

**Birla Institute of Technology & Science, Pilani, Rajasthan 333031**  
**First Semester 2015-2016**

**Course Number: CHEM F111**

**Course Title: General Chemistry**

**Marks: 10**

**Tutorial Problem Set 1 (based on Lecture No.'s: 1-5 in the course hand out)**

**Instructions to the student:** *The following problems should be solved as home assignment within a week of display. Any one problem will be assigned as a closed book class test in the following tutorial hour.*

**Useful data:**  $m_e = 9.11 \times 10^{-31} \text{ kg}$ ,  $h = 6.626 \times 10^{-34} \text{ Js}$ ,  $1 \text{ eV} = 1.602 \times 10^{-19} \text{ J}$ ,  $\hbar = 1.055 \times 10^{-34} \text{ Js}$   
 $c = 3.0 \times 10^8 \text{ ms}^{-1}$ ;  $1 \text{ J} = 1 \text{ kg m}^2 \text{ s}^{-2}$

**1. (i)** Calculate the power radiated (in Watts) by the surface of a cylindrical wire of length 5.0 cm and radius 0.12 mm that is heated to 3300 K by an electric current. **(ii)** The energy required for the ionization of a certain atom is 3.44 aJ ( $\text{aJ} = 10^{-18} \text{ J}$ ). The absorption of a photon of unknown wavelength ionizes the atom and ejects an electron with velocity  $1.03 \text{ Mm s}^{-1}$  ( $1 \text{ Mm} = 10^6 \text{ m}$ ). Calculate the wavelength (in nanometer) of the incident radiation. **[5+5]**

**2. (a)** Calculate **(i)** the energy difference between  $n = 1$  and  $n = 2$  levels for an electron confined to a one-dimensional box of length  $4 \text{ \AA}$ . **(ii)** What wavelength corresponds to a spectral transition between these levels? **(iii)** In which region of the electromagnetic spectrum does this wavelength lie? **[3+2+1]**

**(b)** What is the minimum uncertainty in the position of a bullet of mass 5.0 gm that is known to have a speed somewhere between  $350.00001 \text{ ms}^{-1}$  and  $350.00000 \text{ ms}^{-1}$ ? **[4]**

**3. (a)** An electron is moving in a cyclic ring (i.e., having two-dimensional rotational motion). If the absorption occurs at a wavelength of 260 nm for a change in rotational level ( $m_l$ ) 3 to 4 then calculate the diameter of the ring (in  $\text{\AA}$ ). **[3+3]**

**(b)** Which of the following is/are eigen function(s) of  $d^2/dx^2$  and find the corresponding eigen value(s). **(i)**  $\psi = 8e^{4x}$  **(ii)**  $\psi = \cos(x/4)$  **[2+2]**

**4. A** electron is confined to a molecule of length of 1 nm (about 5 atoms long). **(i)** What is its minimum energy? **(ii)** What is the minimum excitation from this state? **(iii)** What is the probability of finding it in the region of the molecule lying between  $x = 0$  and  $x = 0.2 \text{ nm}$ ? **[2+3+5]**

**5. (a)** Starting from Planck's radiation law obtain the Stefan Boltzmann law  $E = \sigma' T^4$ , where,  $E$  is the total radiation energy from  $\lambda = 0$  to  $\lambda = \infty$ , that is **[5]**

$$E = \int_0^{\infty} E_{\lambda} d\lambda = \sigma' T^4. \quad \text{Given: } \int_0^{\infty} x^3 dx / (e^x - 1) = \pi^4/15$$

**(b)** What is the speed and de Broglie wavelength of an electron that has been accelerated by a potential difference of 500 V. **[3+2]**

**6. (a)** Planck's radiation distribution law successfully explains the nature of the curve obtained by plotting energy density against the wavelength emitted by black-body. Explain. **(b)** Can Planck's radiation distribution law ever reach to the experimental observation of Wien? Justify. [6+4]

**7. (a)** What is the de Broglie wavelength  $\lambda$  of an electron moving at 1/137th the speed of light? **(b)** What is the minimum uncertainty in the velocity of an electron if the uncertainty in its position is 100 pm? Comment on whether further precision of measurement is possible by more sophisticated instrumental techniques. [3+4+3]

**8. (a)** Obtain an expression for the translational energies that  $N_2$  molecules could have if they were confined to a straight line segment 10 cm long. **(b)** Obtain the number of degenerate states associated for energy level  $14[h^2/(8ml^2)]$  for particles of mass  $m$  in a cubic container (mass of the particle =  $m$ ; side of the cubic box is of length  $l$ ). Identify those states. **(c)** The probability of finding a pendulum in the classically forbidden region is completely negligible. Provide the reason. [5+3+2]

**9. (a)** Which of the following operator combinations would yield eigenvalue equations? What are the eigenvalues of the eigenfunctions. (i)  $\frac{d(e^{-4x^2})}{dx}$  (ii)  $\frac{d^2(\cos\frac{x}{4})}{dx^2}$   
**(b)** Calculate the momentum observable if the wave function  $\psi$  is  $e^{-i4x}$ . [5+5]

**10. (a)** The wavefunction for an one-dimensional electron is,  $\psi = \sqrt{2} \sin\pi x$  in the range  $x = 0$  to 1. Find out the probability that the electron is in the middle half of the range, from  $x = 0.25$  to 0.75. **(b)** Show that the above wavefunction is normalized in the range,  $x = 0$  to 1. [5+5]

**11. (a)**  $\beta$ -Carotenes has a maximum absorption of light occurs at 480 nm. If this transition corresponds to  $n = 11$  to  $n = 12$  transition of an electron in a particle-in-a-box system, what is the approximate length of the molecular box? [5]

**(b)** Treat a rotating HI molecule as a stationary I atom around which an H atom circulates in a plane at a distance of 161 pm. Calculate **(i)** the moment of inertia of the molecule, **(ii)** the greatest wavelength of the radiation that can excite the molecule into rotation. [5]

\*\*\*\*\*END\*\*\*\*\*