Spring 2006 - Entrance Examination: Condensed Matter
Multiple choice quizzes

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1. Which one among the following neutral atoms is magnetic in its ground state?

   A. H.

   B. He.

   C. Be.

   D. Ne.

2. Treating matter as completely classical, its equilibrium thermodynamical properties:

   A. Generally depend on the mass of the atoms, and also depend on the intensity of an external magnetic field.

   B. Are generally independent of the mass of the atoms, and also of the intensity of an external magnetic field.

   C. Generally depend on the mass of the atoms, but are independent of the intensity of an external magnetic field.

   D. Are generally independent of the mass of the atoms, but depend on the intensity of an external magnetic field.

3. An electron gas at zero temperature is:

   A. Nonmagnetic and fluid at low density, magnetic and crystalline at high density.

   B. Nonmagnetic and fluid at high density, magnetic and crystalline at low density.

   C. Nonmagnetic and fluid at all densities.

   D. Magnetic and crystalline at all densities.

4. Consider two electronic levels of an idealized system (for example a molecule) whose geometry could be changed parametrically, and suppose the symmetry of the two levels is known all along. As the geometry changes, the energies of the levels will change parametrically, but

   A. The two levels can never cross, no matter what their symmetry.

B. The two levels can always cross, no matter what their symmetry.

C. The two levels can cross if their symmetry is the same, but cannot if their symmetry is different.

D. The two levels cannot cross if their symmetry is the same, but can cross if their symmetry is different.

5. The nitrogen atom has 7 electrons and by the Hund's rule has spin $S = 3/2$. What is the spin of the nitrogen dimer?

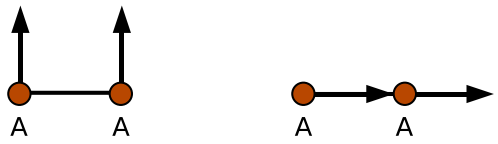
A. The Hund's rule is general so the nitrogen dimer has spin $S = 3$.

B. The π and σ molecular orbitals are bonding and can be filled without degeneracy. Thus the nitrogen dimer is a singlet.

C. By the standard rules for the sum of two $S = 3/2$ spins, the nitrogen dimer in its ground state can allow any spin between 0 and 3.

D. The total spin is not defined in the nitrogen dimer because the system is not fully rotationally invariant as the nitrogen atom.

6. In the figure, we show two possible directions of the magnetization of a ferromagnetic di-atomic molecule:



(a) (b)

Consider the mirror symmetry with respect to a plane perpendicular to the bond and passing through its center. Which one of the following sentences is true?

A. This is an operation of the symmetry group of both a and b.

B. This is an operation of the symmetry group of a only.

C. This is an operation of the symmetry group of b only.

D. This is not an operation of the symmetry groups of a or b.

7. If the speed of light c were infinite, relativistic effects would not exist. What would happen to a Au atom?

A. Nothing would happen. The electrons velocity is so low that no relativistic effect is actually observable in atoms.

B. The size of many core orbitals would expand, but no detectable effect would be observable for the valence $6s$ orbital.

C. The size of many core orbitals and of the $6s$ valence orbital would expand so that the Au atom would expand.

D. Both the size of many core orbitals and of the $6s$ valence orbital would shrink so that the Au atom would shrink.

8. Hund's first rule tell us that, when several electrons are placed into a degenerate partially filled level, the highest-spin state has the lowest energy. Why?

   A. This is false. Hund's first rule states that the lowest-spin state has the lowest energy.

   B. This is due to spin-orbit coupling. High spin couples more effectively with the orbital moment and the energy is lower in this state.

   C. This is due to the magnetic spin-spin interaction. Parallel spins have lower energy than anti-parallel spins.

   D. This is due to the Coulomb electron-electron interaction. The highest-spin state has the lowest Coulomb energy.

9. Defining conventionally an electronic conductor as a system with electrons at the Fermi level that are quantum mechanically degenerate and drift in an applied electric field (at fixed ions), and an ionic conductor as a system with thermally mobile ions that are classically free to drift (without free electrons), most organic living matter is:

   A. Electronically and ionically insulating.

   B. Electronically and ionically conducting.

   C. Electronically insulating and ionically conducting.

   D. Electronically conducting and ionically insulating.

10. Each wave-function of an hydrogen atom is characterized by four quantum numbers n, l, m_l, m_s, whereas the energy levels depend on n only. Which is the degeneracy of each level?

    A. It is non degerate.

    B. n.

    C. $2(2l + 1)$.

    D. $2n^2$.