CHE200F-APPLIED CHEMISTRY I: INORGANIC CHEMISTRY

Final Exam - 2001

Student Name _____ Student #_____

Duration 2.5 hours. Attempt all questions. A periodic table is attached to the end of the exam along with other data.

Question	Mark
1	
2	
3	
4	
5	
6	
Total	

1.(12 %) Write formulas for the following substances

(i) Nitrous acid

(ii) Hexa-aqua-iron(III) chloride

(iii) Sodium arsenate

(iv) Cuprous hypochlorite

(v) Cesium thiosulphate

(vi) Caustic potash

(vii) Calcium phosphide

(viii) Selenium tetrachloride

(ix) Arsenous bromide

(x) Ferric oxide

Name the following compounds:

(xi) $Ba[BrF_4]_2$

(xii) $Ca(MnO_4)_2$

(xiii) LiH_2PO_4

(xiv) KCN

(xv) H_3PO_3

2. (9 %) For each of the following three ions, draw the Lewis dot structure, determine the steric number of the central atom and the prototype geometry, and sketch or name the shape of the ion.

(i) SeF_4^{2-} (Se is central)

(ii) IF_3^{2-} (I is central)

(iii) ClO_2^{1-} (Cl is central)

3. (6%) For each of the following two molecules, draw all important Lewis dot structures, determine formal charges on every atom, and identify the most probable structure.

(i) SO_2Cl_2 (S is central.)

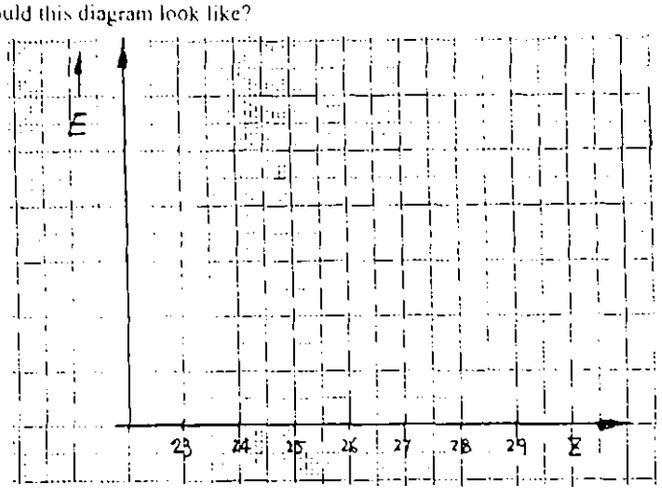
(ii) ONCN (It has a chain structure. Between the N and C in the middle, only single or double bonds are possible.)

4. (23 %) Pretending that you were R.L. Rich in the lab, your colleagues were doing experiments on metals in the first transition series, and found the following electron configurations:

V	$[Ar]4s^2 3d^3$	Z = 23
Cr	$[Ar]4s^1 3d^5$	Z = 24
Mn	$[Ar]4s^2 3d^5$	Z = 25
Fe	$[Ar]4s^2 3d^6$	Z = 26
Co	$[Ar]4s^2 3d^7$	Z = 27
Ni	$[Ar]4s^2 3d^8$	Z = 28
Cu	$[Ar]4s^1 3d^{10}$	Z = 29

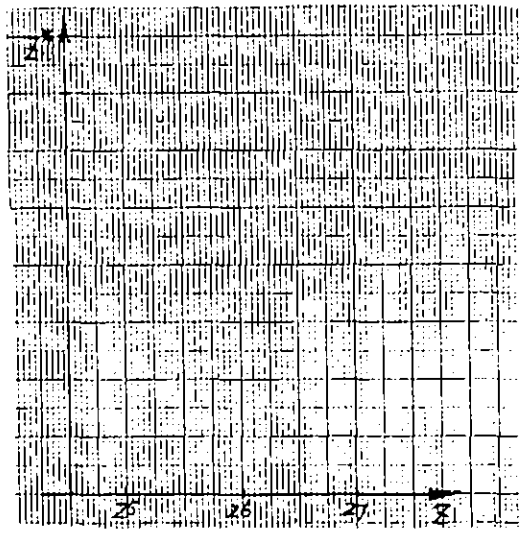
Analysing these data, you constructed a diagram that illustrated the dependence of potential energies of 4s and 3d electrons (paired and unpaired) on Z. This diagram (now known as Rich's energy diagram) could be used to predict the electron configurations of these transition metals.

(i) How would this diagram look like?



(ii) Using Slater's rules, determine values of Z* on 4s and 3d electrons for Mn, Fe and Co. Plot these Z* values against their Z values for 4s and 3d electrons, respectively.

	Z	Z*(3d)	Z*(4s)
Mn	25		
Fe	26		
Co	27		



(iii) Considering the physical meaning of Z*, could the trends shown in part (ii) (i.e. the dependence of Z* on Z for 4s and 3d electrons) be used to rationalize qualitatively the dependence of potential energy on Z in Rich's energy diagram in part (i)? Explain your answer.

(iv) Predict electron configurations of Mn^{2+}, Fe^{2+}, and Co^{2+}. Given that all three ions form sulphate salts, identify the sulphate salt that is the most paramagnetic, and calculate its magnetic moment (μ in BM).

	configurations
Mn^{2+}	
Fe^{2+}	
Co^{2+}	

The most paramagnetic sulphate is _____

μ = _____BM

5. (22 %) Carbon monoxide (CO) is a combustion product that is readily oxidized in air. Photoelectron spectrum measurements show that potential energies of 2s and 2p electrons of C are –19.5 eV and –10.7 eV, and potential energies of 2s and 2p of O are –32.4 eV and –15.9 eV. Experiments also show that molecular orbitals (MOs) of CO have orbital mixing.

(i) Draw the MO energy diagram for CO, name all the MOs, arrange valence electrons in the MOs, and identify HOMO and LUMO.

(ii) Determine bond order of CO. How would the C-O bond length change if the CO loses an electron? Between a C atom and the CO molecule, which would have a higher 1st ionisation energy?

(iii) Sketch the shape of HOMO and LUMO and determine their symmetry (Cn, n is rotation order). Show the atomic orbitals that interact to form these two MOs. Which end of this linear molecule would attach to the Ni in $Ni(CO)_4$?

(iv) Are there any non-bonding MOs in the diagram in part "i"? Using sketch, give two examples showing that two atomic orbitals overlap and form a non-bonding MO.

(v) Given that the potential energy of 3p of S is –12.0 eV, which bond would be more covalent, C-O or C-S? Why?

6. (28 %) Answer the following questions briefly.

(i) Using reactions, show that H_2O can function as a

- Bronsted-Lowry acid: _____
- Lewis base: _____
- Lux-Flood acid: _____
- Lux-Flood base: _____

(ii) NH_3 is a common solvent. Write the autodissociation reaction of NH_3, and identify the acid and base. Using a reaction give an example of acidic substances in NH_3.

Autodissociation of NH_3: _____

NH_3 + _____ => _____ + _____

(iii) Philip Gbor's research was on the effectiveness of leaching of transition metals (Co, Ni, Cu) from slags with aqueous solution of SO_2. He found that if the same moles of H_2SO_4 or SO_2 were added into leaching solutions, the H_2SO_4 solution was more effective in dissolving Ni and Co than the SO_2 solution. Rationalize this observation based on the strength of oxyacids.

(iv) Arrange the following groups of acidic substances in an increasing order of acidity in water.

- HCl, HI and HF _____ < _____ < _____
- H_2S, SiH_4 and PH_3 _____ < _____ < _____
- H_3PO_4, $HClO_3$ and HPO_4^{2-} _____ < _____ < _____
- Mn^{7+}, Fe^{3+} and Ru^{3+} _____ < _____ < _____

(v) Values of the Lux-Flood acidity parameter, "a", are tabulated for some common oxides in the attachment. Identify the strongest acid and base. What is the reaction between the strongest acid and H_2O? How much heat could be generated from this reaction?

Strongest acid:_____; Strongest base:_____

Reaction: _____

Heat:_____

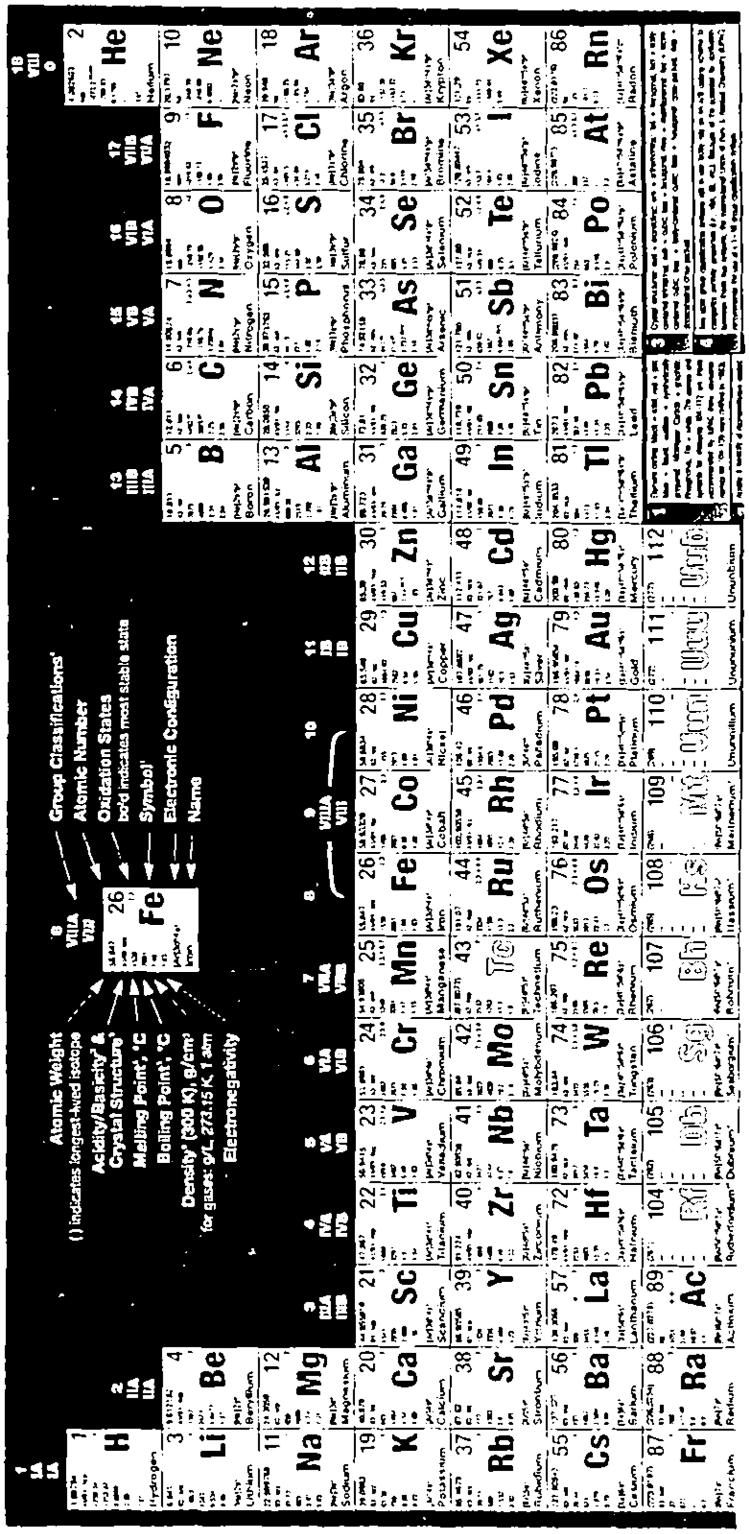
(vi) Using Fajans rule identify the compound that is more covalent from each of the following pairs.

- CaS and CuS
- $BeBr_2$ and $CaBr_2$
- CsF and CsBr
- $Mg(OH)_2$ and $Hg(OH)_2$

(vii) Give the reactions of the following hydrogen compounds with water.

- LiH _____
- HI _____
- H_2Se _____
- CH_4 _____

Periodic Table and Lux-Flood Acidity Parameters, "a", for Selected Oxides



Oxide	a	Oxide	a
H_2O	0.0	FeO	−3.4
Li_2O	−9.2	Fe_2O_3	−1.7
Na_2O	−12.5	CoO	−3.8
K_2O	−14.6	NiO	−2.4
Rb_2O	−15.0	Cu_2O	−1.0
Cs_2O	−15.2	CuO	−2.5
BeO	−2.2	Ag_2O	−5.0
MgO	−4.5	ZnO	−3.2
CaO	−7.5	CdO	−4.4
SrO	−9.4	HgO	−3.5
BaO	−10.8	B_2O_3	1.5
RaO	−11.5	Al_2O_3	−2.0
Y_2O_3	−6.5	CO_2	5.5
La_2O_3	−6.1	SiO_2	0.9
Lu_2O_3	−3.3	N_2O_3	6.6
TiO_2	0.7	N_2O_5	9.3
ZrO_2	0.1	P_4O_{10}	7.5
ThO_2	−3.8	As_2O_5	5.4
V_2O_5	3.0	SO_2	7.1
CrO_3	6.6	SO_3	10.5
MoO_3	5.2	SeO_2	5.2
WO_3	4.7	SeO_3	9.8
MnO	−4.8	Cl_2O_7	11.5
Mn_2O_7	9.6	I_2O_5	7.1
Tc_2O_7	9.6		
Re_2O_7	9.0		

[a] Values from Smith, D. W. *J. Chem. Educ.* 1987, *64*, 480.

Blank page for rough work not for submission