CHEMISTRY 1A - Fall 2017
EXAM 2 - 100 points

Name Key

Part 1 Multiple Choice: Circle the letter on the exam that corresponds to the **one** best answer for each question below. 2 points each. Total: **40 points.**

1. Which of the following electromagnetic waves has the shortest wavelength?
A) microwaves B) infrared radiation C) radiowaves D) x-rays E) γ-rays

2. What is the energy of an electromagnetic wave that has a wavelength of 656 nm?
A) 3.03×10^{-17} J B) 4.68×10^{-17} J C) 3.03×10^{-19} J D) 4.68×10^{-19} J E) 3.03×10^{-21} J

3. Calculate the wavelength of a photon of light emitted when an electron travels from n=5 to n=2 orbital in a hydrogen atom.
A) 3.88×10^{-6} m B) 155 nm C) 434nm D) 486 nm E) 542 nm

4. The maximum total number of electrons that can be accommodated in a shell with n = 3 is:
A) 2 B) 8 C) 16 D) 18 E) 32

5. How many orbitals are contained in the fourth principal level ($n = 4$) of a given atom?
A) 4 B) 9 C) 12 D) 16 E) 32

6. Which of the following is **not** an allowed set of quantum numbers for an electron in an atom? (n, ℓ, m_ℓ, m_S)
A) (4,1,-1, ½) B) (3,-2,-2, ½) C) (3,1,0, -½) D) (4,2,2, -½) E) (3,2,0, -½)

7. Which of the following bonds is the **most polar**?
A) H–O B) H–S C) H–C D) H–P E) H–Cl

8. Which of the following molecule(s) has a net dipole moment?
I. CBr_4 II. $SeBr_4$ III. IBr_3 IV. $XeBr_4$
A) II only B) III only C) II and III D) III and IV E) II, III, and IV

9. According to valence bond theory, SCl_2, PH_3, SiF_4 all have sp^3 hybridization. Why do these molecules have different bond angles?

A) These molecules have different bond orders.
B) These molecules have different numbers of resonance structures.
C) The central atoms have different number of lone electron pairs.
D) The central atoms have different electronegativity.

10. Which element would have the following ionizations energies (kJ/mol)?
$I_1 = 578$, $I_2 = 1817$, $I_3 = 2745$, $I_4 = 11575$, $I_5 = 14830$, $I_6 = 18376$ $I_7 = 23293$

A) Si B) S C) Al D) Mg E) Na

11. Which electron **excitation** in a hydrogen atom requires the most energy?

A) 1s to 2p B) 2p to 3s C) 3p to 4d D) 5p to 6s E) 6d to 2p

12. Which of the following lists the species in order of **increasing ionic radius** (smallest to largest)?

A) $K^+ < Cl^- < Ca^{2+} < Ar$ B) $Cl^- < Ar < K^+ < Ca^{2+}$ C) $Ca^{2+} < K^+ < Cl^- < Ar$
D) $Ca^{2+} < K^+ < Ar < Cl^-$ E) $Ar < Cl^- < K^+ < Ca^{2+}$

13. Which of the following set of four quantum numbers (n, l, m_l, m_s) could designate an electron in 5p orbital?

A) 5, 0, 1, +1/2 B) 5, 0, 0, -1/2 C) 5, 2, 0, -1/2 D) 5, 1, 2, +1/2 E) 5, 1, -1, -1/2

14. Which of the following solids have the largest (most exothermic) lattice energy?

A) NaCl B) MgO C) CaO D) CaS E) MgS

15. For the elements Na, Al, P, and Cl, the first ionization energy increases (smallest to largest) in the order:

A) Na < Al < P < Cl B) Na < Al < Cl < P C) Al < Na < Cl < P
D) Cl < P < Al < Na E) P < Cl < Na < Al

Na Al P Cl
496 578 1012 1251

16. Which of the following molecules/ions would have the smallest bond angle between terminal atoms?

A) SO_2 B) SO_3 C) CO_2 D) NO_3^- E) H_2O
119° 120° 180° 120° 104.5°

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17. Which of the following species is paramagnetic?

A) Ca^{2+} B) Ti^{2+} C) Pb^{2+} D) Cl^- E) Ar

Use Molecular Orbital Theory and/ or refer to the Molecular Orbital Diagram for questions 18 – 20.

18. Which of following will be paramagnetic?

A) O_2^{2+} B) B_2^{2-} C) F_2 D) N_2^{2-} E) none of these, all of them are diamagnetic.

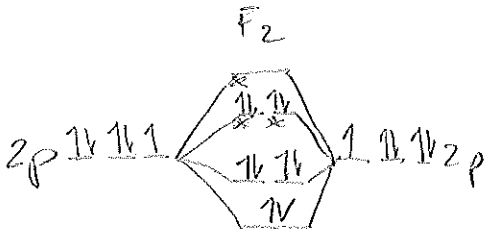
19. Which of the following has the set of molecules correctly arranged in order of increasing bond length (shortest to longest bond length)?

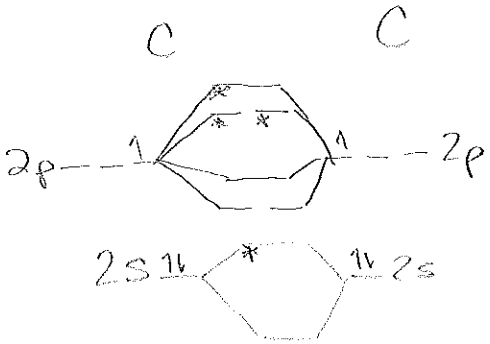
A) $C_2^+ < C_2 < C_2^-$ B) $C_2^- < C_2 < C_2^+$ C) $C_2^- < C_2^+ < C_2$
D) $C_2 < C_2^+ < C_2^-$ E) ~~$C_2 < C_2^- < C_2^+$~~

20. Arrange the following in terms of increasing bond order (smallest bond order to largest bond order).

C_2^{2-}, F_2, Be_2^+, N_2^{2+}

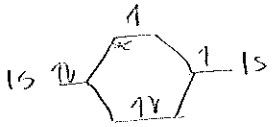
A) $Be_2^+ < F_2 < N_2^{2+} < C_2^{2-}$ B) $C_2^{2-} < N_2^{2+} < F_2 < Be_2^+$ C) $F_2 < Be_2^+ < C_2^{2-} < N_2^{2+}$
D) $N_2^{2+} < F_2 < C_2^{2-} < Be_2^+$ E) They all have the same bond order





C_2^{2-} BO: $\frac{8-2}{2} = 3$ N_2^{+2} BO: $\frac{6-2}{2} = 1$

Be_2^+ BO: $\frac{2-1}{2} = \frac{1}{2}$ F_2 BO: $\frac{8-6}{2} = 1$



C_2 BO: $\frac{6-2}{2} = 3$ Shortest to largest

C_2^+ BO: $\frac{5-2}{2} = 1.5$ (1) 3

C_2^- BO: $\frac{7-2}{2} = 2.5$ (2)

$C_2^+ < C_2^- < C_2$

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Part II: Short Answers; Total = 60 points.

1. Demonstrate your knowledge of electron configurations by drawing orbital diagrams for the following elements or ions. You may abbreviate by using the noble gas core. Label all orbitals. (8 points)

Example: Li = [He] $\underset{2s}{\boxed{\uparrow}}$

A) P

[Ne] $\underset{3s}{\uparrow\downarrow}$ $\underset{3p}{\uparrow\ \uparrow\ \uparrow}$

B) Pt

[Xe] $\underset{6s}{\uparrow\downarrow}$ $\underset{4f}{\uparrow\downarrow\ \uparrow\downarrow\ \uparrow\downarrow\ \uparrow\downarrow\ \uparrow\downarrow\ \uparrow\downarrow\ \uparrow\downarrow}$ $\underset{5d}{\uparrow\downarrow\ \uparrow\downarrow\ \uparrow\downarrow\ \uparrow\downarrow\ \uparrow}$

C) Ag

[Kr] $\underset{5s}{\uparrow\downarrow}$ $\underset{4d}{\uparrow\downarrow\ \uparrow\downarrow\ \uparrow\downarrow\ \uparrow\downarrow\ \uparrow\downarrow}$

D) Zn^{2+}

[Ar] $\underset{4s}{\ }$ $\underset{3d}{\uparrow\downarrow\ \uparrow\downarrow\ \uparrow\downarrow\ \uparrow\downarrow\ \uparrow\downarrow}$

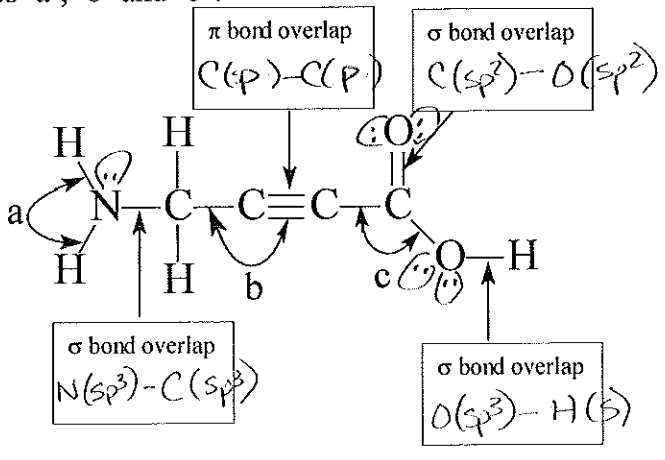
2. For the molecule given below:
A) All atoms in the molecule given below have zero formal charge.
Show the lone pair electrons on both the oxygen atoms and nitrogen atom.

B) Write which hybrid orbitals overlap to form the bonds in the four boxes.

C) What are the approximate values for bond angles 'a', 'b' and 'c'?

a = 109.5°; b = 180°; c = 120°

(8 points)



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3. Consider the polyatomic ion, ClO_3^-. (8 points)

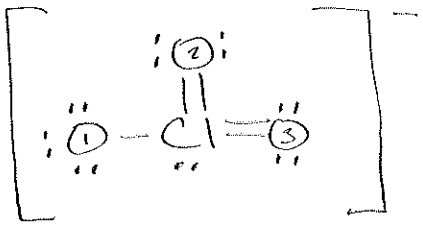
A) Draw the lewis structure of ClO_3^- including all resonance structures (where the octet is satisfied for all atoms and also structures with expanded octets).

B) Show all non-zero formal charges on the atoms in all structures.

C) Circle the most stable resonance structure(s).

D) What is the bond order of the chlorine oxygen bond for the most stable resonance structure(s) identified in part C)?

A) $7 + 6(3) + 1 = 26$ ve⁻

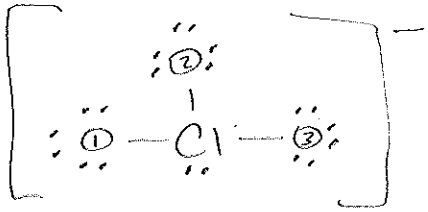


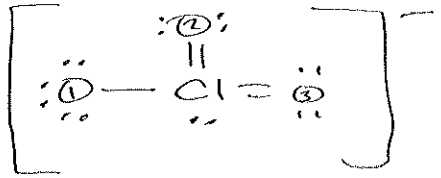
FC: Ve⁻ − NBe⁻ − ½ Be⁻

Cl 7 − 2 − 5 = 0

O_1 6 − 6 − 1 = −1

$O_{2\&3}$ 6 − 4 − 2 = 0





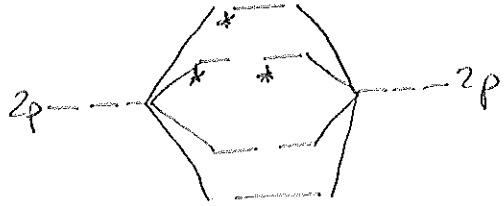
most stable

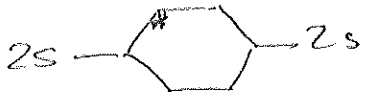
FC: Ve⁻ − NBe⁻ − ½ Be⁻

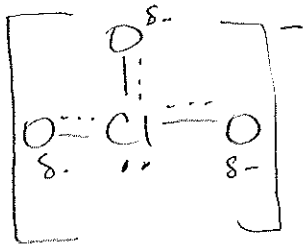
Cl 7 − 2 − 3 = +2

$O_{1,2,3}$ 6 − 6 − 1 = −1, −1, −1 → −1 but +2 charge on Cl not the most stable.

Bond order



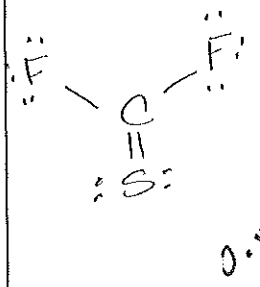
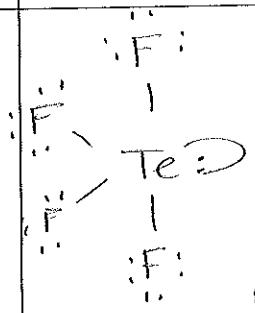
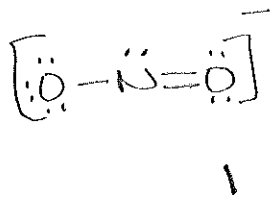
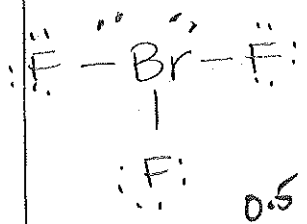




B.O. = 5/3

Cl–O 5 bonds to Cl split over 3 O's

4. Fill in the table below. 1) Draw the Lewis Dot structures for each molecule or ion. 2) Write the name that best describes the electron domain shape or electron geometry. 3) Write the name that best describes the molecular shape. 4) Identify **all** relevant bond angles. 5) Indicate whether the molecule is polar (P) or nonpolar (N). **Note: No credit will be given if the dot structure is incorrect**. (16 points)

	Lewis Structure	Electron Domain Shape Name	Molecular Shape Name	Bond Angle(s)	Polarity
CF_2S	 0.5	trigonal planar	Trigonal Planar	120°	P
TeF_4	 0.5	Trigonal bipyramidal	See saw	Ax: 120° Eq: 90°	P
NO_2^-	 1	trigonal planar	Bent	>120°	
BrF_3	 0.5	trigonal bipyramidal	T-Shape	90°	P

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Part III- Show a complete and logical method of solving the problem. Make sure all numbers are labeled with the appropriate units and significant figures. Place answer in the lines or box provided. Total = 10 points

5. Calculate the lattice energy of $MgCl_{2(s)}$ from the data given below:

* $Cl_2(g) \rightarrow Cl(g)$ (242 kJ/mol)

Given reactions:	
Heat of formation of magnesium chloride	ΔH = -642 kJ/mol
First electron affinity of chlorine	ΔH = -349 kJ/mol
Heat of sublimation of magnesium	ΔH = 146 kJ/mol
First ionization energy of magnesium	ΔH = 738 kJ/mol
Second ionization energy of magnesium	ΔH = 1451 kJ/mol
Bond dissociation energy of Cl_2	See table on page 2

Use the Born-Haber cycle or Hess's law to calculate the lattice energy of magnesium chloride. Your set-up must show all the chemical equations in each step of the Born-Haber cycle or Hess's law and you must show how their ΔH values add up to give your answer.

$2x\left(\Delta H_{aff} = -349 \text{ kJ/mol}\right)$

$Mg^{+2}(g) + 2Cl(g) \longrightarrow Mg^{+2}(g) + 2Cl^-(g)$

$\uparrow \Delta H_{DISS} = 242$ kJ/mol *

$Mg^{+2}(g) + Cl_2(g)$

$\uparrow \Delta H_{ion} = 1451$ kJ/mol

$Mg^{+}(g) + Cl_2(g)$

$\uparrow \Delta H_{ion} = 738$ kJ/mol

$Mg(g) + Cl_2(g)$ $\Delta H_{sub} = 146$ kJ/mol

$\uparrow$

$Mg(s) + Cl_2(g) \longrightarrow MgCl_2(s)$

$\Delta H_{form} = -642$ kJ/mol

LE = ΔH ?

ΔH_f = steps 1 + 2 + 3 + 4 + 5 + (6) LE

$-642 = 146 \text{ kJ/mol} + 738 \text{ kJ/mol} + 1451 \text{ kJ/mol} + 242 \text{ kJ/mol} + [2x - 349] + LE$

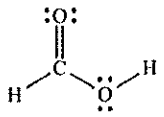
$LE = -2521$ kJ/mol

-2521 kJ/mol

6. A) Use bond energies given in Table on page 2 to calculate the ΔH (in kJ/mol) for the following reaction. (Hint: Draw all Lewis structures before doing calculations)

$2\ HCOOH + O_2 \rightarrow 2CO_2 + 2H_2O$

Lewis structure of HCOOH =

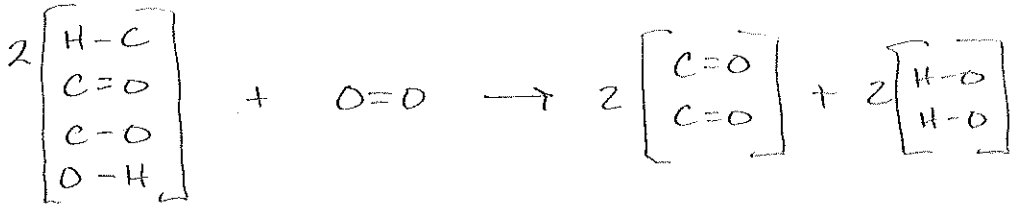


B) Is the reaction exothermic or endothermic? Exothermic

(6 points)

Formed
↳ ΔH < 0

Broken
ΔH > 0



$$\left[2(413+799+358+495)+495\right]+\left[\left(2(-799)\right)+\left(2(-799)\right)+\left(2(-463)\right)+\left(2(-463)\right)\right]$$

4561 − 5048 =

−487 kJ/mol

7. What is the minimum frequency of a photon needed to break a carbon chlorine (C-Cl) bond? (4 points)

C − Cl → 328 kJ/mol $E = h\nu$

$$E = \frac{328\ kJ/mol}{6.024\times10^{23}/mol}\times\frac{10^3\ J}{1\ kJ} = 5.44\times10^{-19}\ J\ \text{per bond}$$

$$\nu = \frac{5.44\times10^{-19}\ J}{6.63\times10^{-3}\ J\cdot s} = 8.21\times10^{14}\ s^{-1}$$

$8.21\times10^{14}\ s^{-1}$