總分 100 分，共8 大題.

Useful physical constants:
Planck constant(\(h\)) = 6.626\times10^{-34} J\cdot s; \quad h/(2\pi) = 1.05\times10^{-34} J\cdot s
Electron mass = 9.11\times10^{-31} kg; \quad Electron charge = 1.6\times10^{-19} C

1. (10 points) Copper has lattice constant (a) = 0.36153 nm, mass density = 8.92\times10^6 g/m^3, and atomic mass = 63.546 g/mol. It is analyzed with an X-ray diffractometer.
   1) Show that the atomic arrangement is face-centered cubic (F.C.C.), with given data. (5 points)
   2) What’s the angle between the incident X-ray (wavelength = 0.1542 nm) beam and (200) crystal plane. (5 points)

2. (10 points) For a reaction \(A + B \rightarrow Z\) with a mechanism:
   \[ A + B \leftrightarrow X \] (with forward rate constant \(k_1\), backward rate constant \(k_0\))
   \[ X \rightarrow Z \] (with forward rate constant \(k_2\))
   1) Write differential rate equations for species \(A, B, X,\) and \(Z\). (4 points)
   2) Define the reaction rate as the formation rate of product \(Z\). While the concentration of \(X\) is small, there is consequently a steady state for \(X\). Present the reaction rate as a function of reactant concentrations. (3 points)
   3) While \(k_2\) is much greater than \(k_1\), try to simplify the equation obtained from the above question, and write the single rate-controlling step in the mechanism. (3 points)

3. (10 points) For an electron in 3d orbitals of a hydrogenlike atom,
   1) Give the orbital angular momentum of an electron. (2 pt)
   2) Give the possible values of \(z\) component of orbital angular momentum. (3 pt)
   3) Give the possible values of \(z\) component of magnetic dipole moment. (3 pt)
   4) Give the total spin angular momentum. (2 pt)

4. (10 points) An electron has a kinetic energy of \(1.602\times10^{-17} J\),
   1) Find the momentum of an electron. (3 pt)
   2) Find the wavelength of an electron. What’s the wavenumber? (4 pt)
   3) If the uncertainty in the position of the electron is 1 nm, use the Heisenberg uncertainty principle to find the uncertainty of momentum. (3 pt)
5. (10 points) Given the wavefunction for 1s electron in hydrogenlike atom (atomic number \( Z \)):
\[
\Psi = \pi^{-1/2}(Z/a_0)^3 \exp(-Zr/a_0)
\]
where \( r \) is distance between the nucleus and electron.

1) Give the physical meaning of \( a_0 \) in the above expression. What is its numerical value? (3 pt)
2) Define radial probability density, and find the probability for the electron appearing between \( r = 0.5a_0 \) and \( r = 0.6a_0 \). (Note: You don't need to evaluate the value of integral.) (4 pt)
3) The ionization energy of hydrogen is 13.6 eV. What's the binding energy for the electron in Li\(^{2+} \) ion? (Z of Li atom = 3) (3 pt)

6. The van der Waals equation is common used to describe the real gas behavior. For one mole of gas, it is written as
\[
(P + a/V^2)(V - b) = RT
\]

Where \( P \) is the measured pressure of the gas, \( a/V^2 \) is a correction term for the interactions which occur among the particles of the gas, \( V \) is the measured volume of the gas, and \( b \) is a correction term for the finite volume of the particles. Please show the "a" and "b" with critical properties of the gas in the van der Waals equation. Where \( T_c, P_c, \) and \( V_c \) are the critical temperature, pressure and volume of the gas.

(15 points)

7. (a) What is the Giggs-Duhem (G-D) equation? (5 points)
(b) Use the G-D equation, please show the following equations,
\[
\overline{M_1} = M + x_1 \frac{dM}{dx},
\]
\[
\overline{M_2} = M - x_1 \frac{dM}{dx},
\]
where the \( \overline{M_1} \) & \( \overline{M_2} \) are the partial properties of \( M_1 \) and \( M_2 \).

M can be expressed as \( G, H \) and \( V \). (15 points)

8. Explain the following terms:
(a) Phase Rule. (5 points)
(b) First Law of Thermodynamics. (5 points)
(c) excess property. (5 points)