

**UNIVERSITY OF VICTORIA**

**CHEMISTRY 101**

**From Atoms to Materials**

**CRN: 10492, 10493, 10494**

**Instructors: T. Jarisz, S. McIndoe**

Display your student ID card on the right hand corner of your desk.

Do not begin until instructed by the invigilator.

Print and code your last name, first name, and your student ID number on the back of this exam booklet and on the blue bubble sheet. Sign the bubble sheet and exam.

This test has 72 multiple choice questions on 16 pages.

The only calculator permitted for the final exam is the Sharp EL510.

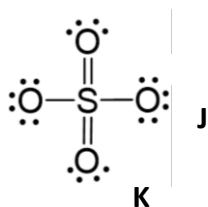
Select the best response for each question and record your answer on the blue bubble sheet.

The exam and the blue bubble sheet must be submitted at the end of the exam.

A Data Sheet is provided.

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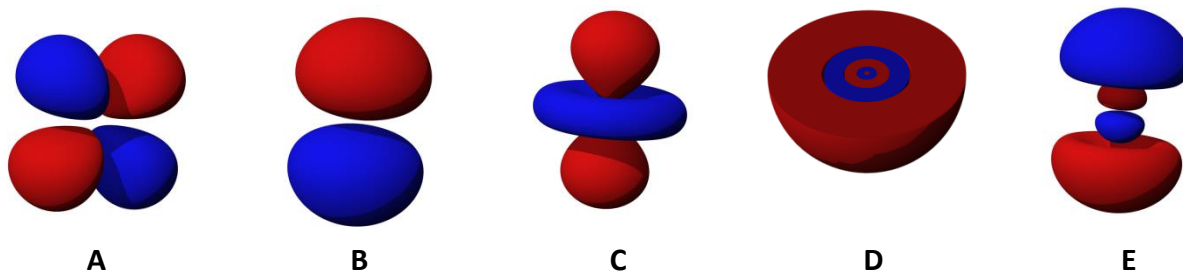
1. The principle quantum number specifies the electron shell, while the angular momentum quantum number specifies subshell. How many subshells and how many orbitals are there in the  $n = 3$  shell?
  - a. 2 subshells; 4 orbitals
  - b. 2 subshells; 9 orbitals
  - c. 3 subshells; 9 orbitals
  - d. 3 subshells; 4 orbitals
  - e. 0 subshells; 1 orbital
2. Which of the following statements regarding the photoelectric effect is INCORRECT?
  - a. If a photon of green light (510 nm) causes an electron to be ejected, so will a photon of blue light (450 nm).
  - b. If the energy of an incoming photon is above a certain threshold, an electron will be ejected from a metal with some kinetic energy that is inversely proportional to the wavelength of the photon.
  - c. Once enough photons of varying energies have been absorbed by a metal, an electron is ejected.
  - d. When a photon of sufficient energy is absorbed by a metal, an electron is ejected.
  - e. The photoelectric effect provides evidence that energy is quantized.
3. In the Lewis Structure for  $[\text{SO}_4]^{2-}$  shown below, what are the formal charges on sulfur (S), the oxygen labeled J, and the oxygen labeled K?



- a. S: -1, J: 0, K: -1
  - b. S: +1, J: -1, K: 0
  - c. S: 0, J: +1, K: -1
  - d. S: 0, J: -1, K: 0
  - e. S: 0, J: 0, K: -1
4. What is the wavelength (in nm) of an X-ray photon that has an energy of  $3.3 \times 10^{-16}$  J?
    - a.  $6.0 \times 10^{-10}$
    - b.  $1.6 \times 10^9$
    - c.  $2.2 \times 10^{-12}$
    - d. 0.60
    - e. 650

5. What is the energy change (in J) associated with the electronic transition from  $n = 3$  to  $n = 7$  in the hydrogen atom?
- $2.20 \times 10^{-20}$
  - $2.20 \times 10^{-18}$
  - $1.98 \times 10^{-19}$
  - $-1.98 \times 10^{-19}$
  - $4.15 \times 10^{-19}$
6. How many angular nodes exist in a  $4f$  atomic orbital?
- 0
  - 1
  - 2
  - 3
  - 4

Below are some depictions of atomic orbitals. Questions 7 and 8 refer to these pictures.



7. Which orbital(s) has/have a value of 1 for  $\ell$ ?
- A and C only
  - D only
  - C only
  - B only
  - B and E only
8. Which orbital has no node at the nucleus?
- A
  - B
  - C
  - D
  - E
9. Which of the following sets of quantum numbers describes a valence electron of Ca?
- $n = 3, \ell = 2, m_\ell = 0, m_s = 1/2$
  - $n = 4, \ell = 1, m_\ell = -1, m_s = 1/2$
  - $n = 3, \ell = 0, m_\ell = 0, m_s = -1/2$
  - $n = 4, \ell = 0, m_\ell = 0, m_s = 1/2$
  - $n = 4, \ell = 2, m_\ell = 2, m_s = 1/2$

10. In the isoelectronic series:  $F^-$ ,  $Na^+$ ,  $O^{2-}$ , and  $Mg^{2+}$ , which ion is expected to have the *smallest* ionic radius in the gas phase?

- a.  $O^{2-}$                       b.  $F^-$                       c.  $Na^+$                       d.  $Mg^{2+}$                       e. They are all the same size

11. Which of the following ions has 3 unpaired electrons?

- a.  $Ni^+$                       b.  $Cl^+$                       c.  $Cr^{2+}$                       d.  $Pb^{2+}$                       e.  $S^{2-}$

12. Which of the following equations describes an atom's or ion's electron affinity?

- a.  $Mg(g) \rightarrow Mg^+(g) + e^-$   
b.  $Na(s) - e^- \rightarrow Na^+(g)$   
c.  $Na^+(s) + Cl^-(g) \rightarrow NaCl(s)$   
d.  $Br(g) + e^- \rightarrow Br^-(g)$   
e.  $H^+(g) + OH^-(g) \rightarrow H_2O(l)$

13. Which of the following atoms has the *smallest* first ionization energy?

- a. Be                      b. Cs                      c. Ca                      d. Pb                      e. Ge

14. Effective nuclear charge ( $Z_{eff}$ ) increases from left to right across the periodic table because

- a. the number of valence electrons increases.  
b. the number of protons in the nucleus increases, and the electrons added do not shield each other effectively.  
c. the number of neutrons in the nucleus increases.  
d. *d* and *p* orbitals become more occupied with electrons.  
e. the charge on the atom increases.

15. Which electron configuration is INCORRECT for the ground state atom listed?

- a.  $Mg = [Ne] 3s^2$   
b.  $Ge = [Ar] 4s^2 3d^{10} 4p^2$   
c.  $Br = [Ar] 4s^2 3d^{10} 3p^5$   
d.  $Ta = [Xe] 6s^2 4f^{14} 5d^3$   
e.  $Zr = [Kr] 5s^2 4d^2$

16. The nitrate ion  $[\text{NO}_3]^-$  has 3 resonance structures. Which of the following statements about the *real* nitrate ion (i.e. the resonance hybrid) is CORRECT?

- a. All three N-O bonds are single bonds.
- b. All three N-O bonds are double bonds.
- c. One N-O bond is a double bond and the other two are single bonds.
- d. All three N-O bonds are the same length.
- e. The O-N-O bond angles are all  $109^\circ$

17. How many pairs of bonding electrons (lines) are drawn in the BEST Lewis structure for  $[\text{PO}_4]^{3-}$ ?

- a. 3
- b. 4
- c. 5
- d. 6
- e. 7

18. What is the molecular shape for  $\text{BrF}_5$ ?

- a. Square pyramidal
- b. See-saw
- c. Trigonal pyramidal
- d. Trigonal bipyramidal
- e. Octahedral

19. Which of the following ionic compounds has the greatest lattice energy?

- a.  $\text{Na}_2\text{O}$
- b.  $\text{MgCl}_2$
- c.  $\text{NaCl}$
- d.  $\text{LiCl}$
- e.  $\text{MgO}$

20. Which of the following bonds is the most polar (has the greatest dipole moment)?

- a. N-N
- b. C-O
- c. C-Br
- d. C-I
- e. C-S

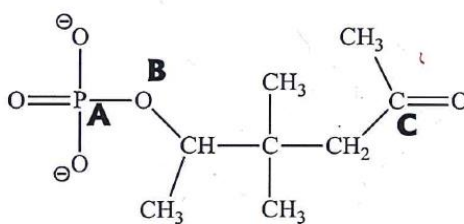
21. Which of the following molecules is polar?

- a.  $\text{AlCl}_3$
- b.  $\text{CF}_4$
- c.  $\text{KrF}_4$
- d.  $\text{BrCl}_3$
- e.  $\text{CO}_2$

22. Which of the following statements about covalent bonds is INCORRECT?

- a. Bond enthalpies are positive because breaking bonds is an endothermic process.
- b. Multiple bonds are stronger than single bonds.
- c. The enthalpy of a reaction can be estimated using the sum of the enthalpies of bonds broken, minus the sum of the enthalpies of bonds formed.
- d. Covalent bonds are stronger than ionic bonds.
- e. Bonds between atoms with an electronegativity difference of around 1.0 are polar covalent bonds.

23. Consider the following molecule, in which lone pairs are not shown. What is the approximate P-O-C bond angle at the oxygen atom labeled **B**?



- a. 120°
- b. 109°
- c. 90°
- d. 180°
- e. 60°

24. A tellurium (Te) atom has 52 electrons. Electrons in the \_\_\_\_\_ subshell experience the lowest effective nuclear charge.

- a. 1s
- b. 4d
- c. 3d
- d. 5s
- e. 5p

25. Which of these descriptors does NOT apply to a gas?

- a. Total disorder
- b. Much empty space
- c. Slow diffusion
- d. Compressible
- e. Particles moving rapidly

26. In the liquid phase, which of these compounds does not exhibit hydrogen bonding with another molecule of the same compound?

- a. Ethanol, C<sub>2</sub>H<sub>5</sub>OH
- b. Ammonia, NH<sub>3</sub>
- c. Difluoromethane, CH<sub>2</sub>F<sub>2</sub>
- d. Butanol, C<sub>4</sub>H<sub>9</sub>OH
- e. Putrescine, H<sub>2</sub>N(CH<sub>2</sub>)<sub>4</sub>NH<sub>2</sub>

27. Which of these properties is unaffected by intermolecular forces?

- a. Boiling point
- b. Melting point
- c. Vapour pressure
- d. Viscosity
- e. Polarity

28. What is the correct order of boiling points for these compounds if they all have approximately the same molecular weight?

- a. Alkane > alcohol > ether > carboxylic acid
- b. Carboxylic acid > alcohol > alkane > ether
- c. Carboxylic acid > alcohol > ether > alkane
- d. Ether > alcohol > carboxylic acid > alkane
- e. Alcohol > carboxylic acid > alkane > ether

29. Which force is primarily responsible for the ability of ionic compounds to dissolve in polar solvents?

- a. Ion-dipole interactions
- b. London dispersion forces
- c. Dipole-dipole interactions
- d. Hydrogen bonding
- e. Covalent bonding

30. Which of the following molecules would you expect to have the LOWEST boiling point?

- a. 2,2-dimethylpropane
- b. 3-methylpentane
- c. 2-methylbutane
- d. 2,2-dimethylbutane
- e. Pentane

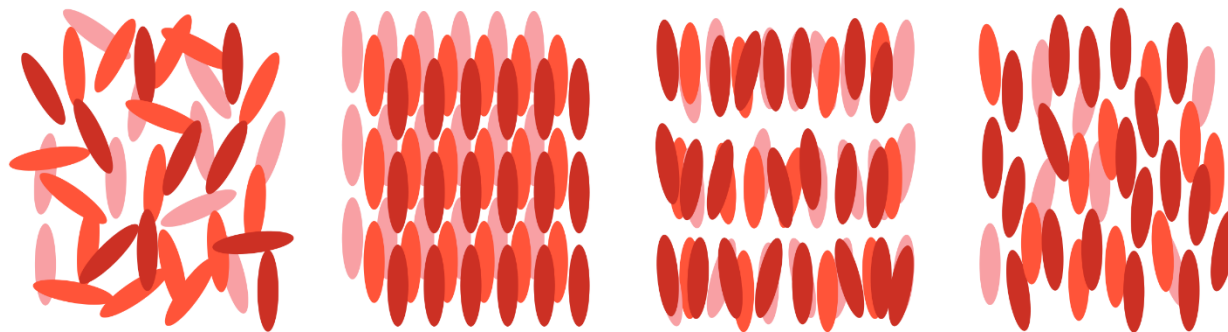
31. Which process is NOT happening at the triple point of a substance?

- a. Condensing
- b. Freezing
- c. Subliming
- d. Dissolving
- e. Melting

32. A soft solid with a low melting point and low thermal and electrical conductivity is most likely:

- a. A molecular solid
- b. An ionic solid
- c. A metallic solid
- d. A covalent network solid
- e. A superconducting solid

33. Left to right, which substances do the pictures below represent?



- a. Liquid, solid, smectic liquid crystal, nematic liquid crystal
- b. Liquid, cholesteric liquid crystal, smectic liquid crystal, nematic liquid crystal
- c. nematic liquid crystal, solid, cholesteric liquid crystal, smectic liquid crystal
- d. gas, solid, liquid crystal, liquid
- e. gas, solid, nematic liquid crystal, smectic liquid crystal

34. Which statement about liquid crystals is INCORRECT?

- a. Liquid crystals are often long, rod-like molecules
- b. Liquid crystals exhibit ordered phases above the melting point
- c. Liquid crystals are polar molecules
- d. Smectic liquid crystals exhibit more ordering than nematic liquid crystals
- e. Liquid crystals can not be solidified

35. Which of these substances is NOT a covalent network solid?

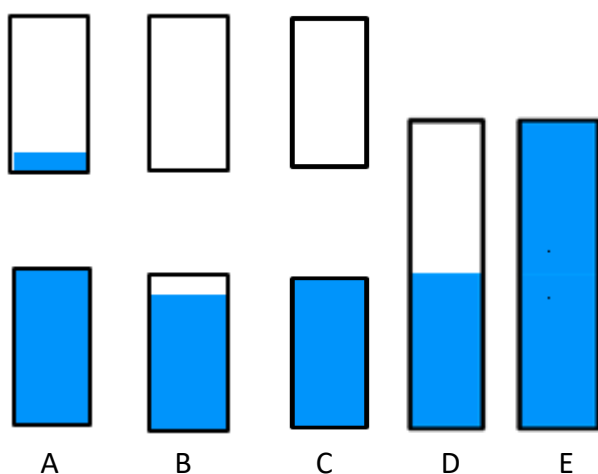
- a. Graphite
- b. Diamond
- c. Quartz
- d. Silicon
- e. Polyethylene



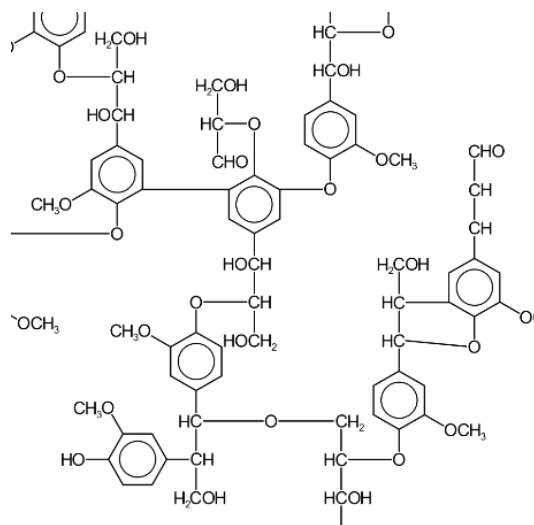
36. What makes a polymer LESS rigid?

- a. High molecular weight
- b. Addition of a plasticizer
- c. Crosslinking
- d. Increased crystallinity
- e. Strong intermolecular forces between polymer chains

37. Which of these band structures represents a p-type semiconductor?



38. Below is part of the structure of lignin, a polymeric material that makes up approximately half of most wood. What functional group is NOT present in lignin?

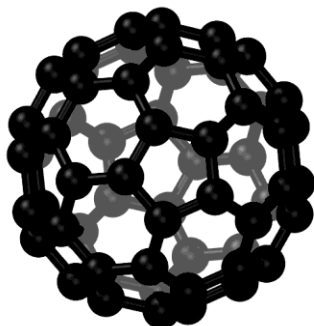


- a. Alcohol
- b. Aromatic
- c. Ether
- d. Aldehyde
- e. Amide

39. Why are addition polymers hard to depolymerize?

- a. Because sigma bonds are stronger than pi bonds
- b. Because addition is easier than subtraction
- c. Because the formation of addition polymers involves loss of water
- d. Because addition polymers are thermoplastic materials
- e. Because addition polymers are crosslinked

40. Buckminsterfullerene,  $C_{60}$ , is an allotrope of carbon. Examine its structure below, and predict how many unhybridized p orbitals there are in a  $C_{60}$  molecule.



- a. 10      b. 20      c. 30      d. 60      e. 120

41. Semiconductors are covalent network solids that have an average of how many valence electrons per atom?

- a. 2      b. 3      c. 4      d. 5      e. 6

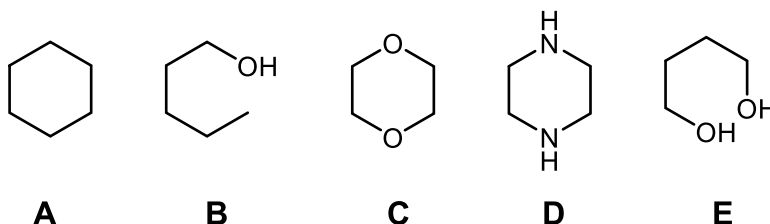
42. Which statement about p-type semiconductors is INCORRECT?

- a. The dopant atom has fewer electrons than the host atom
- b. There are holes in the valence band
- c. The conduction band is partially occupied
- d. p-type semiconductors are more conductive than the undoped material
- e. Doping is the introduction of controlled amounts of an impurity

43. Which of these polymers is made of repeating glucose molecules?

- a. Cotton
- b. Lignin
- c. Collagen
- d. Keratin
- e. Bakelite

44. Which of these liquids would you expect to be the most viscous?



45. Which statement about OLEDs is INCORRECT?

- a. OLEDs are polymeric
- b. OLEDs can be made into flexible and/or curved displays
- c. OLEDs conduct electricity because electrons can be delocalized along the organic molecules
- d. OLEDs do not require backlighting
- e. The O in OLEDs stands for orthogonal

46. Which of these polymers is not naturally occurring?

- a. Cotton
- b. Nylon
- c. Chitin
- d. Lignin
- e. Cellulose

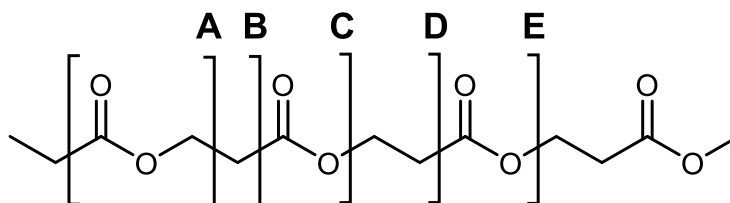
47. Which of these statements about carbon nanomaterials is INCORRECT?

- a. Graphene is very good at conducting heat
- b. Carbon nanotubes can be single-walled or multi-walled
- c. Carbon nanotubes are very strong for their size
- d. Graphene is made by flattening C<sub>60</sub> molecules
- e. C<sub>60</sub> molecules contain sp<sup>2</sup>-hybridized carbon atoms

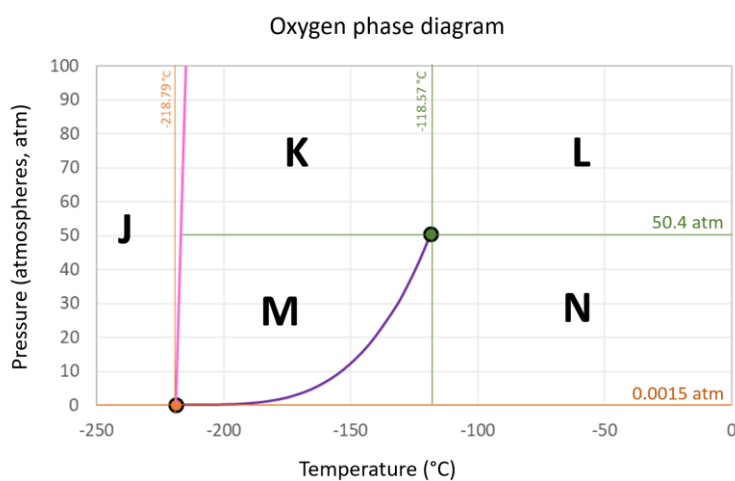
48. When does a liquid boil?

- a. When the vapour pressure is equal to the external pressure
- b. When the liquid reaches its critical point
- c. At 100°C
- d. When the rate of deposition equals the rate of sublimation
- e. When the liquid changes its composition

49. Which set of brackets describes the repeating unit in the polymer polyhydroxybutyrate, which is produced by microorganisms under conditions of physiological stress?

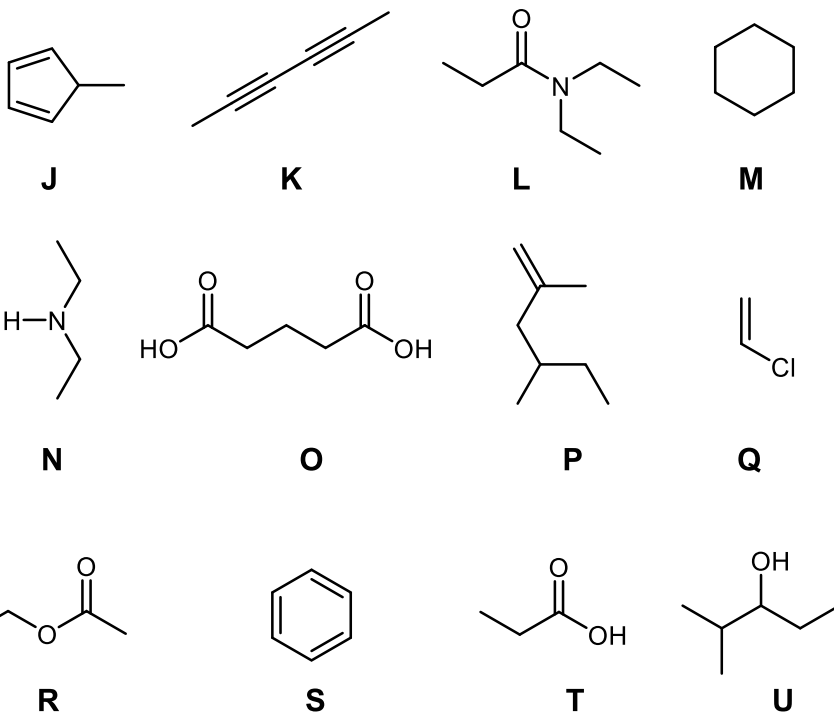


50. What phase is oxygen in after starting at position K then raising the temperature by  $100^\circ\text{C}$ ?



- a. Solid
- b. Liquid
- c. Gas
- d. Supercritical fluid
- e. Plasma

Questions 51-59 are about the collection of molecules below.



51. Which molecule has a structural isomer present in the collection of molecules?

- a. J      b. K      c. M      d. P      e. R

52. How many of these molecules are chiral?

- a. 0      b. 1      c. 2      d. 3      e. 4

53. Which molecule can be used as a co-monomer in a condensation polymerization?

- a. K      b. L      c. N      d. O      e. T

54. Which molecule is the monomer for the addition polymer PVC?

- a. L      b. M      c. N      d. O      e. Q

55. How many of these molecules are carboxylic acids?

- a. 0      b. 1      c. 2      d. 3      e. 4

56. How many of these molecules contain  $sp^2$  hybridized atoms?

- a. 6      b. 7      c. 8      d. 9      e. 10

57. Which molecule can be made by combining two of the other molecules?

- a. L      b. O      c. R      d. T      e. U

58. How many of these molecules can exhibit geometric (cis/trans) isomers?

- a. 0      b. 1      c. 2      d. 3      e. 4

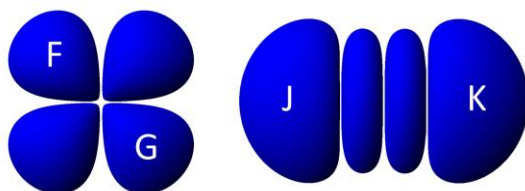
59. Which of these molecules is NOT present?

- a. 2,4-dimethyl-1-heptene  
b. cyclohexane  
c. ethyl ethanoate  
d. 2-methyl-3-pentanol  
e. propanoic acid

60. Which of these have the greatest bond order?

- a.  $\text{H}_2^+$   
b.  $\text{H}_2^-$   
c.  $\text{He}_2^+$   
d.  $\text{HHe}$   
e.  $\text{HHe}^+$

61. For the orbitals represented below, is **F** the same phase as **G**? Is **J** the same phase as **K**?



- a. Yes, yes  
b. Yes, no  
c. No, yes  
d. No, no  
e. Unable to determine

62. How many isomers of difluorobenzene ( $\text{C}_6\text{H}_4\text{F}_2$ ) are there? How many are polar?

- a. 1, 1  
b. 2, 2  
c. 2, 1  
d. 3, 1  
e. 3, 2

63. Which metal's s-d band most closely resembles the figure below?



- a. Sr
- b. Nb
- c. Mo
- d. Pd
- e. Ag

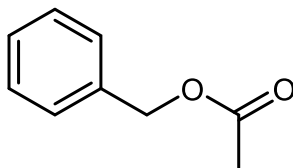
64. A tiny chunk of tungsten (W) metal contains one billion ( $10^9$ ) atoms. How many electrons are in the s-d band of this metal chunk?

- a. 1 billion
- b. 2 billion
- c. 3 billion
- d. 6 billion
- e. 12 billion

65. Which statement about band theory is INCORRECT?

- a. Metals have no gap between the valence band and the conduction band
- b. Insulators have a large gap between the valence band and the conduction band
- c. A band is made up of an enormous number of orbitals that are very close in energy
- d. Band theory is only applicable to metals in the d block of the periodic table
- e. Band theory can be used to predict some of the properties of metals based on the number of valence electrons

Benzyl acetate (below) has a sweet odor and is found in pears, strawberries and jasmine. Questions 66-71 concern this molecule.



66. How many  $\pi$  (pi) bonds are there in this molecule?

- a. 1
- b. 3
- c. 4
- d. 6
- e. 8

67. What functional group is present in this molecule?

- a. ether
- b. ester
- c. ketone
- d. carboxylic acid
- e. amide

68. How many resonance structures can be drawn of this molecule, including the provided structure, where the formal charge is 0 on all atoms?

- a. 1      b. 2      c. 3      d. 4      e. 5

69. What is the chemical formula of this molecule?

- a.  $C_8H_{10}O_2$   
b.  $C_9H_{10}O_2$   
c.  $C_9H_{12}O_2$   
d.  $C_9H_{10}O_3$   
e.  $C_9H_{11}O_2$

70. How many  $sp^2$  hybrid ORBITALS are there in this molecule?

- a. 6      b. 8      c. 12      d. 16      e. 24

71. How many  $sp^3$  hybridized ATOMS are there in this molecule?

- a. 1      b. 2      c. 3      d. 4      e. 5

72. How many isomers of  $C_4H_8$  are there (excluding any enantiomers)?

- a. 3  
b. 4  
c. 5  
d. 6  
e. 7

#### ANSWER KEY

1. C	2. C	3. D	4. D	5. C	6. D	7. E	8. D	9. D	10. D	11. A	12. D
13. B	14. B	15. C	16. D	17. C	18. A	19. E	20. B	21. D	22. D	23. B	24. E
25. C	26. C	27. E	28. C	29. A	30. A	31. D	32. A	33. A	34. E	35. E	36. B
37. B	38. E	39. A	40. D	41. C	42. C	43. A	44. E	45. E	46. B	47. D	48. A
49. B	50. D	51. B	52. C	53. D	54. E	55. C	56. C	57. A	58. A	59. A	60. E
61. B	62. E	63. A	64. D	65. D	66. C	67. B	68. B	69. B	70. E	71. B	72. D