CHM320 EXAM #1 USEFUL INFORMATION

Constants

mass of electron: \( m_e = 9.11 \times 10^{-31} \) kg.

Rydberg constant: \( R_H = 109737.35 \text{ cm}^{-1} = 2.1798 \times 10^{-18} \text{ J} \).

speed of light: \( c = 3.00 \times 10^8 \text{ m/s} \)

Planck constant: \( 6.626 \times 10^{-34} \text{ Js} \)

\( \kappa = \frac{1}{4\pi\varepsilon_0} = 8.99 \times 10^9 \text{ kgm}^3/c^2s^2 \)

charge of electron: \( e = 1.6 \times 10^{-19} \text{ C} \)

Bohr radius: \( a_0 = 52.9 \text{ pm} \)

Avogadro’s number: \( N_A = 6.02 \times 10^{23} \text{ mol}^{-1} \)

Unit Conversion

1 J = 1 kgm^2/s^2

1 eV = 1.6 \times 10^{-19} \text{ J}.

1 J = 5.03 \times 10^{22} \text{ cm}^{-1}

1 amu = 1.67 \times 10^{-27} \text{ kg}.

1 Å = 1.0 \times 10^{-10} \text{ m}.

1 N (newton) = 1 kg·m/s^2

Formula

(1) Energy of a particle in classical mechanics: \( E = \text{kinetic (} T \text{) + potential (} V \text{)} \)

\[ E = T + V = \frac{p^2}{2m} + V \]

where \( p \) is the linear momentum \( (p = \text{mv}) \). Force is related to the potential energy as \( F = -\nabla V \). For one-dimensional system, \( F = -\frac{dV}{dx} \).
(2) Electromagnetic wave (classical view):

\[ E(x,t) = E_0 \sin(kx - \omega t) \]

where \( k = \frac{2\pi}{\lambda} \) (wavenumber) and \( \omega = 2\pi \nu \) (angular frequency). \( E_0 \) is called the amplitude of wave. The period of oscillation is \( \Gamma = \frac{1}{\nu} \). \( \lambda \) is the wavelength and \( \nu \) is the frequency of oscillation. The frequency and wavelength of light are related through the speed of light \( (c) \) as

\[ \nu = \frac{c}{\lambda} \]

(3) Photoelectric Effect:

\[ T_e = E_{\text{photon}} - \Phi \]

where \( T_e \) is the kinetic energy of ejected electron and \( \Phi \) is the work function. The photon energy is given by

\[ E_{\text{photon}} = h\nu = \frac{c}{\lambda} = h\tilde{\nu} \]

where \( c \) is the speed of light and \( \tilde{\nu} = \frac{1}{\lambda} \).

(4) Rydberg formula for hydrogen atom emission spectra:

\[ \tilde{\nu} (\text{cm}^{-1}) = \frac{1}{\lambda} = R_H \left( \frac{1}{n_1^2} - \frac{1}{n_2^2} \right) \]

where \( n_2 > n_1 \) and \( R_H \) is the Rydberg constant in cm\(^{-1}\). Lymann, Balmer and Paschen series of emission lines involve \( n_1 = 1, 2, \) and \( 3, \) respectively.

(5) de Broglie hypothesis:

\[ \lambda = \frac{h}{p} \]

(6) Classical physics of angular motion:

1. angular momentum: \( l = pr \).
2. kinetic energy: \( T = \frac{p^2}{2mr^2} \)
3. centripetal force: \( F_{\text{cent}} = \frac{r^2}{mr^2} \)
(7) Bohr model of hydrogen atom:

**Postulate:** Angular momentum is quantized, \( l = n\hbar \)

\[
E_n = -\left( \frac{\kappa m_e e^4}{2\hbar^2} \right) \frac{1}{n^2} = -\frac{R_H}{n^2}, \quad n = 1, 2, 3, ..
\]

where \( \kappa = \frac{1}{4\pi\epsilon_0} \) and \( R_H \) is the Rydberg constant.

(8) Uncertainty Principle:

\[
\Delta x \Delta p = \hbar
\]

(9) Schrodinger Equation (1-dimensional):

\[
-\frac{\hbar^2}{2m} \frac{d^2\psi(x)}{dx^2} + V(x)\psi(x) = E\psi(x)
\]

(10) Probability:

Probability to find the particle with wavefunction \( \psi(x) \) between \( x = a \) and \( x = b \) is given by

\[
P = \int_a^b |\psi(x)|^2 dx
\]

**Normalization condition:** Since the particle should be found somewhere, sum of all probability must be equal to 1.

\[
\int_{-\infty}^{\infty} |\psi(x)|^2 dx = 1
\]

(11) Particle in a box (1-dimensional, \( 0 < x < a \))

\[
\psi(x) = \sqrt{\frac{2}{a}} \sin \left( \frac{n\pi x}{a} \right)
\]

\[
E_n = \left( \frac{\hbar^2}{8ma^2} \right) n^2
\]

where \( a \) is the box length.
Math formula

(1) Integral formula:
\[ \int \sin^2 ax \, dx = \frac{x}{2} - \frac{\sin(2ax)}{4a}, \quad \int \cos^2 ax \, dx = \frac{x}{2} + \frac{\sin(2ax)}{4a}, \]

(2) Trigonometric relation:
\[ \sin \alpha \sin \beta = \frac{1}{2} [\cos(\alpha - \beta) - \cos(\alpha + \beta)] \]
\[ \sin(A \pm B) = \sin A \cos B \pm \cos A \sin B \]

(3) Gaussian integral:
\[ \int_{-\infty}^{\infty} e^{-\alpha x^2} \, dx = \sqrt{\frac{\pi}{\alpha}} \]

(4) Integral formula:
\[ \int_{0}^{\infty} x^2 e^{-ax} \, dx = \frac{2}{a^3} \]