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CHM 2353

Midterm 1

2-Oct-2015

Family name: ________________

Given name: ________________

Student number ______________

Midterm: 1h : 15min

Question	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Total**
Points	**5 (+1)**	**5**	**5**	**5**	**5**	**5 (+1)**	**5**	**5**	**40**
Remarks									

Please keep your work covered and keep your eyes on your own paper! Cheating or any appearance of cheating will result in an F in the course and possible expulsion from the University.

A periodic table is given at the end of the exam. You may rip this off of the exam and use them to cover your work.

Please write the exam using a pen, you can use colorful pen however avoid red pens.

Traditional calculators and molecular models are allowed.

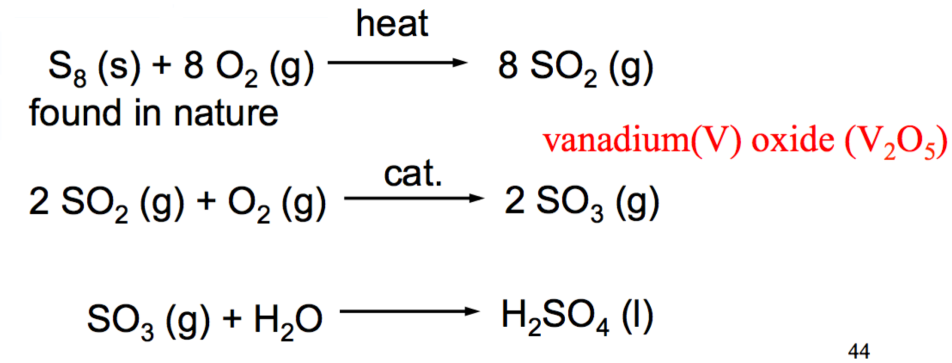
Please provide detailed explanation for your answers.

1) (5 points)a) Describe the reduction of CuS to Cu metal process with chemical reactions

$2\,CuS + 3\,O_2 \rightarrow 2\,CuO + 2\,SO_2$

$CuO + C \rightarrow Cu + CO$

b) Describe the process of obtaining H_2SO_4 form S using chemical reactions



$$S_8\,(s) + 8\,O_2\,(g) \xrightarrow{\text{heat}} 8\,SO_2\,(g)$$

found in nature

vanadium(V) oxide (V_2O_5)

$$2\,SO_2\,(g) + O_2\,(g) \xrightarrow{\text{cat.}} 2\,SO_3\,(g)$$

$$SO_3\,(g) + H_2O \longrightarrow H_2SO_4\,(l)$$

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Bonus (1 points): What is the catalyst commonly used in the production of H_2SO_4?

V_2O_5

c) Write balanced chemical equation for the reaction of Sodium metal with water.

$2\,Na\,(s) + 2\,H_2O\,(l) \longrightarrow 2\,NaOH\,(aq) + H_2\,(g)$

d) Write balanced chemical equation for the reaction of heating calcium oxide with carbon

$CaO\,(s) + 3\,C \longrightarrow CaC_2(s) + CO(g)$

e) Write balanced chemical equation for the reaction of Rubidium metal with dioxygen

$Rb(s) + O_2\,(g) \longrightarrow RbO_2(s)$

2) Write the most plausible Lewis structure of nitrosyl chloride, NOCl. (use formal charges to predict the most stable structure)

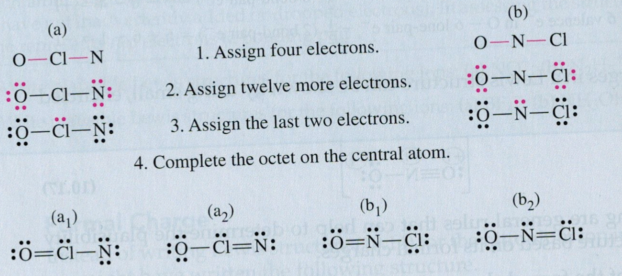
To determine the best structure, we must first complete the skeletal structures and then assign formal charges. The best structure will have the fewest and smallest formal charges.

Solve

Regardless of the skeletal structure chosen, the number of valence electrons (dots) that must appear in the final Lewis structure is

5 from N + 6 from O + 7 from Cl = 18

When we apply the four steps listed below to the two possible skeletal structures, we obtain a total of four Lewis structures—two for each skeletal structure. This doubling occurs because in step 4, there are two ways to complete the octets of the central atoms. The final Lewis structures obtained are labeled (a_1), (a_2), (b_1), and (b_2).



Evaluate formal charges by using equation (10.16). In structure (a_1),

for the N atom,

$$FC = 5 - 6 - \frac{1}{2}(2) = -2$$

for the O atom,

$$FC = 6 - 4 - \frac{1}{2}(4) = 0$$

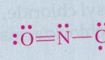
for the Cl atom,

$$FC = 7 - 2 - \frac{1}{2}(6) = +2$$

Proceed in a similar manner for the other three structures. Summarize the formal charges for the four structu

	(a_1)	**(a_2)**	**(b_1)**	**(b_2)**
N:	−2	−1	0	0
O:	0	−1	0	−1
Cl:	+2	+2	0	+1

Select the best Lewis structure in terms of the formal-charge rules. First, note that all four structures obey requirement that formal charges of a neutral molecule add up to zero. In structure (a_1), the formal cha are large (+2 on Cl and −2 on N) and the negative formal charge is not on the most electronegative atom. Struc (a_2) has formal charges on all atoms, one of them large (+2 on Cl). Structure (b_1) is the ideal we seek—no fo charges. In structure (b_2), we again have formal charges. The best Lewis structure of nitrosyl chloride is



Assess

Based on structure (b_1), ONCl is a better way to write the formula of nitrosyl chloride.

PRACTICE EXAMPLE A: Write a Lewis structure for nitrosyl chloride based on the skeletal structure N—O and show that this structure is not as plausible as the one obtained in Example 10-8.

PRACTICE EXAMPLE B: Write two Lewis structures for cyanamide, NH_2CN, an important chemical fertilizer and plastics industries. Use the formal charge concept to choose the more plausible structure.

3) (5 points) Which process is energetically favorable:

a) Adding an electron to K to form K^-; or b) losing an electron to form K^+? Explain.

a) adding an electron to K to form the anion is more energetically favorable; the first electron affinity for group one metals is negative (exothermic) as the incoming electron feels more attraction to the nucleus than repulsion from the other electron. Losing an electron, ionizing to form a cation always requires energy!

*The ionization energy is always endothermic (energy must be added in order to remove an electron); the electronic affinity is rather exothermic (**Adding an electron is usually energetically FAVORABLE**). According to these trends, it would be easier to add an electron to a potassium atom. Note that this seems conter intuitive but note that these values correspond to transformation in the gas phase (or atom / ion is isolated)*

4. (5 points) Which of Na or Cl will have the greatest first ionization energy? Which will have the greatest second ionization energy? Explain.

First ionization energy is the energy to remove the outermost (highest energy) electron from an atom in the gas phase. Ionization energy (generally) increases as you move down a column in the periodic table (as the electrons get further and further from the nucleus) and increases as you move across a row (as the effective nuclear charge increases as you move across the table resulting in a stronger attraction between the electron and the nucleus and also a decrease in the size of the atom). As a result the IE1 for Cl is greater than for Na (same row).
Second ionization energy is the energy to remove the outermost electron from a cation of +1 charge, in the gas phase. Second ionization energies are always more positive than first. Once again the magnitude of the second ionization energy will decrease down a column (same reason as above). Trend across a row in the periodic table is not so well defined as it depends on the "kind" of electron being removed.
The effective nuclear charge felt by the outer most electron in both Na+ is smaller than that felt by Cl+ , which would suggest that Na+ have a lower second IE; HOWEVER the second electron being removed from Na comes out of a 2p orbital rather than a 3p, and since the principal quantum number governs the size of the orbital, the 2p is smaller than the 3p and as a result it is more difficult to remove the second electron from Na.

5. (5 points) Place the following carbon tetrahalides (CF_4, CCl_4, CBr_4 and CI_4) in order of increasing melting point. Provide an explanation for this trend and be specific.

CF_4, CCl_4, CBr_4 and CI_4 These are covalent compounds, with no net dipole – must use analysis of intermolecular forces to determine melting. Melting of covalent compounds depends on the strength of intermolecular interactions (not bonds). Since these compounds have no net dipole, induced dipole effects will be most important. As the number of electrons in the molecule goes up, it becomes more polarisable and able to form stronger induced dipole/induced dipole interactions, therefore strongest interactions occur for CI_4 and weakest for CF_4.

6. (5 points) predict and draw the molecular shape of the following molecules according to the VSEPR theory:

a) NF_3
26 electrons in total: AB_3E will have a Trigonal pyramidal geometry

b) SO_3
AB_3 : Triangular plane or planar trigonal

c) H_2Se
Bent structure AB_2E_2

d) SbF_5
Trigonal bipyramidal

e) $[BH_4]^-$
tetrahedral

f) bonus (1 point) **:** IF_7
pentagonal bipyramidal

7) (5 points) Remembering the principle of electronegativity, determine whether these single bonds are polar and (if appropriate) in what direction is the dipole moment.

a) N-H
Polar H |→ N
b) F-Br
Polar Br |→ F
c) C-H
slightly Polar H |→ C
d) P-Cl
Polar P |→ Cl
e) H-H
Non polar

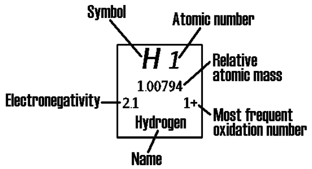
8) (5 points) Calculate the effective nuclear charge for K in the following electronic configurations:
-K : $1s^{2}2s^{2}2p^{6}3s^{2}3p^{6}3d^{1}$
-K : $1s^{2}2s^{2}2p^{6}3s^{2}3p^{6}4s^{1}$

For K, Z = 19
supporting rules Slater effective nuclear charge experienced by the electron configuration for 4s is : $1s^{2}2s^{2}2p^{6}3s^{2}3p^{6}4s^{1}$

Zeff =Z-S
=19-[(8x0.85)+(10x1.00)]=2.20

effective nuclear charge experienced by the nuclear 3d electron configuration is :$1s^{2}2s^{2}2p^{6}3s^{2}3p^{6}3d^{1}$
Zeff =Z-S
= 19 –(18x1.00)
=1

What is the energetically most stable? and why?
It is therefore the electron in 4s (rather than in 3d) is under the influence of the greater effective nuclear charge and, in the ground state of K, the atomic orbital 4s is



	1 IA	2 IIA	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8	9 VIII	10	11 IB	12 IIB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA
1	*H 1* 1.00794 2.1 1+ Hydrogen																	*He 2* 4.002602 - - Helium
2	**Li 3** 6.941 1.0 1+ Lithium	**Be 4** 9.012182 1.5 2+ Beryllium											**B 5** 10.811 2.0 3+ Boron	**C 6** 12.011 2.5 4+,4- Carbon	*N 7* 14.00674 3.0 3+,3- Nitrogen	*O 8* 15.9994 3.5 2- Oxygen	*F 9* 18.9984032 4.0 1- Fluorine	*Ne 10* 20.1797 - - Neon
3	**Na 11** 22.989768 0.9 1+ Sodium	**Mg 12** 24.3050 1.2 2+ Magnesium											**Al 13** 26.981539 1.5 3+ Aluminum	**Si 14** 28.0855 1.8 4+ Silicon	**P 15** 30.973762 2.1 5+ Phosphorus	**S 16** 32.066 1.8 4+ Sulfur	*Cl 17* 35.4527 3.0 1- Chlorine	*Ar 18* 39.948 - - Argon
4	**K 19** 39.0983 0.8 1+ Potassium	**Ca 20** 40.078 1.0 2+ Calcium	**Sc 21** 44.955910 1.3 3+ Scandium	**Ti 22** 47.88 1.5 4+ Titanium	**V 23** 50.9415 1.6 5+ Vanadium	**Cr 24** 51.9961 1.6 3+ Chromium	**Mn 25** 54.93805 1.5 2+ Manganese	**Fe 26** 55.847 1.8 3+ Iron	**Co 27** 58.9332 1.8 2+ Cobalt	**Ni 28** 58.6934 1.8 2+ Nickel	**Cu 29** 63.546 1.9 2+ Copper	**Zn 30** 65.39 1.6 2+ Zinc	***Ga 31*** 69.723 1.6 3+ Gallium	**Ge 32** 72.61 1.6 4+ Germanium	**As 33** 74.92159 2.0 3+,3- Arsenic	**Se 34** 78.96 2.4 4+ Selenium	***Br 35*** 79.904 2.8 1- Bromine	*Kr 36* 83.80 - - Krypton
5	**Rb 37** 85.4678 0.8 1+ Rubidium	**Sr 38** 87.62 1.0 2+ Strontium	**Y 39** 88.90585 1.3 3+ Yttrium	**Zr 40** 91.224 1.4 4+ Zirconium	**Nb 41** 92.90638 1.6 5+ Niobium	**Mo 42** 95.94 1.8 6+ Molybdenum	Tc 43 98.9063 1.9 7+ Technetium	**Ru 44** 101.57 2.2 3+,4+ Ruthenium	**Rh 45** 102.9055 2.2 3+ Rhodium	**Pd 46** 106.42 2.2 2+ Palladium	**Ag 47** 107.8682 1.9 1+ Silver	**Cd 48** 112.411 1.7 2+ Cadmium	**In 49** 114.82 1.7 3+ Indium	**Sn 50** 118.71 1.8 4+ Tin	**Sb 51** 121.757 1.9 3+,3- Antimony	**Te 52** 127.60 2.1 4+ Tellurium	**I 53** 126.90447 2.5 1- Iodine	*Xe 54* 131.29 - - Xenon
6	***Cs 55*** 132.90543 0.7 1+ Cesium	**Ba 56** 137.327 0.9 2+ Barium	**La 57** 138.9055 1.1 3+ Lanthanum	**Hf 72** 178.49 1.3 4+ Hafnium	**Ta 73** 180.9479 1.5 5+ Tantalum	**W 74** 183.85 1.7 6+ Tungsten	**Re 75** 186.207 1.9 7+ Rhenium	**Os 76** 190.2 2.2 4+ Osmium	**Ir 77** 192.22 2.2 4+ Iridium	**Pt 78** 195.08 2.2 4+ Platinum	**Au 79** 196.96654 2.4 3+ Gold	***Hg 80*** 200.59 1.9 2+ Mercury	**Tl 81** 204.3833 1.8 1+ Thallium	**Pb 82** 207.2 1.8 2+ Lead	**Bi 83** 208.98037 1.9 3+ Bismuth	**Po 84** 208.9824 2.0 2+ Polonium	**At 85** 209.9871 2.2 1- Astatine	*Rn 86* 222.0176 - - Radon
7	***Fr 87*** 223.0197 0.7 1+ Francium	**Ra 88** 226.0254 0.9 2+ Radium	**Ac 89** 227.0278 1.1 3+ Actinium	Rf 104 261.11 - - Rutherfordium	Db 105 262.11 - - Dubnium	Sg 106 263.12 - - Seaborgium	Bh 107 262.12 - - Bohrium	Hs 108 264 - - Hassium	Mt 109 266.1378 - - Meitnerium	Uun 110 269 - - Ununnilium	Uuu 111 272 - - Unununium	Uu 112 277 - - Ununbium		Uuq 114 289 - - Ununquadium		Uuh 116 289 - - Ununhexium		Uuo 118 293 - - Ununoctium

6	**Ce 58** 140.115 1.1 3+ Cerium	**Pr 59** 140.90765 1.1 3+ Praseodymium	**Nd 60** 144.24 1.1 3+ Neodymium	Pm 61 144.9127 1.1 3+ Promethium	**Sm 62** 150.36 1.2 3+ Samarium	**Eu 63** 151.965 1.2 3+ Europium	**Gd 64** 157.25 1.2 3+ Gadolinium	**Tb 65** 168.92534 1.2 3+ Terbium	**Dy 66** 162.50 1.2 3+ Dysposium	**Ho 67** 164.93032 1.2 3+ Holmium	**Er 68** 167.26 1.2 3+ Erbium	**Tm 69** 168.93421 1.2 3+ Thulium	**Yb 70** 173.04 1.1 3+ Ytterbium	**Lu 71** 174.967 1.2 3+ Lutetium
7	**Th 90** 232.0381 1.3 4+ Thorium	**Pa 91** 231.03588 1.5 5+ Protactinium	**U 92** 238.0289 1.4 6+ Uranium	Np 93 237.082 1.3 5+ Neptunium	Pu 94 244.0642 1.3 4+ Plutonium	Am 95 243.0614 1.3 3+ Americium	Cm 96 247 1.3 3+ Curium	Bk 97 247.0703 1.3 3+ Berkelium	Cf 98 251.0796 1.3 3+ Californium	Es 99 252.03 1.3 - Einsteinium	Fm 100 257.0951 1.3 - Fermium	Md 101 258.01 1.3 - Mendelevium	No 102 259.1009 1.3 - Nobelium	Lr 103 260.1053 - - Lawrencium

Under normal conditions, bold symbols correspond to solid state, bold italic correspond to liquid state, italic correspond to gaseous state and normal correspond to synthetic elements.