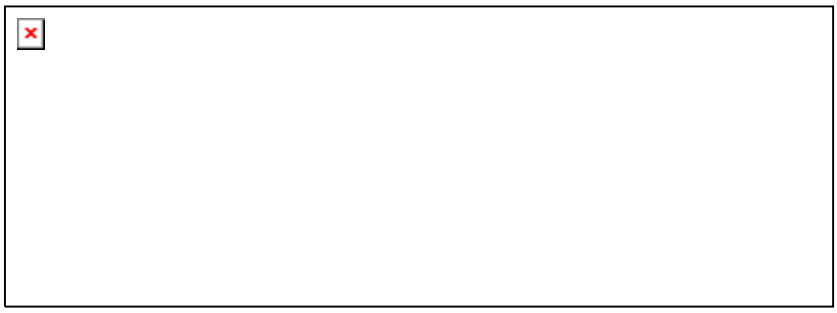
THE UNIVERSITY OF BRITISH COLUMBIA

CHEMISTRY 121 EXAMINATION

3rd December 1996

1. The emission spectrum below for a one-electron (hydrogen-like) species in the gas phase shows **all** the lines resulting from transitions **to the first excited state** fom higher energy states. Line A has a wavelength of 30.4 nm.



(a) Label the lines marked A and B according to the initial and final states (give the principal quantum numbers) involved in the corresponding transition.

	Upper principal quantum number	Lower principal quantum number
Line A		
Line B		

(b) Identify the one-electron species that exhibits the spectrum above (i.e. give the symbol for the element and the charge on the species).

Element:_____ Charge:_____

(c) Calculate the wavelength of the line B (in nm).

Wavelength:_____ nm

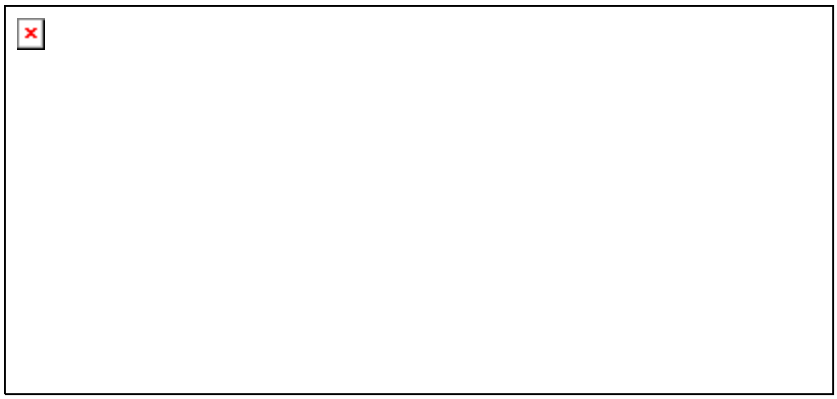
(d) Calculate the frequency of line A (in Hz).

Frequency:_____ Hz

2. Complete the following table by giving the atomic number, writing the electron configuration, identifying the species, indicating whether it is in the ground state or an excited state, or whether it is paramagnetic or diamagnetic. The first line is given as an example.

Atomic Number	Configuration	Species	State	Paramagnetic (P) or Diamagnetic
1	$1s^2$	H^-	Ground	D
5	$1s^2\ 2p^2$			
15	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^4$	S^{2-}	Ground	
		Fe^{2+}	Ground	
29	$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^9$			

3. (a) Sketch the cross-sections of the following orbitals on the ry-plane, indicating the relative algebraic signs in the various regions.



(b) An electron in an atom is characterized by a set of quantum numbers [n, *E*, m~,m,]. Indicate, by responding with a *Y* or A; whether the sets of quantum numbers given in the table below are allowed or not.

	Allowed (Y/N)?
[1,0,0,-½]	
[3, 1, 2, 8]	
[3, 2, 1, 0]	
[4,4,3, ½]	
[5,0, 0, ½]	

(c) Consider the subshell with n = 5 and *l* = l.

(i) What is the designation for the subshell with n=5 and *l* = 1?

(ii) How many orbitals are there in this subshell?

(iii) What is the value of m, for each of these orbitals?

3. (d) (i) What is the maximum number of electrons that the n = 2 shell can accomodate?

(ii) How many nodal planes (angular nodes) does a $3d_{xy}$ orbital have?

(e) Indicate whether each of the following statements is true or false by circling the corresponding word.

(i) The energy of an electron in a hydrogen atom depends only on the value of the principd quantum number.

true false

(ii) The energies of the electrons in H and He^+ are the same if their principal quantum numbers are the same.

true false

(iii) The number of orbitals in a subshell with angular quantum number *E* is the same regardless of the value of n.

true false

(f) From the ground states of neutral atoms with 18 < Z <=36 (i.e. for atoms in the fourth row of the periodic table), select one for each of the following:

(i)_____ has a half-filled 4p subshell,

(ii) _____ has six unpaired electrons.

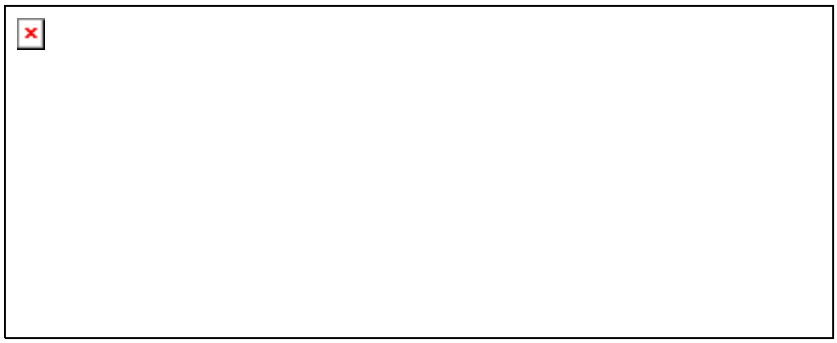
(iii)_____ has three electrons in the 3d subshell.

(iv)_____ is a halogen.

(v) _____ is a metalloid.

(vi) _____ is an alkaline earth.

(g) Shown below are the radial probability distribution ($4pir^2R^2$) plots for hydrogen atomic orbitals as a function of the distance (r) from the nucleus.. Insert a letter in the blank space provided in the box below each plot to complete the orbital description.



1____	2____	2_____

(h) Select the appropriate species from each group according to the property indicated:

Species	Property	Smallest	Largest
flea, cat, elephant	size	flea	elephant
Cr, Fe, P, Ar	number of unpaired electron spins		
Na,K, Si, Ar	size		
Ne, Mg^{2+}, F, Na+	ionization energy		
Ca, S,F, Cs	electronegativity		

4. For the following molecules, write the Lewis structure, molecular shape as predicted by VSEPR, hybridization of the central atom, and whether the molecule is polar or nonpolar. (The central atom in each molecule is underlined. Be sure to show all non-bonding valence electrons as dots.)

Molecule or Ion	Lewis Structure	Moleeular Shape (in words)	Hybridization of Central Atom	Polar (P) or Nonpolar (N)
XeFg				
CS_2				
H_2CO				
$F\underline{Cl}O_3$				
IF_5				

$XeOF_2$				

5. Selenium dioxide has the formula SeO_2.

(a) Draw a Lewis dot representation of SeO_2 that satisfies the octet rule for all atoms.

(b) Experimental results suggest that the bonds between the central Se and each of the 0 atoms in SeO_2 are identical. Explain this in terms of your proposed structure.

(c) Describe the geometric arrangement of electron pairs around the Se in SeO_2 **and** state what type of hybridization of atomic orbitals of Se would give such an arrangement.

(d) Describe the geometric arrangement of atoms in SeO_2.

(e) Is SeO_2 polar or non-polar?

6. (a) Complete the Lewis dot structure for propyne, C_3H_4, using the skeleton below which shows the sequence in which the atoms are bonded. Draw all bonds as lines, and include all non-bonded electrons as dots.

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   H

H  C  C  C  H

   H
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(b) (i) How many *sigma* bonds are there in propyne?

(ii) How many *pi* bonds are there in propyne?

(c) (i) Describe the hybridization at the left-most C atom.

(ii) Describe the hybridization at the central C atom.

(iii) Describe the hybridization at the right-most C atom.

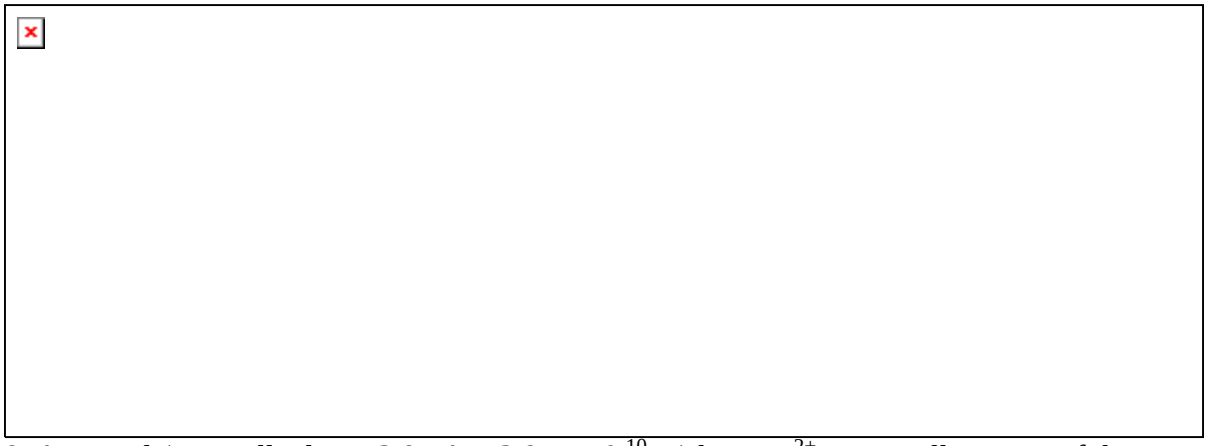
(d) Estimate the bond angle from:

(i) the left-most H to the left-most C to the central C atom. _____ degrees

(ii) the central C to the right-most C to the right-most H atom. _____ degrees

(e) The maximum number of atomic nuclei in the three-dimensional structure of propyne through which it is possible to draw a straight line is

7. In the table below are listed the molecular orbital valence-electron configurations for five homonuclear diatomic molecules or molecular ions. Complete the table.



8. A crystal (unit cell edge = 3.94 A = 3.94 x 10^{-10} m) has Mg^{2+} ions at all corners of the cubic cell, F^- ions at the mid-points of all edges, and K^+ ions at the body-centre position.

(a) What is the empirical formula?

(b) What is the shortest Mg F and K *F* distances in A?

Mg F distance:_____ A

K F distance:_____ A

(c) What are the coordination numbers of Mg and K?

Coordination number of Mg: _____

Coordination number of K: _____

9. Germanium has a cubic unit cell, whose side length is 5.65 A (5.65×10^{-10} m). Its density is 5.36 g/cm^3.

(a) How many germanium atoms are there in the unit cell?

Number of Ge atoms =_____

(b) Consider the following five crystal types as possible structures for germanium. How many atoms per unit cell would there be for each structure?

(i) Simple cubic

(ii) Body-centred cubic

(iii) Face-centred cubic

(iv) Face-centred cubic with all tetrahedral holes filled

(v) Face-centred cubic with half the tetrahedral holes filled

(c) Of the choices in (b) above, which describes the germanium lattice?

10. (a) Complete the following table:

Compound	Ionic Solid (Y or N)	Choose a number from the list to the bottom to identify a use or description of the compound
$NaHCO_3$		
P_4O_{10}		
$H_2SO_3(aq)$		
BrCl		
SiO_2		
P_4S_3		
$(CH_3)_2SiCl_2$		
$MgSO_47H_2O$		

l. Interhalogen

2. Epsom salts

3. Matches

4. Used in baking

5. Acid rain

6. Polymer precursor

7. Sandpaper

8. Colourless gas

9. Dessicant

(b) Draw the structure of elemental sulphur.

(c) Give the formula for one allotrope of sulphur that exists in the gas phase in equilibrium with elemental rhombic sulphur when it is heated.

(d) Draw the structure of P_40_6.

(e) Name three allotropes of carbon.

(f) Draw the structure of aluminum trichloride as it exists in a nonpolar solvent.

11. (a) Complete and balance the following equations:

(i) $Mg_2Si + HC1(aq) \rightarrow$ _____ + _____

(ii) $Cl_2 + NaOH(aq) \rightarrow$_____ + _____ + _____

(iii) $Al + Fe_2O_3 \rightarrow$ _____ + _____

(iv) $(C_2H_5)_3Al + H_2O \rightarrow$ _____ + _____

(v) $Ca_3(PO_4)_2 + SiO_2 +$_____ ---> _____ + CO + _____

(vi) $S_2O_3^{2-}(aq) + I_2(aq) \rightarrow$ _____ + _____

(b) Describe the electrolyte and the balanced electrode reactions for the process used in the industrial electrolytic production of sodium hydroxide (the Chlor-Alkali Process):

(i) Electrolyte:

(ii) Anode reaction:

(iii) Cathode reaction:

(iv) Overall reaction:

12. (a) Give the formula for:

(i) Hypochlorous acid:

(ii) Silane:

(iii) Calcium dihydrogen phosphate:

(iv) Silica:

(d) Give the chemical names in words of the following:

(i) $H_4P_2O_7$

(ii) $Na_2S_2O_3$

(iii) PCl_5

(iv) $Cl0_2$

THE END

MERRY CHRISTMAS!