

General Instructions: Read each question carefully and express your answers in the expected format, using proper English grammar and punctuation. Show *all* of your work for *all* calculation problems and include units on answers where appropriate. Express your answers in the correct number of significant figures. To speed calculations, round all atomic weights to one decimal place.

Part A. Definitions (2 points each). Define each term or differentiate between the pairs of terms.

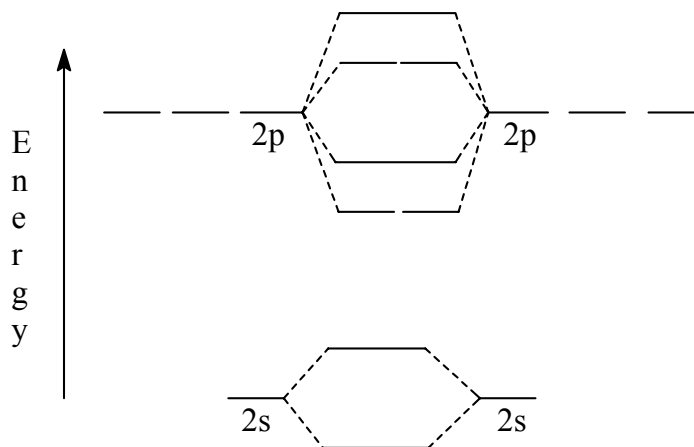
1.  $sp^3$  hybrid atomic orbital –
2. \_\_\_\_\_ is when an atom has unpaired electron(s) and is weakly attracted to magnetic fields.
3. \_\_\_\_\_ is the temperature above which gas cannot be compressed to liquid.
4. sigma bond –
5. enthalpy of fusion –
6. bond order –
7. bonding vs. antibonding orbital –
8. intermolecular vs. intramolecular forces –
9. normal boiling point vs. boiling point –
10. ionic solid vs. molecular solid –

Part B Short answer

11. Hybridization does not depend on elements involved. If the empirical formula of a fictitious compound is  $MyWi_5$ , and all bond lengths are equal in length and reactivity, what

hybridization does the compound display? Sketch the compound according to the VSEPR model (as accurately as possible) and specify its molecular geometry. (10 points)

12. Making the simplifying assumption that the molecular orbitals for a compound are as follows, draw the atomic and molecular orbitals of  $F_2$ . Is this molecule expected to be paramagnetic or diamagnetic? (10 points)



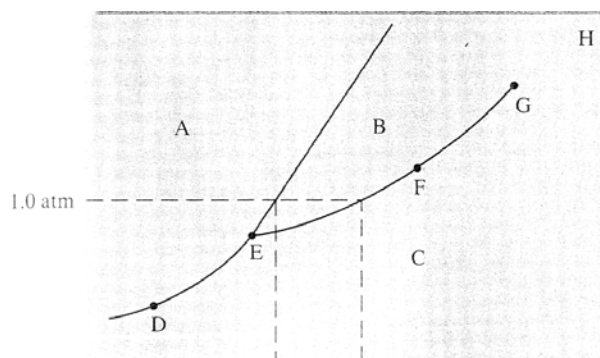
13. Using two *different* molecules of your choice, show how they would be held together by hydrogen bonding, and use that diagram to explain what hydrogen bonding is. (10 points)

14. Given the following molecules arranged in alphabetical order, rank them in order of increasing melting point:  $\text{CH}_3\text{CH}_2\text{OH}$ ,  $\text{CH}_2\text{O}$ ,  $\text{CO}_2$ , Ne

lowest melting point \_\_\_\_\_ highest melting point. (4 points)

15. On exam three, I used the question “If 5.0 kJ of energy is added to a 10.0-g sample of water at  $10.^\circ\text{C}$ , the water is \_\_\_\_\_” Show that the correct answer was “boiling”. The enthalpy of fusion is 0.33 kJ/g, the enthalpy of vaporization is 2.26 kJ/g, and specific heat is  $4.18 \text{ J/g}^\circ\text{C}$ . (6 points)

16. Consider the phase diagram given here.  
What phases are present at points A through H?



A-

B-

C-

D-

E-

F-

G-

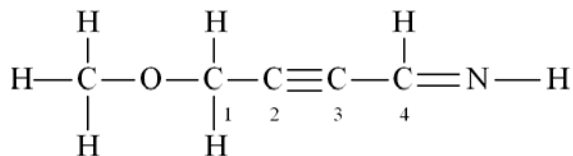
H-

Identify the triple point, normal boiling point, normal freezing point, and critical point. (5 points)

17. Iridium (Ir) has a face-centered cubic (fcc) unit cell with an edge length of 383.3 pm. Calculate the density of iridium. (5 points)

Part C. Multiple choice (3 points each) Place the *capital* letter of the *best* answer in the blank to the left of the answer.

- \_\_\_\_\_ 20. In the molecule  $C_2H_4$  the valence orbitals of the carbon atoms are assumed to be  
 A) not hybridized.  
 B)  $sp$  hybridized.  
 C)  $sp^2$  hybridized.  
 D)  $sp^3$  hybridized.  
 E)  $dsp$  hybridized.
- \_\_\_\_\_ 21. Atoms which are  $sp$  hybridized form \_\_\_\_\_ pi bond(s).  
 A) 0  
 B) 1  
 C) 2  
 D) 3  
 E) 4
- \_\_\_\_\_ 22. Consider the following Lewis structure:



What is the hybridization of the oxygen atom and carbon atoms 1, 2, and 4, respectively?

- |           | O      | C-1    | C-2    | C-4    |
|-----------|--------|--------|--------|--------|
| Option 1: | $sp^3$ | $sp^3$ | $sp$   | $sp^2$ |
| Option 2: | $sp$   | $sp^3$ | $sp$   | $sp$   |
| Option 3: | $sp$   | $sp^2$ | $sp$   | $sp^2$ |
| Option 4: | $sp^2$ | $sp^3$ | $sp^2$ | $sp^3$ |
| Option 5: | $sp$   | $sp^3$ | $sp^2$ | $sp$   |
- A) Option 1  
 B) Option 2  
 C) Option 3  
 D) Option 4  
 E) Option 5

- \_\_\_\_\_ 23. In which of the following groups of substances would London dispersion forces be the *only* significant factors in determining boiling points?
- I.  $\text{Cl}_2$                       II.  $\text{HF}$                       III.  $\text{Ne}$   
IV.  $\text{KNO}_2$                       V.  $\text{CCl}_4$
- A) I, III, V  
B) I, II, III  
C) II, IV  
D) II, V  
E) III, IV, V
- \_\_\_\_\_ 24. Which of the following molecules has a bond order of 1.5?
- A)  $\text{O}_2^+$   
B)  $\text{N}_2$   
C)  $\text{O}_2^-$   
D)  $\text{C}_2$   
E) none of these
- \_\_\_\_\_ 25. Which of the following statements are *incorrect*?
- A) Diamond is a covalent crystal.  
B) The size of the unit cell of Li and the unit cell of Cs is the same.  
C) Molecular crystals usually have low melting points.  
D) Metallic crystals are usually good electrical conductors.  
E) All of the statements A through D are correct.
- \_\_\_\_\_ 26. In any cubic lattice an atom lying at the corner of a unit cell is shared equally by how many unit cells?
- A) 1  
B) 2  
C) 4  
D) 8  
E) 16
- \_\_\_\_\_ 27. The process of evaporation happens when which of the following occurs?
- A) A solid becomes a liquid.  
B) A liquid becomes a solid.  
C) A liquid becomes a gas.  
D) A gas becomes a liquid.  
E) A solid becomes a gas.

- \_\_\_\_\_ 28. A metal crystallizes with a face-centered cubic lattice. The edge of the unit cell is 408 pm. The diameter of the metal atom is:
- A) 144 pm
  - B) 204 pm
  - C) 288 pm
  - D) 408 pm
  - E) none of these
- \_\_\_\_\_ 29. Steel is considered to be a(n) \_\_\_\_\_.
- A) interstitial alloy
  - B) ionic solid
  - C) molecular solid
  - D) substitutional alloy
  - E) more than one of these