

**HOUR EXAM #2**

NAME: \_\_\_\_\_ SPIRE ID # /\_/\_/\_/\_/\_/\_/\_/\_/\_/\_

**\*\*Not all pieces of information on this page are needed to complete this exam correctly\*\*****Physical Constants and Conversion Factors**

$$e = 1.602 \times 10^{-19} \text{ C}$$

$$1 \text{ u} = 1.66 \times 10^{-24} \text{ g}$$

$$1 \text{ eV} = 96.48 \text{ kJ/mol}$$

$$R = 1.097 \times 10^7 \text{ m}^{-1} \text{ (Rydberg Constant)}$$

$$N_A = 6.022 \times 10^{23}$$

$$h = 6.63 \times 10^{-34} \text{ J}\cdot\text{s}$$

Electron mass = 0.0005485799 u

$$c = 3.00 \times 10^8 \text{ m/s}$$

Proton mass = 1.007276 u

$$Rhc = 2.18 \times 10^{-18} \text{ J}$$

Neutron mass = 1.008665 u

$$R = 0.082057 \text{ L}\cdot\text{atm/mol}\cdot\text{K} \text{ or } 8.3145 \text{ J/mol}\cdot\text{K} \text{ (Ideal Gas Constant)}$$

Hydrogen atom,  $^1_1\text{H}$ , mass = 1.007825 u

$$1.0 \text{ g/mol} = 9.00 \times 10^{10} \text{ kJ/mol}$$

$$k = 1.38 \times 10^{-23} \text{ JK}^{-1} \text{ (Boltzmann Constant)}$$

**Other information**

(1) Periodic Table (back of this page)

(2) Electronegativities

H – 2.1

B – 2.0

C – 2.5

N – 3.0

O – 3.5

F – 4.0

Si – 1.7

P – 2.1

S – 2.4

Cl – 3.0

As – 2.2

Se 2.5

Br – 2.7

**NOTE: FOR FULL CREDIT, ALL WORK MUST BE SHOWN FOR ANY QUESTION REQUIRING CALCULATIONS OR COMPUTATIONS.**

**Problems (52 points)**

- (1) Answer the following questions about an atom of Vanadium (V),  $Z=23$ . (16 pts)
- Write its orbital box electron configuration.
  - Write its spectroscopic sublevel electron configuration.
  - Write its noble gas abbreviated sublevel electron configuration.
  - Write its outer configuration.
  - What type of magnetic properties would you expect for this atom and why?
  - Give a possible set of quantum numbers for the last electron in this atom.
  - Write the noble gas abbreviated electron configuration for the  $V^{2+}$  ion.
  - Is the  $V^{2+}$  ion diamagnetic or paramagnetic and why?
- (2) Phospham, NPNH, has the atomic arrangement N-P-N-H. For this molecule: (14 pts)
- Draw a valid Lewis structure and one other (total two) reasonable resonance structure.
  - Label these two resonance structures as major or minor contributors.
  - Draw the resonance hybrid based on the resonance contributors you drew in (a).
  - What are the N-P-N and P-N-H bond angles in this molecule?
- (3) Sulfur forms a series of compounds with fluorine. Two are  $SF_2$  and  $SF_4$ . For these two compounds: (12 pts)
- Determine whether the molecule is polar or non-polar. Briefly explain or show why.
  - If polar, show the direction of the molecular dipole (showing using an arrow with a crossed tail, such as  $+\rightarrow$ ).
- (4) Early automobiles used carbide headlamps to find their way in the dark. The carbide anion has the structure  $C_2^{2-}$ . Using molecular orbital theory: (10 points)
- Determine the bond order of this ion.
  - Propose another ion of  $C_2$  that has a shorter bond than the carbide ion.
  - With what neutral homonuclear diatomic molecule is the carbide ion isoelectronic?

**Multiple-Choice (48 points - 3 each - 16 of 17 counted for grade)**

- (1) Which has three unpaired electrons?
- (a)  $Sc^{1+}$                       (b)  $Mn^{3+}$                       (c)  $Ti^{1+}$                       (d)  $Cr^{1+}$
- (2) Which statement is true?
- Br has a larger atomic radius than As
  - $Br^{1-}$  has a larger ionic radius than  $Sr^{2+}$
  - I has a smaller atomic radius than Br
  - The ionic radius of  $Sr^{2+}$  is larger than the atomic radius of Sr.

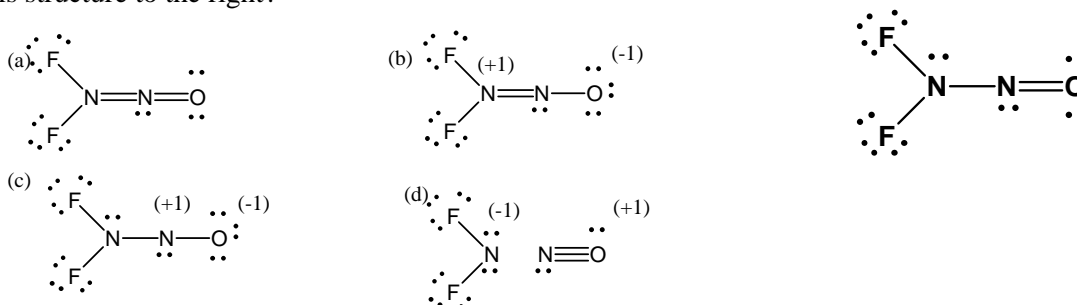
(3) Which species is paramagnetic?

- (a) F                      (b) S<sup>2-</sup>                      (c) Zn<sup>2+</sup>                      (d) Mg

(4) True/False. Label each statement as either true or false in the space provided

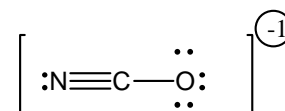
- (a) Calcium nitrate is Ca(NO<sub>3</sub>)<sub>2</sub> \_\_\_\_\_  
 (b) N<sup>3-</sup> has a sublevel electron configuration of 1s<sup>2</sup>2s<sup>2</sup>2p<sup>6</sup> \_\_\_\_\_  
 (c) The lattice energy of NaI is less than that of NaF \_\_\_\_\_  
 (d) All ionic compounds are solid \_\_\_\_\_

(5) Which is a reasonable resonance structure (likely to make a contribution to the hybrid) for the Lewis structure to the right?



(6) What is the formal charge on atoms N, C, and O respectively in the Lewis structure shown to the right?

- (a) N = 0; C = +1; O = -1                      (b) N = -1; C = +1; O = -1  
 (c) N = -1; C = 0; O = 0                      (d) N = 0; C = 0; O = -1

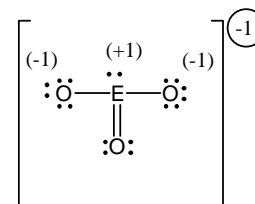


(7) The number of shared and unshared electrons pairs respectively, around the central bismuth atom in the BiI<sub>4</sub><sup>1-</sup> ion are:

- (a) 4,0                      (b) 5,0                      (c) 4,1                      (d) 5,1

(8) Which atom could be E in this structure?

- (a) Br                      (b) C                      (c) S                      (d) P



(9) A student needs a species with the following characteristics for a research project: +1 cation, contains four fluorine atoms and no other peripheral atoms, is polar, and has a fourth period element as its central atom. Which element provides these characteristics?

- (a) Br                      (b) Se                      (c) As                      (d) Ge

(10) The resonance hybrid of the nitrite ion,  $\text{NO}_2^{1-}$ , has \_\_\_\_ pairs of localized (fixed) electrons and \_\_\_\_ pairs of delocalized (dispersed) electrons.

- (a) 9,2                      (b) 7,4                      (c) 7,2                      (d) 9,0

(11) Which species obeys the Octet Rule?

- (a)  $\text{BeCl}_2$                       (b)  $\text{NO}^{1+}$                       (c)  $\text{NO}$                       (d)  $\text{SF}_4$

(12) What is the electron pair geometry (EPG) of  $\text{SnCl}_3^{1-}$ ?

- (a) trigonal planar              (b) trigonal pyramid              (c) tetrahedral              (d) square planar

(13) The molecular shape of  $\text{XeF}_3^{1-}$  is:

- (a) T-shaped                      (b) square planar                      (c) octahedral                      (d) trigonal bipyramid

(14) What is the smallest bond angle in degrees that exists for the molecule  $\text{OXeF}_2$ ? (Xe central)

- (a) 90                      (b) 109                      (c) 120                      (d) 180

(15) Which molecule is polar?

- (a)  $\text{CCl}_4$                       (b)  $\text{XeF}_4$                       (c)  $\text{BrF}_5$                       (d)  $\text{BF}_3$

(16) Which species has the weakest bond?

- (a)  $\text{O}_2^{1-}$                       (b)  $\text{O}_2^{1+}$                       (c)  $\text{O}_2^{2+}$                       (d)  $\text{O}_2$

(17) According to MO theory which species is diamagnetic?

- (a)  $\text{O}_2^{1-}$                       (b)  $\text{O}_2^{1+}$                       (c)  $\text{O}_2^{2+}$                       (d)  $\text{O}_2$

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$$N_A = 6.022 \times 10^{23}$$

$$h = 6.63 \times 10^{-34} \text{ J}\cdot\text{s}$$

Electron mass = 0.0005485799 u

$$c = 3.00 \times 10^8 \text{ m/s}$$

Proton mass = 1.007276 u

$$Rhc = 2.18 \times 10^{-18} \text{ J}$$

Neutron mass = 1.008665 u

$$R = 0.082057 \text{ L}\cdot\text{atm/mol}\cdot\text{K} \text{ or } 8.3145 \text{ J/mol}\cdot\text{K} \text{ (Ideal Gas Constant)}$$

Hydrogen atom,  $^1_1\text{H}$ , mass = 1.007825 u

$$1.0 \text{ g/mol} = 9.00 \times 10^{10} \text{ kJ/mol}$$

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**Other information**

(1) Periodic Table (back of this page)

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F – 4.0

Si – 1.7

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Se 2.5

Br – 2.7

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**Problems (52 points)**

- (1) Answer the following questions about an atom of Titanium (Ti),  $Z=22$ . (16 pts)
- Write its orbital box electron configuration.
  - Write its spectroscopic sublevel electron configuration.
  - Write its noble gas abbreviated sublevel electron configuration.
  - Write its outer configuration.
  - What type of magnetic properties would you expect for this atom and why?
  - Give a possible set of quantum numbers for the last electron in this atom.
  - Write the noble gas abbreviated electron configuration for the  $Ti^{2+}$  ion.
  - Is the  $Ti^{2+}$  ion diamagnetic or paramagnetic and why?
- (2) A molecule has the atomic arrangement H-O-N-S. For this molecule: (14 pts)
- Draw a valid Lewis structure and one other (total two) reasonable resonance structure.
  - Label these two resonance structures as major or minor contributors.
  - Draw the resonance hybrid based on the resonance contributors you drew in (a).
  - What are the H-O-N and O-N-S bond angles in this molecule?
- (3) Phosphorus forms a series of compounds with fluorine. Two are  $PF_3$  and  $PF_5$ . For these two compounds: (12 pts)
- Determine whether the molecule is polar or non-polar. Briefly explain or show why.
  - If polar, show the direction of the molecular dipole (showing using an arrow with a crossed tail, such as  $+\rightarrow$ ).
- (4) The nitrogen cation,  $N_2^{2+}$  has been identified in interstellar space. Using molecular orbital theory: (10 points)
- Determine the bond order of this ion.  $N_2^{2+}$
  - Propose another ion of  $N_2$  that has a shorter bond than  $N_2^{2+}$ .
  - With what neutral homonuclear diatomic molecule is  $N_2^{2+}$  isoelectronic?

**Multiple-Choice (48 points - 3 each -16 of 17 counted for grade)**

- (1) Which has three unpaired electrons?
- (a)  $Ti^{1+}$                       (b)  $Mn^{3+}$                       (c)  $Sc^{1+}$                       (d)  $Cr^{1+}$
- (2) Which statement is true?
- $Br^{1-}$  has a larger ionic radius than  $Sr^{2+}$
  - Br has a larger atomic radius than As
  - I has a smaller atomic radius than Br
  - The ionic radius of  $Sr^{2+}$  is larger than the atomic radius of Sr.

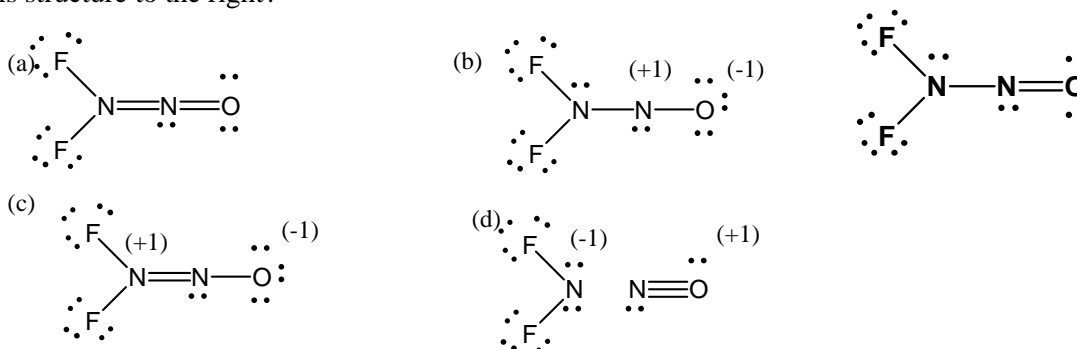
(3) Which species is paramagnetic?

- (a) F                      (b)  $Zn^{2+}$                       (c)  $S^{2-}$                       (d) Mg

(4) True/False. Label each statement as either true or false in the space provided

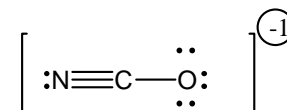
- (a) All ionic compounds are solid \_\_\_\_\_  
 (b) Calcium nitrate is  $Ca(NO_3)_2$  \_\_\_\_\_  
 (c)  $N^{3-}$  has a sublevel electron configuration of  $1s^2 2s^2 2p^6$  \_\_\_\_\_  
 (d) The lattice energy of NaI is less than that of NaF \_\_\_\_\_

(5) Which is a reasonable resonance structure (likely to make a contribution to the hybrid) for the Lewis structure to the right?



(6) What is the formal charge on atoms N, C, and O respectively in the Lewis structure shown to the right?

- (a) N = 0; C = 0; O = -1                      (b) N = -1; C = +1; O = -1  
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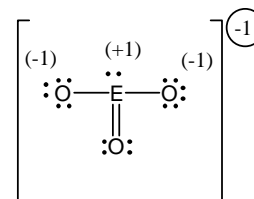


(7) The number of shared and unshared electrons pairs respectively, around the central bismuth atom in the  $BiI_4^{1-}$  ion are:

- (a) 4,1                      (b) 5,0                      (c) 4,0                      (d) 5,1

(8) Which atom could be E in this structure?

- (a) P                      (b) C                      (c) S                      (d) Br







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Si – 1.7

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Cl – 3.0

As – 2.2

Se 2.5

Br – 2.7

**NOTE: FOR FULL CREDIT, ALL WORK MUST BE SHOWN FOR ANY QUESTION REQUIRING CALCULATIONS OR COMPUTATIONS.**

**Problems (52 points)**

- (1) Answer the following questions about an atom of Scandium (Sc),  $Z=21$ . (16 pts)
- Write its orbital box electron configuration.
  - Write its spectroscopic sublevel electron configuration.
  - Write its noble gas abbreviated sublevel electron configuration.
  - Write its outer configuration.
  - What type of magnetic properties would you expect for this atom and why?
  - Give a possible set of quantum numbers for the last electron in this atom.
  - Write the noble gas abbreviated electron configuration for the  $\text{Sc}^{1+}$  ion.
  - Is the  $\text{Sc}^{1+}$  ion diamagnetic or paramagnetic and why?
- (2) A molecule has the atomic arrangement H-N-S-O. For this molecule: (14 pts)
- Draw a valid Lewis structure and one other (total two) reasonable resonance structure.
  - Label these two resonance structures as major or minor contributors.
  - Draw the resonance hybrid based on the resonance contributors you drew in (a).
  - What are the H-N-S and N-S-O bond angles in this molecule?
- (3) Chlorine forms a series of compounds with fluorine. Two are  $\text{ClF}_3$  and  $\text{ClF}_5$ . For these two compounds: (12 pts)
- Determine whether the molecule is polar or non-polar. Briefly explain or show why.
  - If polar, show the direction of the molecular dipole (showing using an arrow with a crossed tail, such as  $+\rightarrow$ ).
- (4) The diatomic neon cation  $\text{Ne}_2^{2+}$  has been identified in interstellar space. Using molecular orbital theory: (10 points)
- Determine the bond order of this ion.
  - Propose another ion of  $\text{Ne}_2$  that has a shorter bond than  $\text{Ne}_2^{2+}$ .
  - With what neutral homonuclear diatomic molecule is  $\text{Ne}_2^{2+}$  isoelectronic?

**Multiple-Choice (48 points - 3 each - 16 of 17 counted for grade)**

- (1) Which has two unpaired electrons?
- (a)  $\text{Sc}^{1+}$                       (b)  $\text{Mn}^{3+}$                       (c)  $\text{Ti}^{1+}$                       (d)  $\text{Cr}^{1+}$
- (2) Which statement is true?
- Br has a smaller atomic radius than As
  - $\text{Br}^{1-}$  has a smaller ionic radius than  $\text{Sr}^{2+}$
  - I has a smaller atomic radius than Br
  - The ionic radius of  $\text{Sr}^{2+}$  is larger than the atomic radius of Sr.

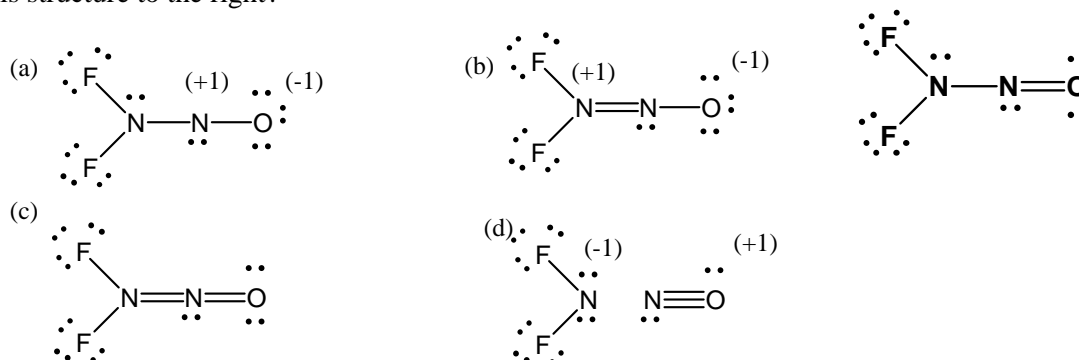
(3) Which species is paramagnetic?

- (a)  $F^{1-}$                       (b) S                      (c)  $Zn^{2+}$                       (d) Mg

(4) True/False. Label each statement as either true or false in the space provided

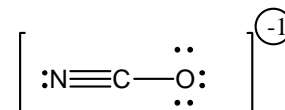
- (a) The lattice energy of NaI is less than that of NaF \_\_\_\_\_  
 (b) Calcium nitrate is  $Ca(NO_3)_2$  \_\_\_\_\_  
 (c)  $N^{3-}$  has a sublevel electron configuration of  $1s^2 2s^2 2p^6$  \_\_\_\_\_  
 (d) All ionic compounds are solid \_\_\_\_\_

(5) Which is a reasonable resonance structure (likely to make a contribution to the hybrid) for the Lewis structure to the right?



(6) What is the formal charge on atoms N, C, and O respectively in the Lewis structure shown to the right?

- (a) N = 0; C = +1; O = -1                      (b) N = -1; C = +1; O = -1  
 (c) N = 0; C = 0; O = -1                      (d) N = -1; C = 0; O = 0

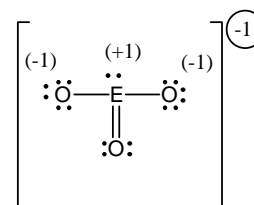


(7) The number of shared and unshared electrons pairs respectively, around the central bismuth atom in the  $BiI_4^{1-}$  ion are:

- (a) 4,0                      (b) 5,0                      (c) 5,1                      (d) 4,1

(8) Which atom could be E in this structure?

- (a) S                      (b) C                      (c) Br                      (d) P



- (9) A student needs a species with the following characteristics for a research project: +1 cation, contains four fluorine atoms and no other peripheral atoms, is polar, and has a fourth period element as its central atom. Which element provides these characteristics?
- (a) Br                      (b) As                      (c) Se                      (d) Ge
- (10) The resonance hybrid of the nitrite ion,  $\text{NO}_2^{1-}$ , has \_\_\_\_ pairs of localized (fixed) electrons and \_\_\_\_ pairs of delocalized (dispersed) electrons.
- (a) 7,2                      (b) 7,4                      (c) 9,2                      (d) 9,0
- (11) Which species obeys the Octet Rule?
- (a)  $\text{BeCl}_2$                       (b) NO                      (c)  $\text{NO}_2^{1-}$                       (d)  $\text{SF}_4$
- (12) What is the electron pair geometry (EPG) of  $\text{SnCl}_3^{1-}$ ?
- (a) trigonal planar                      (b) trigonal pyramid                      (c) square pyramid                      (d) tetrahedral
- (13) The molecular shape of  $\text{XeF}_3^{1-}$  is:
- (a) octaquadrangle                      (b) square planar                      (c) T-shaped                      (d) trigonal bipyramid
- (14) What is the smallest bond angle in degrees that exists for the molecule  $\text{OXeF}_2$ ? (Xe central)
- (a) 109                      (b) 120                      (c) 90                      (d) 180
- (15) Which molecule is polar?
- (a)  $\text{CCl}_4$                       (b)  $\text{BrF}_5$                       (c)  $\text{BF}_3$                       (d)  $\text{XeF}_4$
- (16) Which species has the weakest bond?
- (a)  $\text{O}_2^{2+}$                       (b)  $\text{O}_2^{1+}$                       (c)  $\text{O}_2^{1-}$                       (d)  $\text{O}_2$
- (17) According to MO theory which species is diamagnetic?
- (a)  $\text{O}_2^{2+}$                       (b)  $\text{O}_2^{1+}$                       (c)  $\text{O}_2^{1-}$                       (d)  $\text{O}_2$