

CHEM 4616: Exam #1

Name: _____ ID#: _____

Some potentially useful information:

- $h = 6.6261 \times 10^{-34}$ J s (Planck's constant)
- $\hbar = h/2\pi = 1.0546 \times 10^{-34}$ J s
- Speed of light in a vacuum, $c = 2.9979 \times 10^8$ m s⁻¹
- Mass of an electron, $m_e = 9.1094 \times 10^{-31}$ kg
- Mass of a hydrogen atom, $m_H = 1.0078$ amu
- Mass of a deuterium atom, $m_D = 2.0140 \approx 2m_H$ amu
- Rydberg constant for a hydrogenic atom of atomic number Z , $\mathcal{R}_H = 109737 Z^2$ cm⁻¹
- 1 eV = 1.6022×10^{-19} J
- 1 J = 1 N m = 1 kg m² s⁻²
- 1 Å = 1.0×10^{-10} m

Mathematical identities:

$$\sin^2 \alpha = \frac{1}{2} - \frac{1}{2} \cos 2\alpha$$

$$\sin \alpha \sin \beta = \frac{1}{2} \cos(\alpha + \beta) - \frac{1}{2} \cos(\alpha - \beta)$$

Multiple Choice Questions (5 points each):

(1) Max Planck won the Nobel prize in physics in 1918 for his explanation of what physical phenomenon:

- (a) The photoelectric effect.
- (b) Blackbody radiation.
- (c) The structure of DNA.
- (d) General relativity.
- (e) All of the above.

(2) Which of the following is the correct electron configuration of the Cr atom?

- (a) $[\text{Ar}] 4s^2 3d^4$
- (b) $[\text{Ar}] 4s^1 3d^5$
- (c) $[\text{Ar}] 3d^6$
- (d) $[\text{Ar}] 3d^7$
- (e) $[\text{Ar}] 3d^8$

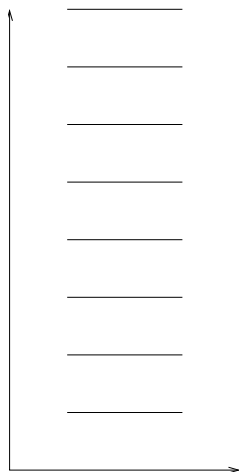
(3) Which of the following is the **correct** expression for the quantized energy of a hydrogenic atom with quantum number n :

- (a) $E_n = \hbar \sqrt{\frac{k}{\mu}} (n + \frac{1}{2})$
- (b) $E_n = \sqrt{\frac{2}{l}} \sin(\frac{n\pi x}{l})$
- (c) $E = \frac{3}{2} k_B T$
- (d) $E_n = \frac{\hbar^2 \pi^2 n^2}{2ml^2}$
- (e) $E_n = -\frac{m_e Z^2 e^4}{2(4\pi\epsilon_0)\hbar^2 n^2}$

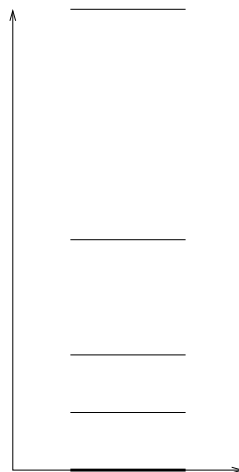
(4) Which of the following is an **incorrect** statement about the one-dimensional particle-in-a-box model:

- (a) All of the energy is kinetic.
- (b) The energy levels are equally spaced.
- (c) As the width of the box decreases, the uncertainty in the particle's position decreases.
- (d) The number of nodes in the wave function increases with the quantum number.
- (e) The ground state has non-zero total energy.

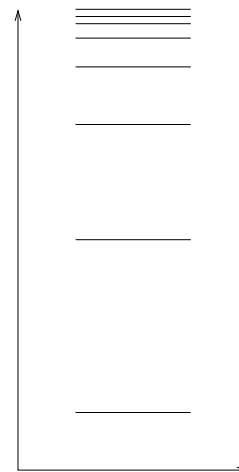
(5) Which of the following schematic diagrams correctly represents the energy levels of a hydrogen atom?



(a)



(b)



(c)

(1) (35 points) Calculate the ionization energy (in eV) of the Be^{3+} cation. Show your work.

(2) (35 points) The radial wave function for a $3p$ electron in a hydrogen atom is

$$R_{3,1}(r) = \frac{8}{27\sqrt{6a_0^5}} \left(1 - \frac{1}{6a_0}r\right) r \exp^{-r/3a_0}$$

Locate the node(s) in this wave function.

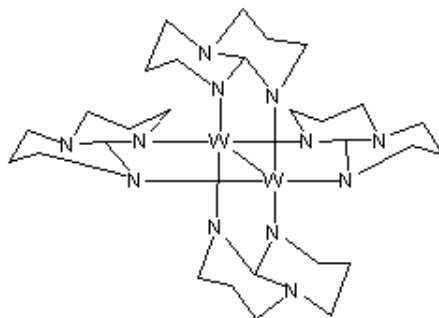
(3) (35 points) For the ground state of a particle in a one-dimensional box of width L , calculate the probability that the particle is located in the left half of the box. Show your work.

(4) (35 points) Use the following equation to calculate the wavelength (in nm) of the electronic transition in linear polyenes for $N = 6, 8,$ and 10 :

$$\lambda = \frac{8m_e L^2 c}{h(N + 1)}$$

To estimate the length of the polyene, L , use values of 1.54 \AA for each C–C single bond, 1.35 \AA for each C–C double bond, and include 0.77 \AA for the radius of each C atom at the ends of the chain. Show your work.

(5) (35 points) Ditungstentetra(hexahydropyrimidopyrimidine) (abbreviated $W_2(hpp)_4$) was first synthesized in 2002 at Texas A&M University and was shown to have the lowest ionization energy of any known element or non-transient, neutral compound. If $W_2(hpp)_4$ is exposed to a 300 nm UV photon, an electron is ejected with a speed of 4.681×10^5 m/s.



(a) What is the de Broglie wavelength of the ejected electron (in nm)?

(b) What is the ionization energy of $W_2(hpp)_4$ (in eV)?