PHY 3202 Mid-term examination

March 8, 2010

11:30am – 1:15 pm

Answer all questions.

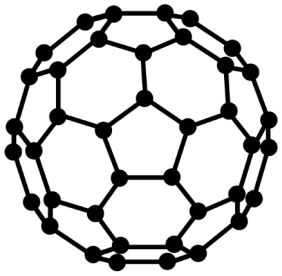

Fig. 1 The structure of C60

(1) (C60)

(a) Copy Fig. 1 to your answer book & label all double bonds with double lines on the figure. (5 marks)

(b) Describe very briefly how C60 can be mass-produced in a laboratory. (5 marks)

(2) To construct the ground state wavefunction for H_2, we assume that each electron is in the 1s bonding state ψ_+ of H_2^+. Write down the ground state wavefunction for H_2. (5 marks)

(3) (Vibrational-rotational spectrum)

(a) (TZD Ch. 12, Prob. 52) (15 marks)

Use the information in Fig. 2 to find the force constant and bond length of HI molecule. (Mass of H atom = 1 u. Mass of I atom = 127 u. u is the atomic mass unit.)

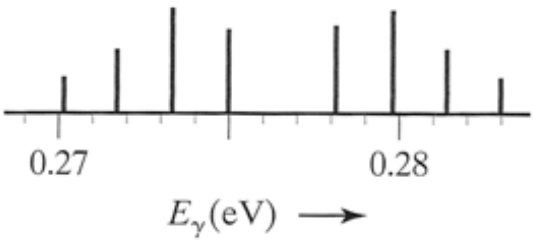

Fig. 2 The vibrational-rotational spectrum of HI molecule.

(b) Each spectral line corresponds to a change of quantum number ℓ. What is the change of ℓ for the line at 0.2750 eV? (5 marks)

(c) What are the selection rules for the vibrational-rotational transitions? (5 marks)

(continued on next page)

(4) (CsCl crystal)

CsCl crystal has a cubic structure with unit cell shown in Fig. 2.

(a) Describe its crystal structure in terms of lattice type and basis. (5 marks)

(b) CsCl crystal is an ionic solid. Derive an expression (with only **the first 3 terms**) for the Madelung constant α by considering the electrostatic potential energy of an ion. (15 marks)

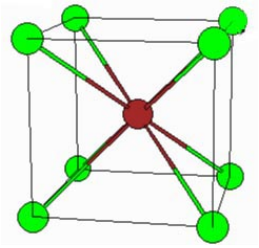

Fig. 2 Cs (green) & Cl (brown) ions in CsCl unit cell.

(5) (SMM Ch.3, Prob. 39)

X-rays from a molybdenum target (wavelength $\lambda = 0.0626$ nm) are incident on an NaCl crystal, which has the atomic arrangement shown in Fig. 3.

If NaCl has a density of 2.17 g/cm^3 and the $n = 1$ diffraction maximum from (atomic) planes separated by d is found at $\theta = 6.41°$, compute Avogadro's number. (25 marks)

(Molar mass of Na: 23 g/mole. Molar mass of Cl: 35.4 g/mole.)

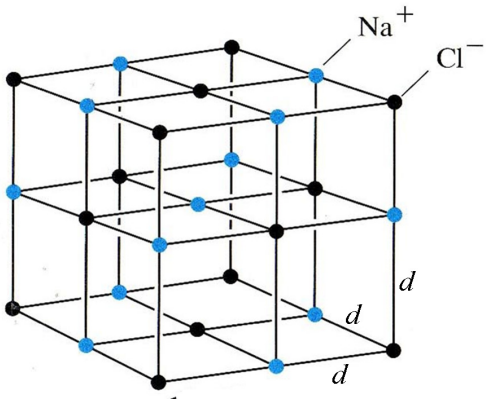

Fig. 3 The conventional unit cell of NaCl

(6) (SMM Ch. 10, Prob. 24(b))

Copper has a Fermi energy of 7.0 eV at 300 K. Calculate the ratio of the number of occupied levels at an energy of 8.5 eV to the number of occupied levels at the Fermi energy. (5 marks)

(7) At room temperature (300 K), the mean free path in a clean metal sample is about 150 nm. The resistance ratio of the metal R_{300K} / R_{4K} is measured to be 100.

What is the mean free path in the metal at $T = 4$ K ? (10 marks)

- End -