Fall 2007 – Entrance Examination: Condensed Matter
Multiple choice quizzes

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1. Classical equilibrium thermodynamical properties of matter do not depend on the mass of nuclei. So how could the properties of heavy water and of ordinary water differ?

   A. They in fact differ only in kinetics, and not in equilibrium properties.

   B. They must differ in kinetics and also a little in their equilibrium properties, due to quantum effects.

   C. They do not differ at all.

   D. They cannot really be compared, because they have different quantum numbers

2. The rotational properties of the hydrogen molecule H_2 are very different depending on whether the total nuclear spin state is in a S=0 state (parahydrogen) or S=1 (orthohydrogen).

   A. True. This is because the total wavefunction must be antisymmetric.

   B. True. This is because the total wavefunction must be normalized.

   C. True. This is because the total wavefunction must be real.

   D. False. The difference is minute, and totally irrelevant. H_2 is just an ordinary rotor.

3. Many elemental solids in nature (e.g. iron) are metallic, whereas most molecular solids (e.g., ice) are insulating. Why is that?

   A. Atoms are small, can touch intimately, and thus exchange electrons. Molecules are big, cannot generally touch so well.

   B. Molecules feel mutual van der Waals interactions, which the atoms do not.

   C. Atoms are much lighter, and their zero point motion keeps the electrons much more mobile.

   D. Electrons are generally paired in bonding states in molecules, but not in atoms.

4. Near absolute zero temperature, the electronic specific heat of an s-wave superconductor behaves as:

   A. $\approx |T - T_c|^{-\gamma}$, where γ is an appropriate critical exponent.

   B. $\approx T$

   C. $\approx T^3$

   D. $\approx \mathrm{e}^{\frac{-\Delta}{k_B T}}$, where Δ is the gap.

5. One eigenfunction of the Hamiltonian of a particle moving in a one-dimensional local potential is non-degenerate and odd with respect to parity. Which one of the following statements is true?

A. The eigenstate cannot be the ground state.

B. The eigenstate can only be the ground state if the potential is odd.

C. The eigenstate can only be the ground state if the particle is a fermion.

D. The eigenstate can be either the ground or an excited state, according to details of the potential which are not specified.

6. Rubber is made of *spaghetti*-like disordered polymer fibers joined together at random points. It has an increasing elastic modulus as T grows.

   A. False. Rubber elasticity gets better at low T. Rubber only melts at high T.

   B. True. Stretching causes increased adhesion between the polymer fibers, decreasing the potential energy, and that effect is more important at high T.

   C. True. Stretching orients the polymer fibers which decreases the entropy, and that is more important at high T.

   D. True. Disorder in rubber forces all modes to be Anderson localized, so that their zero point energy is stretch dependent.

7. Is it possible to distinguish a metal from an insulator by looking at its phonon dispersions?

   A. By applying pressure the phonon frequencies decrease in metals and increase in insulators.

   B. By applying pressure the phonon frequencies increase in metals and decrease in insulators.

   C. Only in insulators there might be discontinuities in the derivatives of the frequency-wavevector dispersion curves.

   D. Only in metals there might be discontinuities in the derivatives of the frequency-wavevector dispersion curves.

8. Which one of the following sentences is true for a ferromagnetic solid.

   A. It is always a metal.

   B. It is always an insulator.

   C. It must contain some transition metal with d electrons.

   D. It cannot have O_h point group symmetry.

9. A negative charge q is at a distance R from an isolated metallic sphere which is negatively charged with charge Q. Which is the sign of the force acting on the charge q?

   A. It is always repulsive.

   B. It is always attractive.

   C. It is repulsive at large distances, attractive at short distances.

   D. It is repulsive at short distances, attractive at large distances.

10. The ground state electronic configuration of an iron atom is $[Ar]3d^6 4s^2$ where $[Ar]$ is the electronic configuration of the Argon atom. According to Hund's rules which are its orbital (L) and spin (S) angular momenta?

A. $L = 2$, $S = 2$.

B. $L = 1$, $S = 2$.

C. $L = 2$, $S = 4$.

D. $L = 1$, $S = 4$.

11. The Clausius-Clapeyron equation states that the slope of the coexistence line between a solid and its melt, $P(T)$, is equal to the ratio between the entropy and volume difference of the two phases: $\frac{dP}{dT} = \frac{\Delta S}{\Delta V}$. Suppose the melting pressure decreases with increasing temperature. One deduces that:

    A. The solid floats on its melt.

    B. The solid sinks into its melt.

    C. This cannot happen at equilibrium because of the second principle of thermodynamics.

    D. The Clausius-Clapeyron relation does not allow to draw any conclusions on the floating/melting behavior of the solid with respect to its melt.

12. The low-temperature phase of tin is called *gray tin*, whose crystal structure is diamond-like. At temperatures higher that 13.2 $^\circ\mathrm{C}$, tin turns to the *white tin* phase, whose structure is hexagonal. What can be concluded about the vibrational properties of the two phases?

    A. Gray tin has vibrational frequencies that are, on the average, higher than white tin's

    B. White tin has vibrational frequencies that are, on the average, higher than white white's

    C. The Debye frequency of white tin increases with temperature, while gray tin's decreases

    D. The Debye frequency of gray tin increases with temperature, while white tin's decreases

13. The Hamiltonian of an assembly of magnetic atoms is invariant with respect to the reversal of all the atomic magnetic moments. One can conclude that:

    A. No finite magnetization of the system is allowed at equilibrium at any finite temperature.

    B. No magnetization is allowed ad finite temperature for finite systems, whereas a finite magnetization is allowed in infinite systems below the Curie temperature

    C. The system is always magnetic below a critical temperature, which is vanishingly small for finite system sizes.

    D. The system is only magnetic when it is finite, for the crytical temperature decreases with the system size