Spring 2005 - Entrance Examination: Condensed Matter
Multiple choice quizzes

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1) The ionization potential of Li (atomic number Z=3) is smaller than that of He (Z=2) and than that of Be (Z=4). Suppose the electron had spin 3/2. Would the ionization potential of Li be:

   A. Smaller than those of He and Be.

   B. Larger than that He and smaller than that Be.

   C. Larger than both those of He and Be.

   D. Smaller than that of He and larger than that of Be.

2) Glassy and amorphous insulating solids generally make much worse heat conductors than the corresponding crystalline solids. Why is that?

   A. Electrons are localized by disorder and cannot propagate freely.

   B. Phonons are localized by disorder and cannot propagate freely.

   C. Electrons scatter with phonons much more strongly due to disorder, thus becoming mutually entangled, and unable to conduct heat.

   D. The ordinary heat conduction equation assumes order and is no longer valid in this regime, where disorder introduces a sink term.

3) Most substances possess at least a solid (S), a liquid (L) and a gas (G) phase. When plotted in the T, P plane:

   A. S and L are always separated from V by a phase boundary, while they themselves join beyond the triple point.

   B. S and V are always separated from L by a phase boundary, while they themselves join beyond the tricritical point.

   C. L and V are always separated from S by a phase boundary, while they themselves join beyond the critical point.

   D. S, L and V are disjoint and there is always a phase boundary between one another.

4) Which one, among the following sentences, is correct for an electronic wave function of a homo-nuclear diatomic molecule (z is along the axis of the molecule, and spin-orbit interactions are neglected).

A. It can be chosen as a simultaneous eigenfunction of the orbital angular momentum, L^2, of the parity operator, P, and of the projection of the spin angular momentum along z, S_z.

B. It can be chosen as a simultaneous eigenfunction of L_z and S^2 but not P.

C. It can be chosen as a simultaneous eigenfunction of L_z, P, and S^2.

D. It can be chosen as a simultaneous eigenfunction of L^2 and P but not S_z.

5) According to the Bloch theorem, each solution $\psi_{\mathbf{k}n}(\mathbf{r})$ of the Schrödinger equation with a periodic potential $V(\mathbf{r})$, where $V(\mathbf{r}+\mathbf{R}) = V(\mathbf{r})$ for all $\mathbf{R}$ in a Bravais lattice, can be associated to a wave vector $\mathbf{k}$ in the first Brillouin zone and to a band index n. Moreover, the following condition holds:

A. $\psi_{\mathbf{k}n}(\mathbf{r}+\mathbf{R}) = \psi_{\mathbf{k}n}(\mathbf{r})$.

B. $\psi_{\mathbf{k}n}(\mathbf{r}+\mathbf{R}) = e^{i\mathbf{k}\cdot\mathbf{r}}\psi_{\mathbf{k}n}(\mathbf{r})$.

C. $\psi_{\mathbf{k}n}(\mathbf{r}+\mathbf{R}) = e^{-i\mathbf{k}\cdot\mathbf{r}}\psi_{\mathbf{k}n}(\mathbf{r})$.

D. $\psi_{\mathbf{k}n}(\mathbf{r}+\mathbf{R}) = e^{i\mathbf{k}\cdot\mathbf{R}}\psi_{\mathbf{k}n}(\mathbf{r})$.

6) Very convenient and common methods to measure the electronic band dispersion (B), the phonon dispersion (P) and the structure (S) in solids are:

A. Inelastic neutron scattering (S), photo-emission (B), elastic X-ray diffusion (P).

B. Inelastic neutron scattering (P), photo-emission (B), elastic X-ray diffusion (S).

C. Inelastic neutron scattering (B), photo-emission (P), elastic X-ray diffusion (S).

D. Inelastic neutron scattering (P), photo-emission (S), elastic X-ray diffusion (B).

7) If the Pauli principle were not valid what would happen to the energy levels of the helium atom?

A. The ground state of helium would have total spin 1 because a triplet with two electrons with the $1s$ wave function ($1s^2\ ^3S$) would have energy lower than the singlet state $1s^2\ ^0S$.

B. The singlet $1s^2\ ^0S$ and the triplet $1s^2\ ^3S$ would be degenerate.

C. The ground state would not change, but there would be also a triplet $1s^2\ ^3S$ at higher energy than the ground state.

D. Nothing would change. The Pauli principle is not affecting the energy levels of the helium atom.

8) Which effect, among the following, is due to spin-orbit coupling?

A. The Stark effect.

B. The splitting of the yellow lines of atomic sodium which corresponds to the transitions between $3p - 3s$ levels.

C. The magnetism of the oxygen molecule.

D. The splitting between the energies of singlet and triplet states in the helium atom.

9) How many normal modes of vibrations with non zero frequency are there in an ethylene molecule (C_2H_4)? And in an acetylene molecule (C_2H_2)?

A. 12 (C_2H_4) and 6 (C_2H_2).

B. 12 (C_2H_4) and 7 (C_2H_2).

C. 12 (C_2H_4) and 5 (C_2H_2).

D. 18 (C_2H_4) and 12 (C_2H_2).

10) Methanol (CH_3OH) is liquid at standard temperature and pressure conditions while methane (CH_4) and oxygen (O_2) are in the gas phase. Suppose you devise a catalytic process converting $CH_4 + 1/2\ O_2$ into methanol at ambient pressure and temperature. What do you expect would be the effect of pressure on the process?

A. Raising the pressure the conversion will be enhanced.

B. Raising the pressure the conversion will be hindered.

C. No marked effect, more details are needed to decide.

D. Only the temperature can enhance the conversion.

11) Consider ozone molecule (O_3). Knowing that CO_2 displays a linear configuration while SO_2 displays a bent one specify what you expect O_3 to be:

A. Linear.

B. Bent.

C. Equilateral triangular.

D. There is no way to guess.

12) The radiative lifetime of the $1s2s\ ^1S$ state of He is very large. How would you decrease it:

A. By applying a uniform electric field.

B. By applying a uniform magnetic field.

C. By increasing the temperature.

D. By increasing the pressure.