



October 2012 - Entrance Examination: Condensed Matter

Multiple choice quizzes

1. Among the following molecules which one can have a three-fold degenerate vibrational mode?
 - A. CO.
 - B. C_2H_2 (C_2H_2 is a linear molecule).
 - C. C_2H_4 (C_2H_4 is a planar molecule).
 - D. CH_4 (CH_4 is a tetrahedral molecule).
2. When an insulator is placed in an electric field \mathbf{E}_0 , the electric field inside is uniform and equal to \mathbf{E} . When the same insulator is placed in a magnetic field \mathbf{B}_0 , the magnetic field inside is uniform and equal to \mathbf{B} . Calling E_0 , E , B_0 , and B the magnitude of the vectors, choose among the following the correct sentence:
 - A. $E \leq E_0$ and $B \geq B_0$ in any insulator.
 - B. $E \leq E_0$ in any insulator but B might be equal, larger, or smaller than B_0 .
 - C. E might be equal, larger, or smaller than E_0 while $B \leq B_0$ in any insulator.
 - D. E might be equal, larger, or smaller than E_0 and B might be equal, larger, smaller than B_0 . It depends on the solid shape.
3. A Boron atom ($Z = 5$) has an electronic configuration $1s^2 2s^2 2p$. Suppose you make a Stern and Gerlach experiment and split a beam of boron atoms with a small nonuniform magnetic field. How many beams do you obtain?
 - A. 1.
 - B. 2.
 - C. 3.
 - D. 4.

4. The same light beam impinges on the surfaces of three solids: one totally transparent, one totally absorbing, one halfway. By measuring their respective heating caused by the light, the energy absorbed by each solid is:
 - A. Largest for the totally absorbing
 - B. Largest for the intermediate
 - C. Largest for the transparent
 - D. Equal for all of them
5. The phase diagram of a simple substance has single-phase regions (like solid, liquid and gas), and others where two different phases coexist, so there is spatial phase separation, such as between liquid and gas. In the liquid-gas case, phase separation occurs
 - A. at constant pressure, as a function of temperature, below the triple point
 - B. at constant temperature (below the critical temperature, as a function of volume
 - C. at constant temperature, as function of pressure, below the triple point
 - D. above the critical temperature
6. According to quantum mechanics we can associate a wave to a particle. Suppose the particle (of mass m) is moving freely along the x axis with a fixed energy E , momentum p , and speed v that are known while the position of the particle is completely undetermined, so that the wave associated to the particle has a wavelength λ and a frequency ν . Which one of the following relationships is false (h is Planck's constant):
 - A. $E = h\nu$.
 - B. $v = p/m$.
 - C. $\nu = v/\lambda$.
 - D. $E = p^2/2m$.
7. Among the following properties, which two cannot coexist in the same solid at the same temperature?
 - A. Ferroelectric and ferromagnetic order.
 - B. Finite electrical conductivity and cubic structure.
 - C. Finite electrical conductivity and ferromagnetic order.
 - D. Ferroelectric order and cubic structure.
8. Among the following diatomic molecules, choose the one that adsorbs electromagnetic radiation of lowest frequency

- A. Au₂.
 - B. AuBr.
 - C. LiH.
 - D. CO.
9. The ground state of an atom can be indicated with the term symbol $^{2S+1}L_J$ where S is the total spin, L the orbital angular momentum (denoted with a standard notation: S, P, D, F, \dots for $L = 0, 1, 2, 3, \dots$) and J the total angular momentum. In the ground state, the nickel atom has an electronic configuration $[Ar]3d^84s^2$, where $[Ar]$ indicates the electronic configuration of the argon atom. According to Hund's rules which is the ground state of nickel?
- A. 3F_4 .
 - B. $^4F_{9/2}$.
 - C. $^4F_{3/2}$.
 - D. 3S_1 .
10. The hydrogen molecule is diatomic and has two electrons. When the two electrons are in the ground state, the bond length is $d_0 = 0.74 \text{ \AA}$. Suppose you excite an electron in the first unoccupied level. What do you expect?
- A. The covalent bond will be weaker and the bond length is slightly longer.
 - B. The covalent bond will be stronger and the bond length is slightly shorter.
 - C. The bond disappears because one electron is in a bonding state and the other is in an anti-bonding state, hence excited hydrogen molecules do not exist.
 - D. The bond exists but it is not covalent anymore. It is due only to the residual electrostatic interaction between two hydrogens. Therefore the bond length is much longer than d_0 .
11. The N atom has seven electrons. Its first ionization energy is 14.5 eV, the second ionization energy is 29.6 eV and the third is 47.5 eV. Estimate approximately the Coulomb repulsion energy U between two $2p$ electrons in N:
- A. 47.0 eV.
 - B. 15.0 eV.
 - C. 30.0 eV.
 - D. 3.0 eV.
12. The zero-point energy of CH_4 is 27 kcal/mol, while the zero-point energy of CH_3 is 17 kcal/mol. If, neglecting zero-point energy, you calculate that the difference between the atomization energy of CH_3 and of CH_4 is 113 kcal/mol, which is the atomization energy difference that you expect to measure?

- A. 103 kcal/mol.
 - B. 113 kcal/mol.
 - C. 123 kcal/mol.
 - D. 69 kcal/mol.
13. Deuterium (atom) is a hydrogen isotope with a nucleus composed by a proton and a neutron. Compare the ionization potentials of deuterium I_D and hydrogen I_H .
- A. $I_D = I_H$.
 - B. I_D is slightly smaller than I_H .
 - C. I_D is slightly larger than I_H .
 - D. $I_D = I_H/2$.
14. Let us consider a cubic box of side L . The ground state of an electron inside the box is non degenerate. What is the degeneracy of the first excited state?
- A. 1.
 - B. 2.
 - C. 3.
 - D. 4.
15. The Fermi energy of a free-electron metal increases with decreasing volume, as
- A. V^{-2} .
 - B. $V^{-2/3}$.
 - C. $V^{-1/3}$.
 - D. It depends on the metal.