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Honor Code:

- You are permitted to use your lecture notes and your textbook
- You may use any calculator for calculations. You may also use Wolfram alpha, symbolab, or other similar online calculators *only for the purpose of solving algebraic expressions.*
- You may not use your calculator for internet searches or communication with others.
- You are permitted to use the internet only to access your textbook, online calculators, and Canvas (for the purpose of submission only).
- You may not perform any internet searches to answer questions, nor may you submit any portion of the exam to any online help sources such as (but not limited to) Chegg or Course Hero.
- You may not collaborate with any other person (in person or electronically) on any portion of the exam, including general discussion of exam question topics prior exam submission by all parties.
- You may not screen capture or otherwise record the questions on this exam.
- All work submitted for this exam must be your own.

Signature: _____

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Question 1: True/False question (**12 points**) (2point each)

a. F Photons of ultraviolet radiation have less energy than photons of infrared radiation.
b. F Quantum mechanical model of the atom treats electrons as particles.
c. T Within a shell, a d subshell is higher in energy than a p subshell.
d. _____ If there are unequivalent resonance structures for a given molecule, then the one that is the greatest contributor to the resonance hybrid is the lowest energy structure.
e. F According to Slater's rules, valence electrons do not contribute at all to the value of *S* (shielding)
f. T The kinetic-molecular theory describes that when molecules collide their collisions are elastic.

Question 2: Multiple choices, multiple answers (**12 points**)

A. Rank the bonds in order of *increasing* ionic character.
S-F
S-O
N-Cl
O-Cl

☐ i. S-F < S-O < O-Cl < N-Cl
☐ ii. N-Cl < O-Cl < S-O < S-F
☐ iii. N-Cl < S-O < O-Cl < S-F
☐ iv. S-F < O-Cl < S-O < N-Cl
☐ v. O-Cl < S-O < N-Cl < S-F

B. Which of the following molecules in the gas phase will have the slowest rate of effusion?

☐ i. F_2 at 315 K
☑ ii. Br_2 at 298 K
☐ iii. CO_2 at 310 K
☐ iv. CH_4 at 325 K

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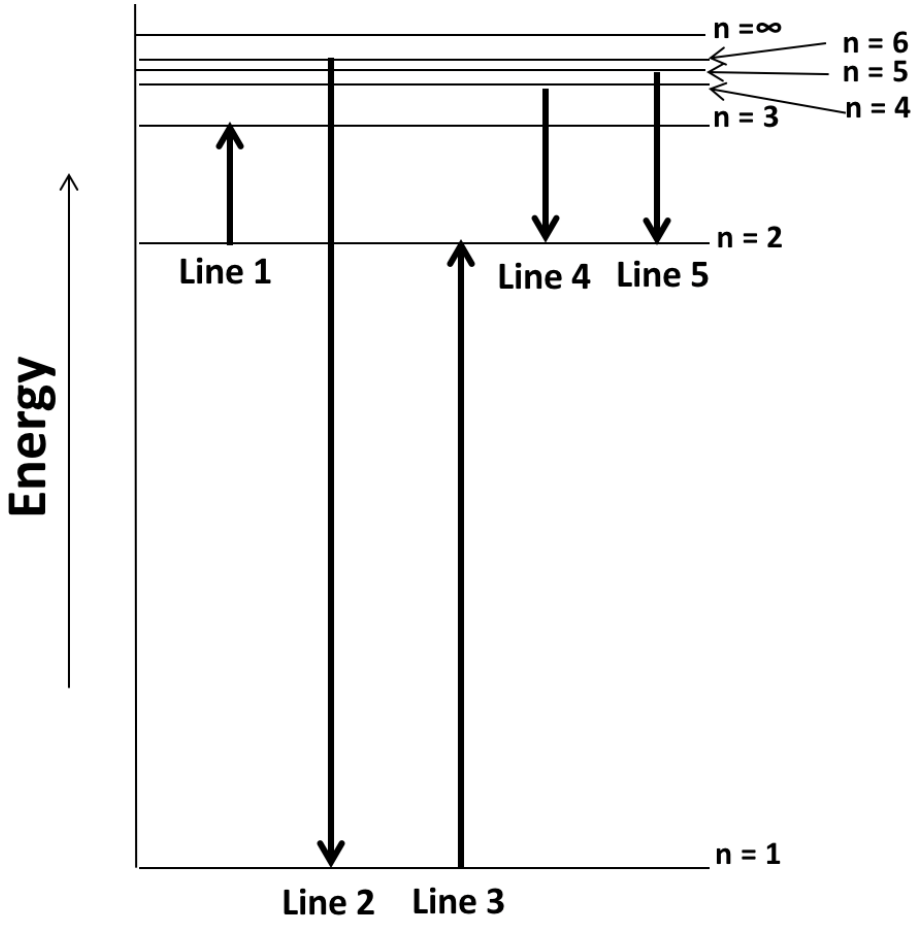
C. Which statement(s) is(are) true regarding the emission spectrum below? Select all that apply.



☐ i. Lines 1 and 3 represent emission and lines 2, 4, and 5 represent absorption.
☐ ii. The line associated with the longest wavelength is line 2.
☑ iii. The frequency associated with line 5 is greater than that associated with line 4.
☑ iv. The wavelength associated with line 3 is shorter than that associated with line 1.
☑ v. The photon of light associated with line 4 is more energetic than that associated with line 1.

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Question 3. What is the partial pressure of CO(g) that results when 7.00 g of C(s) reacts with 1.00 atm of O2(g) in a 4.00 L container at 47°C? The final temperature and volume of the container are 70 °C and 6.00 L. You must show your work. **(10 points)**

Molar masses (in g/mol): C = 12.01; O2 = 32.00; CO = 28.01

$2\ C(s) + O2(g) \rightarrow 2\ CO(g)$

Pi = 2.735 atm

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Question 4: A given photon of light has wavelength λ= 488 nm. How many **moles** of these photons are required to produce 50 kJ of energy? You must show work for partial credit **(8 points)**

.2038 moles

Question 5:

A. Draw out the Lewis electronic structures of CO_2, H_2O and O_2. **(6 points)**

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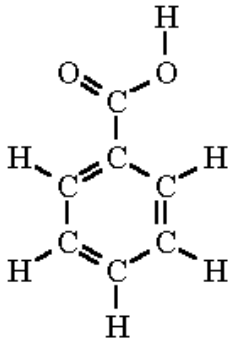
B. From the bond dissociation energies given in the table below, give your best estimate of the standard state combustion enthalpy of Benzoic Acid at 298 K. **(8 points)**

$$2\ C_6H_5COOH + 15O_2 \rightarrow 14CO_2 + 6H_2O$$

Structure of Benzoic Acid:



Bond	Average Bond Energy (kJ/mol)
H—H	436
H—C	414
H—O	464
C—C	347
C=C	611
C—O	360
C=O	799
O—O	142
O=O	498

SKIP

C. Is the reaction exothermic of endothermic? **(2 points)**

Skip

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Question 6: Draw the Lewis structure for the +1 charged polyatomic ion with four hydrogen atoms and a group 15 (or 5A) atom as the central atom (may be denoted as X). Then, answer prompts B-D. **(10 points)**

A. Lewis structure

B. What is the electron geometry for the structure?

C. What is the molecular geometry for the structure?

D. List the *ideal* bond angles for the structure

E. Is the structure polar or nonpolar

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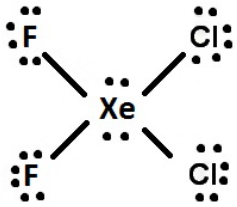
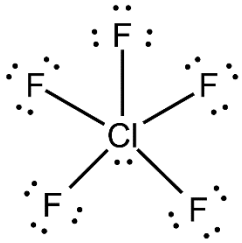
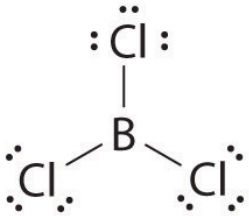
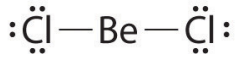
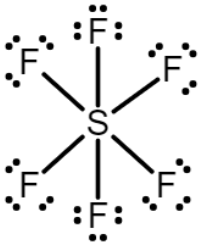
Question 7. Label each molecule as polar or nonpolar based on the Lewis structures. **(18 points)**

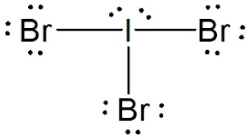


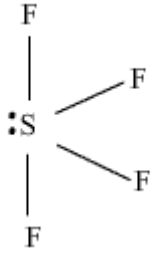


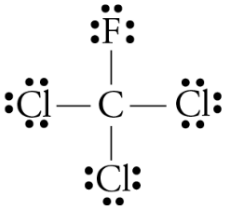


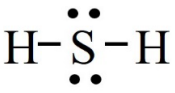












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Question 8. Nitric oxide (NO), which contributes to the natural acidity of rainwater, is formed during lightning storms by the reaction of nitrogen (N_2) and oxygen (O_2). In air, NO is oxidized to nitrogen dioxide (NO_2), which in turn reacts with water to give nitric acid (HNO_3). Calculate ΔH^o_{rxn} for the reaction of $N_2(g)$, $O_2(g)$ and water to form HNO_3 using the thermochemical equations shown below. You must show your work. **(10 points)**

$2N_2(g) + 5O_2(g) + 2H_2O(l) \rightarrow 4HNO_3\ (aq)$

$N_2\ (g) + O_2\ (g) \rightarrow 2NO(g)$ ΔH^o_{rxn}= 180kJ

$2\ NO\ (g) + O_2\ (g) \rightarrow 2NO_2(g)$ ΔH^o_{rxn}= -114kJ

$3\ NO_2\ (g) + H_2O\ (\ell) \rightarrow 2\ HNO_3(aq) + NO(g)$ ΔH^o_{rxn}= -138kJ

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Question 9. Explain how the periodic trends in atomic radii and first ionization energy are related to one another *and* how they relate to effective nuclear charge (2-4 sentences). **(6 points)**

Question 10. Write the complete ground-state electron configuration for the period 4 transition metal with five valence electrons, and then use it to answer prompts B-D.

A. Complete ground-state electron configuration **(2 points)**

B. Determine the number of unpaired electrons in the ground-state electron configuration **(2 points)**

C. Draw an image that depicts the shape of an orbital in the highest energy subshell that is occupied. **(2 points)**

D. What is the total number of unpaired electrons when the element forms a +2 cation? **(2 points)**

E. Write a complete set of quantum numbers that could describe the last electron in the ground-state electron configuration for this element. **(6 points)**

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Question 11. Lithium reacts intensely with water, forming lithium hydroxide and highly flammable hydrogen. In the lab calculate the amount of lithium in microgram (μg) was used to form 20mL of H_2, at 25℃, 1atm. (**10 points**)

$2\ Li(s) + 2\ H_2O \rightarrow 2\ LiOH(aq) + H_2(g)$

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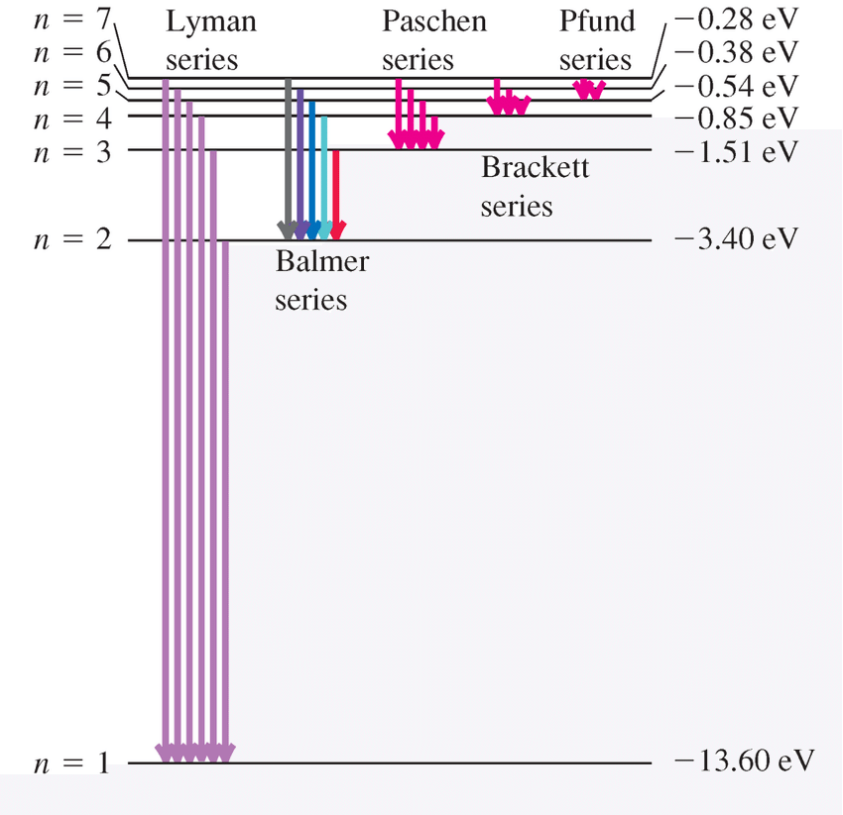
Question 12: The Balmer series of Hydrogen spectrum was measured in the lab. From the quantum chemistry experiment we also learnt that we can associate each transition with a change in energy ΔE. The wavelength of light observed when an emissive transition occurs reflects ΔE and the definition of the energy of the photon.

$$\Delta E = E(n_f) - E(n_i) = -\frac{hc}{\lambda}$$

Using the above equation and the provided energy level. Prove that the four visible colors in Balmer theory is RED, GREEN, BLUE, and VIOLET **(12 points)**

Note: 1eV= 1.60218×10^{-19}J



Question 13. Using principles of the kinetic molecular theory, explain why gases behave less ideally at higher pressures and lower temperatures. Keep your answer brief (2-3 sentences maximum). **(6 points)**

Question 14. Using principles of the kinetic molecular theory, explain why gases behave less ideally at higher pressures and lower temperatures. Keep your answer brief (2-3 sentences maximum). **(6 points)**