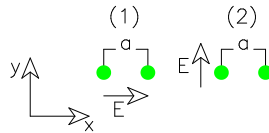


## Fall 2003 – Entrance Examination: Condensed Matter

### Multiple choice quizzes

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1. Let's consider two neutral polarizable Ar atoms at distance  $a$  as shown in the figure. In case (1) the two atoms are in an external electric field parallel to  $x$ , in case (2) they are in an external electric field parallel to  $y$ . The field acting on the atoms is:



- a) Higher than the applied field in case (1) and (2).
  - b) Higher than the applied field in case (1) only.
  - c) Higher than the applied field in case (2) only.
  - d) Always equal to the applied field.
2. The dissociation energy of the  $H_2$  molecule is 4.8 eV while the dissociation energy of the  $H_2^+$  molecule is 2.8 eV. What is the ionization potential of the  $H_2$  molecule?
- a) 7.6 eV
  - b) 15.6 eV
  - c) 16.3 eV
  - d) 2.0 eV
3. The unit cell of an infinite polymeric chain contains  $N$  atoms, not all lined-up. How many non zero vibrational modes do you expect at the  $\Gamma$  point of the 1D-Brillouin zone?
- a)  $3N$
  - b)  $3N - 3$
  - c)  $3N - 6$
  - d)  $3N - 4$
4. How would you describe the difference between a gas, a liquid and a solid, all composed of the same material?

- a) The solid is denser than the liquid, which is denser than the gas: the only difference between them is density.
- b) They differ not only in density, but also in long-range order. The solid has rigidity and crystalline order, the liquid has fluid-like order, and the gas has vapor-like order.
- c) They differ not only in density, but also in long-range order. The solid has has rigidity and crystalline order, the liquid has fluid-like order, and the gas has no order.
- d) They differ not only in density, but also in long-range order. The solid has has rigidity and crystalline order, the liquid and the gas have no order.

5. Which among these statements is correct?

- a) attractive interactions between atoms or molecules are necessary in order to give rise to liquids, and to gases.
- b) attractive interactions between atoms or molecules are unnecessary in order to give rise to liquids, and to gases.
- c) attractive interactions between atoms or molecules are necessary in order to give rise to liquids, but not to gases.
- d) attractive interactions between atoms or molecules are unnecessary in order to give rise to liquids, but not to gases.

6. Which among these statements is correct?

- a) if the mass of the atomic nuclei became very large ordinary semiconductors wouldn't exist
- b) if the mass of the atomic nuclei became very large ordinary superconductors wouldn't exist
- c) if the mass of the atomic nuclei became very large ordinary ferromagnets wouldn't exist
- d) if the mass of the atomic nuclei became very large ordinary metals wouldn't exist

7. Consider the two electron ground state of an  $H_2$  molecule as a function of the atomic distance, where the molecular axis is assumed to be parallel to the  $z$ -axis. At the equilibrium distance the ground state is a singlet with zero total angular momentum  $L_z$  along the  $z$ -axis.

What happens at large finite distance ?

- a) The ground state is no longer a singlet and the electrons prefer to have parallel spins, recovering the Hund's rule.
- b) Both the total orbital angular momentum  $L_z$  and total spin  $S_z$  change but the total angular momentum  $J_z = L_z + S_z$  is conserved.
- c) The ground state is 4-fold degenerate, in order that the spin  $\sigma = \pm 1/2$  of the two electrons are mutually independent.
- d) The ground state is always a singlet with zero angular momentum  $L_z = 0$ .

8. Two identical electric dipoles are held fixed at a certain distance, and constrained to stay parallel or anti-parallel to each other. Let's call  $\mathbf{n}$  the direction of the straight line which joins them. Their stable equilibrium orientation is:

- a) Parallel to  $\mathbf{n}$  when they are parallel to each other, and perpendicular if anti-parallel.
  - b) Always parallel to  $\mathbf{n}$ .
  - c) Always perpendicular to  $\mathbf{n}$ .
  - d) Parallel to  $\mathbf{n}$  when they are anti-parallel to each other, and perpendicular if anti-parallel.
9. An organ pipe is let resonate in an artificial atmosphere where nitrogen has been replaced by (i) helium and (ii) sulfur hexafluoride ( $\text{SF}_6$ ), both chemical inert gases. The same wavelength would sound:
- a) Higher pitch in He-rich and lower pitch in  $\text{SF}_6$ -rich air than in  $\text{N}_2$ -rich air.
  - b) Lower pitch in He-rich and higher pitch in  $\text{SF}_6$ -rich air than in  $\text{N}_2$ -rich air.
  - c) The same as in  $\text{N}_2$ -rich air.
  - d) It depends on temperature: answer a) is correct at low temperature, while answer b) is correct at high temperature.
10. One non-degenerate eigenfunction of the Hamiltonian of a 1D particle moving in the field of a local potential is 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.
11. Suppose that electrons were spin-3/2 particles. What would be the ground-state electronic configuration of the Carbon atom ( $Z=6$ )?
- a)  $1s^2 2s^2 2p^2$
  - b)  $2p^6$
  - c)  $1s^4 2s^2$
  - d)  $1s^1 2s^1 2p^1 3s^1 3p^1 3d^1$
12. Two plates of a capacitor, originally at a distance  $d_1$ , are brought to a distance  $d_2 > d_1$ , while keeping the potential drop across the capacitor constant. Let  $\pm\sigma$  indicate the electric charge per unit surface on the two plates of the capacitor. Which one of the following relations holds?
- a)  $\sigma_1 > \sigma_2$
  - b)  $\sigma_1 = \sigma_2$
  - c)  $\sigma_1 < \sigma_2$
  - d) It depends on the dielectric constant of the medium between the plates.