Chemistry 141 Name

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Exam 3 November 12, 2009

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|  | Points Earned | Points Possible |
| Page 3 multiple choice |  | 30 |
| Page 5 |  | 17 |
| Page 6 |  | 22 |
| Page 7 |  | 20 |
| Page 8 |  | 12 |
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| Page 10 |  | 14 |
| Total |  | 129 |

Note: All work must be shown to receive credit. On calculation problems show answer with the correct number of significant figures using scientific notation if necessary.

PERIODIC CHART

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| IA |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | VIIA | NOBLE GASES |
| 1  **H**  1.008 | IIA |  |  |  |  |  |  |  |  |  |  | IIIA | IVA | VA | VIA | 1  **H**  1.008 | 2  **He**  4.002 |
| 3  **Li**  6.941 | 4  **Be**  9.012 | Transition Metals | | | | | | | | | | 5  **B**  10.81 | 6  **C**  12.01 | 7  **N**  14.01 | 8  **O**  16.00 | 9  **F**  19.00 | 10  **Ne**  20.18 |
| 11  **Na**  23.00 | 12  **Mg**  24.30 | IIIB | IVB | VB | VIB | VIIB | VIIIB | | | IB | IIB | 13  **Al**  27.00 | 14  **Si**  28.09 | 15  **P**  30.97 | 16  **S**  32.06 | 17  **Cl**  35.45 | 18  **Ar**  39.95 |
| 19  **K**  39.10 | 20  **Ca**  40.08 | 21  **Sc**  44.96 | 22  **Ti**  47.90 | 23  **V**  50.94 | 24  **Cr**  52.00 | 25  **Mn**  54.94 | 26  **Fe**  55.85 | 27  **Co**  58.93 | 28  **Ni**  58.70 | 29  **Cu**  63.55 | 30  **Zn**  65.38 | 31  **Ga**  69.72 | 32  **Ge**  72.59 | 33  **As**  74.92 | 34  **Se**  78.96 | 35  **Br**  79.90 | 36  **Kr**  83.80 |
| 37  **Rb**  85.47 | 38  **Sr**  87.62 | 39  **Y**  88.91 | 40  **Zr**  91.22 | 41  **Nb**  92.91 | 42  **Mo**  95.94 | 43  **Tc**  (99) | 44  **Ru**  101.1 | 45  **Rh**  102.9 | 46  **Pd**  106.4 | 47  **Ag**  107.9 | 48  **Cd**  112.4 | 49  **In**  114.8 | 50  **Sn**  118.7 | 51  **Sb**  121.8 | 52  **Te**  127.6 | 53  **I**  126.9 | 54  **Xe**  131.3 |
| 55  **Cs**  132.9 | 56  **Ba**  137.3 | 57  **La**  138.9 | 72  **Hf**  178.5 | 73  **Ta**  180.9 | 74  **W**  183.9 | 75  **Re**  186.2 | 76  **Os**  190.2 | 77  **Ir**  192.2 | 78  **Pt**  195.1 | 79  **Au**  197.0 | 80  **Hg**  200.6 | 81  **Tl**  204.4 | 82  **Pb**  207.2 | 83  **Bi**  209.0 | 84  **Po**  (209) | 85  **At**  (210) | 86  **Rn**  (222) |
| 87  **Fr**  (223) | 88  **Ra**  226.0 | 89  **Ac**  227.0 | 104  **Rf**  (261) | 105  **Db**  (262) | 106  **Sg**  (263) | 107  **Bh**  (262) | 108  **Hs**  (265) | 109  **Mt**  (268) | 110  **??**  (???) |  |  |  |  |  |  |  |  |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 58  **Ce**  140.1 | 59  **Pr**  140.9 | 60  **Nd**  144.2 | 61  **Pm**  (147) | 62  **Sm**  150.4 | 63  **Eu**  152.0 | 64  **Gd**  157.3 | 65  **Tb**  158.9 | 66  **Dy**  162.5 | 67  **Ho**  164.9 | 68  **Er**  167.3 | 69  **Tm**  168.9 | 70  **Yb**  173.0 | 71  **Lu**  175.0 |
| 90  **Th**  232.0 | 91  **Pa**  231.0 | 92  **U**  238.0 | 93  **Np**  (237) | 94  **Pu**  (244) | 95  **Am**  (243) | 96  **Cm**  (247) | 97  **Bk**  (247) | 98  **Cf**  (251) | 99  **Es**  (252) | 100  **Fm**  (257) | 101  **Md**  (258) | 102  **No**  (259) | 103  **Lr**  (260) |

Lanthanide series

Actinide series

Chemistry Formulas and Constants

Formulas

Kinetic energy = ½ mv2

w = -PΔV

Ptotal = P1+P2+P3+…

u = (3RT/MW)½

ΔG = ΔH - TΔS

PV = nRT

Rate ∝ (MW)-½

P1=X1\*Ptotal

C = q/ΔT

w=dxF

E = IR

ΔGo = -nFEo

ΔG = - RTlnK

E = mc2

Ba(Na)2 = fruit

HΨ=EΨ

Amp = C/sec

Π= iMRT

E = hν = hc/λ

M1V1 = M2V2

Ptotal = P1 + P2 + P3 + …

M = mol/L

m = mol/kg solvent

Xi = moli/ moltotal

ΔTb = i(kb)(m)

ΔTf = i(kf)(m)

Psoln = (Psolv)(Xsolv)



Constants

= 10-8 cm

F = 9.65 x 104 C

h = 6.626 x 10-34 J sec

c= 2.9979 x 108 m/sec

e = 1.602 x 10-19 C

NA = 6.022 x 1023/mol

k = 1.381 x 10-23 J/K

K = oC + 273.16

Kw = 1.0 x 10-14M2

mass electron = 9.109 x 10-31 kg

R = 0.0821 L atm/mol K= 8.314 J/K mol= 1.987 cal.mol K= 62.4 L torr/mol K

Standard Temperature and Pressure = 0oC and 1 atm

Multiple Choice (30 points)

1. What is a quantum of light called?
   1. the amplitude
   2. the wavelength
   3. a photon
   4. the frequency
   5. none of the above
2. The intensity of a beam of light is related to its
   1. relative number of photons.
   2. frequency.
   3. wavelength.
   4. speed.
   5. none of the above
3. The number of orbitals in a given subshell, such as the 5*d* subshell, is determined by the number of possible values of
   1. *l*
   2. *ml*
   3. *n*
   4. *ms*
   5. none of the above
4. For an electron in a given atom, the larger *n*, the
   1. larger the average distance from the nucleus and the lower the orbital energy.
   2. smaller the average distance from the nucleus and the higher the orbital energy.
   3. larger the average distance from the nucleus and the higher the orbital energy.
   4. smaller the average distance from the nucleus and the lower the orbital energy.
   5. none of the above
5. Which of the following is *not* a valid set of quantum numbers?
   1. *n* = 3, *l* = 0, *ml* = 0, and *ms* = 1/2
   2. *n* = 3, *l* = 2, *ml* = 3, and *ms* = 1/2
   3. *n* = 2, *l* = 1, *ml* = -1, and *ms* = -1/2
   4. *n* = 2, *l* = 1, *ml* = 0, and *ms* = -1/2
   5. none of the above
6. Which of the following have the same number of valence electrons?
   1. N, As, Bi
   2. K, As, Br
   3. He, Ne, F
   4. B, Si, As
   5. none of the above
7. Arrange the ions N3-, O2-, Mg2+, Na+, and F- in order of increasing ionic radius, starting with the smallest first.
   1. N3-, Mg2+, O2-, Na+, F-
   2. N3-, O2-, Mg2+, F-, Na+
   3. N3-, O2-, F-, Na+, Mg2+
   4. Mg2+, Na+, F-, O2-, N3-
   5. none of the above
8. Which ionic compound would be expected to have the highest lattice energy?
   1. Al2O3
   2. MgO
   3. NaCl
   4. AlF3
   5. Na2O
9. Which ionization process requires the most energy?
   1. S+(*g*) 🡪 S2+(*g*) + e-
   2. Cl(*g*) 🡪 Cl+(*g*) + e-
   3. Na(g) 🡪 Na+(g) + e-
   4. S(*g*) 🡪 S+(*g*) + e-
   5. Cl+(*g*) 🡪 Cl2+(*g*) + e-
10. In the reaction of sodium metal with chlorine gas which of the following processes releases energy?
    1. Cl2(*g*) 🡪 2 Cl(*g*)
    2. Na(*g*) 🡪 Na+(*g*) + e-
    3. Na(*s*) 🡪 Na(*g*)
    4. Cl(*g*) + e- 🡪 Cl-(*g*)
    5. Unable to determine
11. Which bond should have the longest length?
    1. N-N
    2. N=N
    3. N≡N
    4. All three bond lengths should be about the same.
    5. Impossible to determine from the data given
12. The Cl¹Cl bond energy is 243 kJ/mol. Therefore the formation of a single bond between chlorine atoms
    1. should require the absorption of 486 kJ per mole of Cl2 formed.
    2. should result in the release of 243 kJ per mole of Cl2 formed.
    3. should require the absorption of 243 kJ per mole of Cl2 formed.
    4. should result in the release of 486 kJ per mole of Cl2 formed.
    5. none of the above
13. The greater the electronegativity difference between two bonded atoms, the
    1. greater the bond order.
    2. greater the ionic character of the bond.
    3. more unstable the bond.
    4. greater the covalent character of the bond.
    5. none of the above
14. Compare the energies of molecular orbitals of homonuclear diatomic molecules with the energies of the atomic orbitals with which they correlate.
    1. Both bonding and antibonding molecular orbitals lie lower in energy than the atomic orbitals.
    2. Bonding orbitals are higher and antibonding orbitals are lower in energy than the atomic orbitals.
    3. Bonding orbitals are lower and antibonding orbitals are higher in energy than the atomic orbitals.
    4. Both bonding and antibonding molecular orbitals are higher in energy than the atomic orbitals.
    5. none of the above
15. Which orbital hybridization is associated with an trigonal bipyramidal charge cloud arrangement?
    1. *sp*
    2. *sp2*
    3. *sp3d*
    4. *sp3d2*
    5. none of the above

Problems (75 points)

1. (9 points) The blue color of the sky results from the scattering of sunlight by air molecules. The blue light has a frequency of about 7.5 x 1014 Hz.
   1. Calculate the wavelength, in nm, associated with this radiation.
   2. Calculate the energy, in J, of a single photon associated with this frequency.
   3. The retina of a human eye can detect light when radiant energy incident on it is at least 4.0 x 10-17 J. How many photons of “sky blue” light does this correspond to?
2. (8 points) How many photons at 660 nm must be absorbed to melt 5.0 x 102g of ice? (Hint: It takes 334 J to melt 1 gram of ice at 0oC.)

On average, how many H2O molecules does one photon convert from ice to water?

1. (5 points) The ionization energy of gold is 890.1 kJ/mol. Is light with a wavelength of 225 nm capable of ionizing a gold atom (removing an electron) in the gas phase?

The light does not have enough energy to eject an electron from the gold.

1. (4 points) Is is possible for a fluorescent material to emit radiation in the ultraviolet region after absorbing visible light? Explain your answer.

No, UV light has a shorter wavelength and lower energy that visible light. It is impossible to emit light with a higher energy than the incident light.

1. (3 points) Write the complete electron configuration for an atom of sulfur.

1s2 2s2 2p6 3s2 3p4

1. (3 points) Write the shorthand electronic configuration for an atom of Osmium (element number 76) as predicted by the periodic table.

Os [Xe] 6s2 5d6 4f14

1. (3 points) Write the shorthand electronic configuration for a cobalt (II) ion, Co+2.

Co+2 [Ar] 3d7

1. (4 points) The H-1 ion and the He atom have two 1s electrons each. Which of the two species is larger? Explain your reasoning.

The H-1 ion is larger because both have the same number of electrons, (are isoelectronic), but the He has more protons in its nucleus to pull the electrons closer thus giving a smaller ion.

1. (20 points) Draw a Lewis electron dot structure for each of the following. Show resonance structures where appropriate and show any formal charges. Give the molecular geometry and hybridization of the central atom.

|  |  |
| --- | --- |
| Species | Lewis Structure |
| **I3-1**  Orbital geometry  Trigonal bipyramidal  Molecular geometry  linear  Hybridization of iodine  sp3d |  |
| **XeF4**  Orbital geometry  octahedral  Molecular geometry  Square planar  Hybridization of xenon  sp3d2 |  |
| **NO3-1**  Show all resonance structures  Orbital geometry  Trigonal planar  Molecular geometry  Trigonal planar  Hybridization of nitrogen  sp3 |  |
| **NO2-1**  Show all resonance structures  Orbital geometry  Trigonal planar  Molecular geometry  bent  Hybridization of nitrogen  sp2 |  |

1. (4 points) Two structures can be drawn for cyanuric acid:
   1. Are these two resonance structures of the same molecule? Explain.



No, these are not resonance structures. They are different isomers with the same molecular formula

* 1. How many sigma bonds are in structure b?

There are 12 sigma bonds in structure b

* 1. How many pi bonds are in structure b?

There are 3 pi bonds in structure b

1. (4 points) Do you expect the nitrogen-oxygen bond length in the nitrate ion to be the same as in the nitrite ion? If not, describe in detail how they are different.

No, I expect the N-O bonds in nitrate will be longer than the N-O bonds in nitrite. This is because the average bond order in nitrate is 1.3 whereas the average bond order in nitrite is 1.5 based on the lewis structures drawn in question 9. The higher the bond order, the shorter the bond.

1. (4 points) The triiodide ion (I3-1) in which the I atoms are arranged as III is stable, but the corresponding F3-1 ion does not exist. Explain using lewis structures.

In order to form the tri-iodide ion we must expand the valence of iodine to hold 10 electrons. This is not possible with fluorine since there are no available d orbitials to use in expanding the valence. Therefore F3-1 will not exist.

1. (6 points) Possible resonance structures for CNO-1 and NCO-1 have been drawn below. Assign formal charges to all atoms with non-zero formal charges. Based on your assignments predict which structure is more likely to exist. Next circle the best resonance structure and defend your choice.



Best because the negative charge is on the more electronegative oxygen.

NCO-1 is the preferred structure because charge can be better minimized on this isomer.

1. (8 points) Look at the compound pictured below. Explain the bonding in terms of valence bond theory. That is show the atomic orbitals on the Xe atom, describe any electron promotion and hybridization necessary, and label the orbitals involved in both sigma and pi bonding as well as the orbital holding the lone pair of electrons on Xe. You do not need to draw a 3D representation of the orbitals.



Xe

Promotion

Xe

Hybridization

Xe

1. (14 points) Draw lewis electron dot structures for OF and OF-1. Next determine the molecular orbital representation of these two species. Does valence bond theory and molecular orbital theory predict the same bond orders for these two species? Answer the questions regarding these structures in the table below

|  |  |  |
| --- | --- | --- |
|  | OF | OF-1 |
| Lewis Structure |  |  |
| Bond order predicted by VB theory | 1 | 1 |
| Molecular orbital diagram | 10_13-10UN | 10_13-10UN |
| Bond order predicted by MO theory | 1 ½ | 1 |
| Paramagnetic or diamagnetic? | paramagnetic | diamagnetic |

Which species has the shorter bond length based on molecular orbital theory?

OF should have the shortest bond length.