2024 Fall Semester Mid-term Examination

General Chemistry I

Date: October 23(Wed), Time: 19:00 - 21:00

Please enter your information neatly in the spaces provided below; print your Student ID in the upper right corner of every page.

Professor's Name	Class	Student I.D. Number	Student Name

Problem	Point tally	Problem	Point tally	TOTAL Points
1	/20	**6**	/10	**/100**
2	/6	**7**	/10	
3	/18	**8**	/6	
4	/10	**9**	/10	
5	/10			

** This paper consists of XX pages with 9 problems (***pages XX - XX***: Equation, constants & periodic table, ***page XX***: claim form). Please check that all pages are present before taking the exam; if something is missing, the TA's will assist you. Supply your work and enter answers on the Answer sheet. Please write down the unit of your answer when applicable. You will get 30% deduction for a missing unit.

NOTICE: SCHEDULES on RETURN and CLAIM of the MARKED EXAM PAPER.
(채점 답안지 분배 및 이의신청 일정)

1. Period, Location and Procedure

- Return and Claim Period: **October 28 (Monday, 19:00 - 21:00, 2 hrs)**
  The claim is permitted only on this period. Keep that in mind!
- Location: Designated rooms in the Creative Learning Bldg. (Building E11)

Course Section	Room (Building E11)
A	201
C	202

D	301

- Procedure

Rule 1: Students cannot bring writing tools into the rooms (Use a pen only provided by TA)
Rule 2: With or without making a claim, you must submit the paper back to TA. (Do not go out of the room with the exam)

If you have any claims, write them on the claim form and attach it to the top of the exam paper with a staple.
Give the papers to your TA.

WARNING!!
Please don't cheat. If you deliberately alter any the original answers or insert something on your marked paper in an attempt to achieve a better grade, you will get a F grade for this course. Or if you don't keep the rules above, we will regard it as a kind of cheating and give you 0 points.

2. Final Confirmation

1) Period: ***October 31 (Thu.) ~ November 1 (Fri.)***
2) Procedure: During this period, you can check final score of the examination *on the website* again.
(No additional corrections will be made. If no change was made in your score after your reasoning was submitted and reviewed, the claim(s) were not accepted.)

***** For further information, please visit General Chemistry website at www.gencheminkaist.pe.kr***

1. (20 points)

Answer the following questions: (5 pts each)

(1) Provide ground-state electronic configurations for all first- and second-period atoms.

(2) Employing Bohr's assumptions, derive the de Broglie wavelength equation for an electron engaged in circular standing wave oscillations around the atomic nucleus.

(3) (a) Explain the Born-Oppenheimer approximation and (b) provide the potential energy expression for H_2^+ while employing this approximation.

(4) (a) What is the Linear Combination of Atomic Orbitals (LCAO)? (b) Explain how the molecular orbitals $3\sigma_g$ and $3\sigma^*_u$ can be understood using the LCAO approach.

(answer)

(1) H: $1s^1$, He: $1s^2$, Li: $1s^2 2s^1$, Be: $1s^2 2s^2$. B: $1s^2 2s^2 2p_x^1$ (or $2p^1$), C: $1s^2 2s^2 2p_x^1 2p_y^1$ (or $2p^2$)
N: $1s^2 2s^2 2p_x^1 2p_y^1 2p_z^1$ (or $2p^3$), O: $1s^2 2s^2 2p_x^2 2p_y^1 2p_z^1$ (or $2p^4$), F: $1s^2 2s^2 2p_x^2 2p_y^2 2p_z^1$ (or $2p^5$),
Ne: $1s^2 2s^2 2p_x^2 2p_y^2 2p_z^2$ (or $2p^6$)

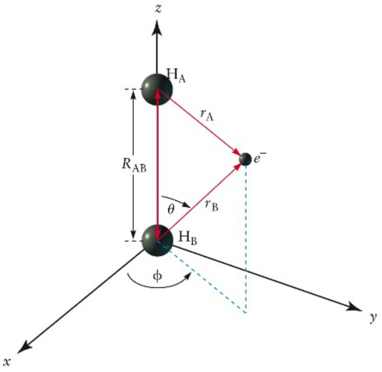
(2) The electron with a circular standing wave oscillating about the nucleus of the atom.

$n\lambda = 2\pi r \qquad n = 1, 2, 3, \ldots$ (1pts)

From Bohr's assumption, $m_e v r = n\frac{h}{2\pi}$ $\quad 2\pi r = n\frac{h}{m_e v}$, $\boldsymbol{\lambda = \frac{h}{m_e v} = \frac{h}{p}}$ (4 pts)

(3) (a) A nucleus is much more massive than an electron is; the nuclei in the molecules will move much more slowly than the electrons. **Consider the nuclei to be fixed at a specific set of positions. Then solve Schrödinger's equation for the electrons which are in motion; obtain the energy levels and wave functions**. Next, move the nuclei a bit, and repeat the calculation. Continue this procedure in steps. (key idea: bold fold, 3pts)

(b) $$\mathbf{V} = -\frac{e^2}{4\pi\varepsilon_0}\left(\frac{1}{r_A}+\frac{1}{r_B}\right)+\frac{e^2}{4\pi\varepsilon_0}\left(\frac{1}{R_{AB}}\right)$$



(2 pts)

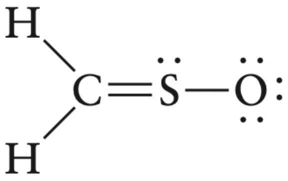
(4) (a) LCAO method: selecting sums and differences (linear combinations) of atomic orbitals to

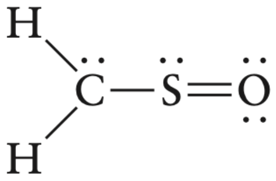
generate the best approximation to each type of molecular orbital (3 pts)

(b) $3\sigma_g = \sigma_{g2p_z} = C_g[2p_z^A - 2p_z^B]$, $3\sigma_u^* = \sigma_{u2p_z}^* = C_u[2p_z^A + 2p_z^B]$ (2 pts)

2. (6 points)

Two possible Lewis diagrams for sulfine (H_2CSO) are:



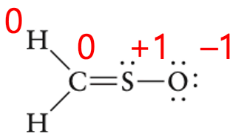


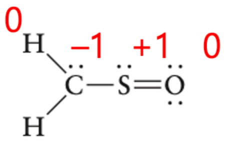
(a) (4 pts) Compute the formal charges on all atoms in both Lewis diagrams.

(b) (2 pts) Draw a Lewis diagram for which all the atoms in sulfine have formal charges of zero.

(answer)

(a) (2 points for each diagram, awarded for correctly assigning the formal charges.)

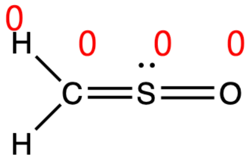




- For H: 1 – 0 – 1 = 0
- For C: 4 – 0 – 4 = 0
- For S: 6 – 2 – 3 = 1
- For O: 6 – 6 – 1 = –1

- For H: 1 – 0 – 1 = 0
- For C: 4 – 2 – 3 = –1
- For S: 6 – 2 – 3 = 1
- For O: 6 – 4 – 2 = 0

(b) (Full point for the correct Lewis structure where all formal charges are zero.)



- For H: 1 – 0 – 1 = 0
- For C: 4 – 0 – 4 = 0
- For S: 6 – 2 – 4 = 0
- For O: 6 – 4 – 2 = 0

3. (18 points)

Consider a particle confined in a one-dimensional box (also known as an infinite potential well) with length L. The potential energy inside the box is zero, and the potential outside the box is infinitely large, so the particle is restricted to move only within the box.

(a) (13 pts) Using the Schrödinger equation, derive the allowed energy levels for a particle confined in this box. What are the energy levels E_n of the particle, and how do they depend on the mass of the particle m, the length of the box L, and the quantum number n?

(b) (5 pts) Calculate the energy of a particle with mass 9.11×10^{-31} kg (mass of an electron) in the first energy level (electron $n = 1$) when the box length is 1.00 nm. Provide your answer in eV.

(answer)

The time-independent Schrödinger equation is given by: (2 pts)

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

For a particle in a one-dimensional box of length L, the potential energy V(x) is: (1 pt)

$$V(x) = \begin{cases} 0, 0 \le x \le L \\ \infty, \ \ x < 0 \; or \; x > L \end{cases}$$

Inside the box, where V(x) = 0, the Schrödinger equation simplifies to: (1 pt)

$$-\frac{\hbar^2}{2m}\frac{d^2}{dx^2}\psi(x) = E\psi(x)$$

Rearranging:

$$\frac{d^2}{dx^2}\psi(x) = \frac{-2mE}{\hbar^2}\psi(x)$$

Let $k^2 = \frac{2mE}{\hbar^2}$, the equation becomes:

$$\frac{d^2}{dx^2}\psi(x) = -k^2\psi(x)$$

The general solution to this differential equation is:

$$\psi(x) = A\sin(kx) + B\cos(kx)$$

Boundary conditions:

At x = 0, $\psi(0) = 0$, so B = 0, leaving $\psi(x) = A\sin(kx)$.

At x = L, $\psi(L) = 0$, so $A\sin(kL) = 0$.

For a non-trivial solution (A ≠ 0), $kL = n\pi$, where n is a positive integer.

Thus, $k = \frac{n\pi}{L}$, where n = 1, 2, 3,... (5 pts)

Energy levels E_n: (4 pts)

Since $k^2 = \frac{2mE}{\hbar^2}$, we can now express the energy E as:

$$E_n = \frac{\hbar^2 k^2}{2m} = \frac{n^2\pi^2\hbar^2}{2mL^2} = \frac{n^2h^2}{8mL^2}$$

This gives the allowed energy levels for the particle in a one-dimensional box, where n is the quantum number, m is the mass of the particle, and L is the length of the box.

(b) Calculating the energy for an electron in the first energy level:

Given:

- Mass of electron, m = 9.11 × 10^{-31} kg
- Length of the box, L = 1.00 nm = 1.00 × 10^{-9} m
- Quantum number for the first energy level, n = 1
- Reduced Planck's constant, $\hbar = \frac{h}{2\pi}$ = 1.05 × 10^{-34} J·s

The energy of the particle in the first energy level E_1 is:

$$E_1 = \frac{\pi^2 \times (1.05 \times 10^{-34}\, kg \cdot m^2/s)^2}{2 \times (9.11 \times 10^{-31}\, kg) \times (1.00 \times 10^{-9}\, m)^2}$$

Numerator: $\pi^2 \times (1.05 \times 10^{-34}\, kg \cdot m^2/s)^2$ ≈ 1.08 × 10^{-67} $J^2 \cdot s^2$

Denominator: $2 \times (9.11 \times 10^{-31}\, kg) \times (1.00 \times 10^{-9}\, m)^2$ ≈ 1.822 × 10^{-48} kg·m^2

E_1 ≈ 5.93 × 10^{-20} J

To convert this energy into electron volts (eV), use the conversion factor 1.000 eV = 1.602 × 10^{-19} J:

E_1 ≈ 0.370 eV

Incorrect answer but correct equation (3 pts)

4. (10 points)

For many-electron atoms, the Hartree approximation is used to describe the electronic structure, taking into account electron-electron interactions.

(a) (4 pts) Briefly explain the Hartree approximation and how it simplifies the many-electron Schrödinger equation.

(b) (4 pts) What is the effective nuclear charge (Z_{eff}) experienced by an electron in a many-electron atom? How does the effective nuclear charge differ from the actual nuclear charge, and what factors influence Zeff?

(c) (2 pts) Calculate the effective nuclear charge (Z_{eff}) for a 2p electron in a carbon atom, given that the screening constant for this electron is 1.96.

(answer)

(a) The Hartree approximation simplifies the treatment of many-electron atoms by assuming that each electron moves independently in an average potential created by the nucleus and the other electrons. In a full, many-electron system, the Schrödinger equation for NNN electrons involves complex terms accounting for the interactions between all electrons. The Hartree approximation decouples these interactions by treating the potential experienced by each electron as a mean field, allowing the overall wavefunction of the system to be written as a product of individual electron wavefunctions (orbitals). The resulting set of coupled differential equations is called the Hartree equations. Each equation is solved iteratively to approximate the behavior of the system by adjusting the potential for each electron until a self-consistent solution is found.

1. Each electron moves in an effective field created by the nucleus and all the other electrons, and the effective field for electron i depends only on its position r_i
2. The effective field for electron i is obtained by averaging its Coulomb potential interactions with each of the other electrons over all the positions of the other electrons so that ri is the only coordinate in the description.
3. The effective field is spherically symmetric, that is, it has no angular dependence

(b) The effective nuclear charge (Z_{eff}) is the net positive charge experienced by an electron in a multi-electron atom. It accounts for the actual nuclear charge Z (the number of protons in the nucleus) reduced by the shielding or screening effect caused by other electrons.

In a many-electron atom, inner electrons partially shield outer electrons from the full nuclear charge. As a result, the outer electrons experience a lower effective nuclear charge than the actual charge of the nucleus. The effective nuclear charge is thus calculated as:

$Z_{\mathrm{eff}} = Z - \sigma$

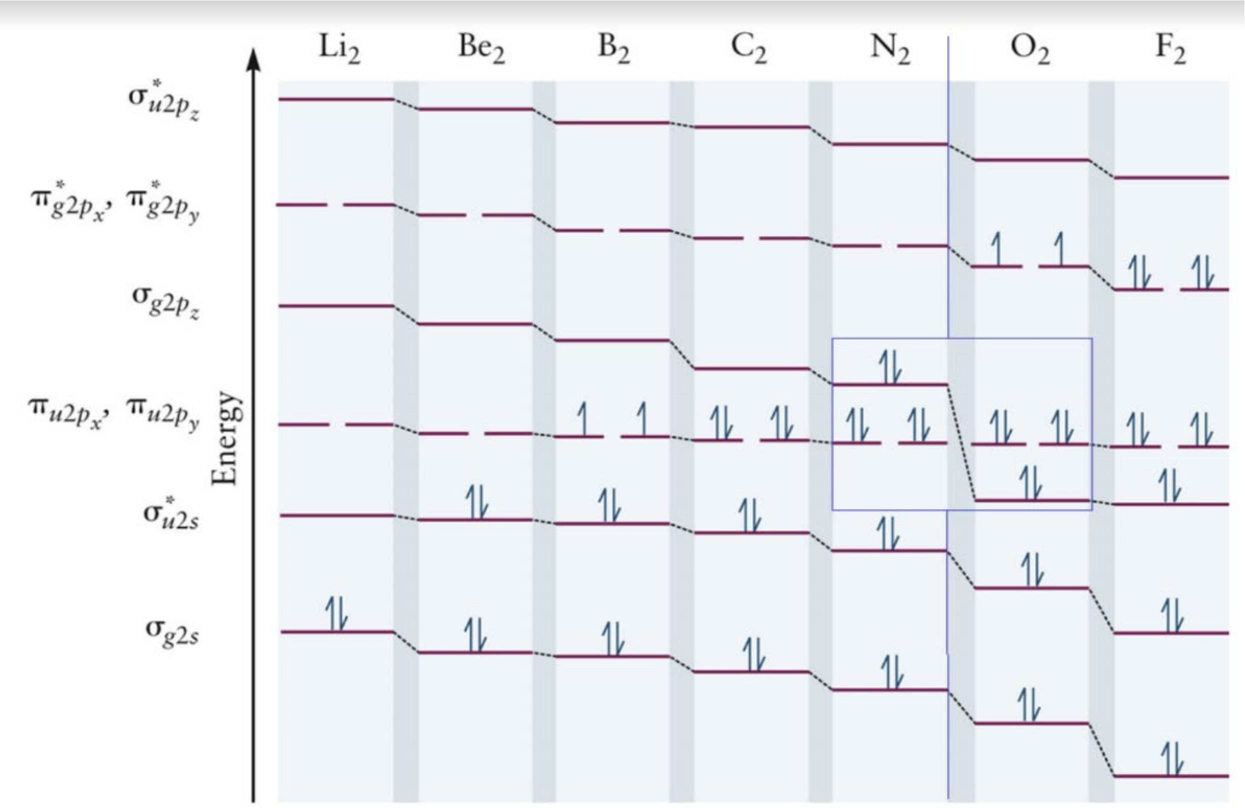
where Z is the actual nuclear charge and σ is the screening constant, which represents the amount of shielding provided by the other electrons.

Factors influencing ZeffZ_{\text{eff}}Zeff include the number of inner-shell electrons, the distance of the electron from the nucleus, and the specific orbital in which the electron resides.

(c) For a carbon atom ($Z = 6$), we want to calculate the effective nuclear charge for a 2p electron. The screening constant (σ) for this electron is given as 1.96.

$Z_{\text{eff}} = 6 - 1.96 = 4.04$

5. (10 points)



Energy levels for the homonuclear diatomics Li_2 through F_2

(1) (5 pts) In the graphic, as presented and discussed in our lecture, there is an inversion of two orbital energy levels (shown in the rectangular box). This inversion is found in the description of the dinitrogen and the neighboring dioxygen molecules. What is the reason for this inversion?

(2) (3 pts) What interesting and particular property is found for O_2 (and B_2) and what experiment was used to demonstrate this property (for O_2)?

(3) (2 pts) The parallel spin configuration of the unpaired electrons is in accord with which rule?

(answer)

(1) For N_2, the large electron-electron spatial repulsions between electrons in σ_{g2pz} and σ^*_{u2s} molecular orbitals (MO's).
For O_2, as Z increases, the repulsion decreases since electrons in MO's are drawn more strongly toward the nucleus (stabilization of σ_{g2pz}).
Only one answer: 3 pts

(2) Dioxygen (and diboron) is paramagnetic; liquid oxygen ($O_{2(l)}$) poured between the two poles of a magnet is attracted and held there.

(3) Hunt's rule

6. (10 points)

Answer the following questions regarding the Reactive Oxygen Species (ROS), which are generated through the addition of one electron to dioxygen (O_2) resulting in O_2^- (superoxide) or through the addition of two electrons to dioxygen generating O_2^{2-} (peroxide). ROS can be harmful in biological systems, prompting organisms to develop mechanisms to eliminate them.

(a) (3 pts) Using only the 2*s* and 2*p* orbitals and with the z-axis aligned parallel to the O-O bond, draw correlation diagrams for O_2, O_2^-, O_2^{2-}. All molecular orbitals should be labeled.

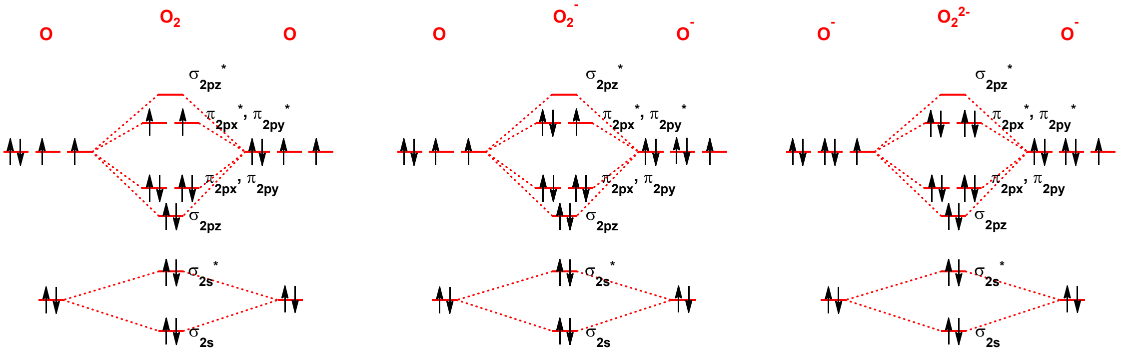
(b) (2 pts) Are these three species paramagnetic or diamagnetic?

(c) (3 pts) Explain why certain enzymes in biological systems would be designed to introduce two electrons to O_2, causing the cleavage of the (formal) double bond in O=O?

(d) (2 pts) Do the first ionization energies of these ROS increase or decrease compared to that of the oxygen atom? Support your answer with "correlation diagrams".

(answer)

(a) 3 points (1 point each)



(b) **2 points (1 point each)** O_2 and O_2^- are paramagnetic, whereas O_2^{2-} is diamagnetic

(c) **3 points (no discussion of bond orders, 1 point)** The bond orders of O_2, O_2^- and O_2^{2-} are 2, 3/2 and 1, respectively. In terms of bond order, O_2^{2-} has the weakest O-O bond strength. So, the bond can be readily dissociated.

(d) **2 points** Those species have electrons in the antibonding orbital originated from the oxygen *p*-orbital (π_{2px}^* and π_{2py}^*). This antibonding orbital has higher energy than that of the original *p*-orbital so, they have lower ionization energies.

7. (10 points)

An electron is confined to a 1.2 nm one-dimensional box. Considering that “visible light” has a wavelength between 400 nm and 700 nm, (a) & (b), determine whether the following transition is observed within the visible spectrum.

The energy is given as

$$E_n = \frac{n^2 h^2}{8mL^2}$$

(a) (3 pts) n = 2 to n = 1

(b) (3 pts) n = 3 to n = 1

(c) (4 pts) Suppose this electron undergoes transitions among all possible states, and several visible spectral lines are observed as a result of these transitions. How many visible spectral lines then must be observed?

(a)

$$E_2 - E_1 = (2^2 - 1^2) \cdot \frac{h^2}{8mL^2} = \frac{3h^2}{8mL^2} = \frac{3 \times (6.626 \times 10^{-34} J\, s^{-1})^2}{8 \times (9.109 \times 10^{-31}\, kg) \times (1.2 \times 10^{-9}\, m)^2}$$

$$= 1.3 \times 10^{-19} J = h\frac{c}{\lambda} \ldots + 1 \text{ pt}$$

$$\therefore \lambda = \frac{hc}{E_2 - E_1} = \frac{(6.626 \times 10^{-34} J\, s^{-1}) \times (2.998 \times 10^{8}\, m\, s^{-1})}{1.3 \times 10^{-19} J} = 1520\, nm \ldots + 2\, pt$$

It is above 700 nm, so it does NOT result in the visible spectrum.

(b)

$$E_3 - E_1 = (3^2 - 1^2) \cdot \frac{h^2}{8mL^2} = \frac{8h^2}{8mL^2} = \frac{8 \times (6.626 \times 10^{-34} J\, s^{-1})^2}{8 \times (9.109 \times 10^{-31}\, kg) \times (1.2 \times 10^{-9}\, m)^2}$$

$$= 3.3 \times 10^{-19} J = h\frac{c}{\lambda} \ldots + 1 \text{ pt}$$

$$\lambda = \frac{hc}{E_2 - E_1} = \frac{(6.626 \times 10^{-34} J\, s^{-1}) \times (2.998 \times 10^{8}\, m\, s^{-1})}{3.3 \times 10^{-19} J} = 600\, nm \ldots + 2 \text{ pt}$$

It is within the 400 nm – 700 nm region, so it DOES result in the visible spectrum.

(c)

For any transition from n_i to n_f where i > f,

$$\lambda = \frac{hc}{\Delta E} = hc \times \frac{8mL^2}{(n_i^2 - n_f^2)h^2} = \frac{8mcL^2}{(n_i^2 - n_f^2)h}$$

$$= \frac{8 \times (9.109 \times 10^{-31}\, kg) \times (2.998 \times 10^{8}\, m\, s^{-1}) \times (1.2 \times 10^{-9}\, m)^2}{(n_i^2 - n_f^2) \times (6.626 \times 10^{-34} J\, s^{1})} = \frac{4750\, nm}{n_i^2 - n_f^2}$$

In order to fall in the visible region:

$$400\, nm < \frac{4750\, nm}{n_i^2 - n_f^2} < 700\, nm \ldots + 2 \text{ pt}$$

$$6.78 < n_i^2 - n_f^2 < 11.9$$

There are four transitions satisfying this condition: 3 to 1, 4 to 3, 5 to 4, and 6 to 5. …+2 pt

Therefore, four visible spectral lines must be observed.

8. (6 points, each 2 pts)

The wave function of an electron in the lowest (that is, ground) state of the hydrogen atom is

$$\psi(r) = \left(\frac{1}{\pi {a_0}^3}\right)^{1/2} exp\left(-\frac{r}{a_0}\right)$$

$$\text{where} \quad a_0 = 0.529 \times 10^{-10}\, m$$

(a) What is the probability of finding the electron inside a sphere of volume 1.0 pm^3, centered at the nucleus (1 pm = 10^{-12} m)?

(b) What is the probability of finding the electron in a volume of 1.0 pm^3 at a distance of 52.9 pm from the nucleus, in a fixed but arbitrary direction?

(c) What is the probability of finding the electron in a spherical shell of 1.0 pm in thickness, at a distance of 52.9 pm from the nucleus?

(answer)

(a) Since 1.0 pm^3 is small enough to assume the constant probability density for the given volume,

$$P = |\psi(r)|^2 \times (10^{-36}\, m).$$

$$\left(\frac{1}{\pi {a_0}^3}\right) exp\left(\frac{0}{a_0}\right) \times (1.0 \times 10^{-36}\ m^3) = \frac{1}{\pi \times 0.529^3} \times 10^{-6} \approx 2.15 \times 10^{-6}$$

(b) $\left(\frac{1}{\pi {a_0}^3}\right) exp\left(-\frac{2a_0}{a_0}\right) \times (1.0 \times 10^{-36}\ m^3) = \frac{1}{\pi \times e^2 \times 0.529^3} \times 10^{-6} \approx 2.91 \times 10^{-7}$

(c)

(i)

$$\frac{1}{\pi(0.529 \times 10^{-10})} \int_{52.4\times10^{-12}}^{53.4\times10^{-12}} r^2 e^{-\frac{2r}{0.529 \times 10^{-10}}} dr \int_0^{\pi} sin\theta\, d\theta \int_0^{2\pi} d\varphi =$$

$$\frac{4\pi}{\pi(0.529 \times 10^{-10})} \int_{52.4\times10^{-12}}^{53.4\times10^{-12}} r^2 e^{-\frac{2r}{0.529 \times 10^{-10}}} dr = \frac{4}{(0.529\times10^{-10})^3} \times 3.78712 \times 10^{-12} \approx 0.0102$$

(ii)

$$\left(\frac{1}{\pi {a_0}^3}\right) exp(-2) \times \frac{4\pi}{3}\{(53.4 \times 10^{-12})^3 - (52.4 \times 10^{-12})^3\} = 0.010234 \ldots \approx 0.0102$$

9. (10 points, 2 pts each)

(a) For a one-electron atom, list all possible values of the quantum numbers l and m when the principal quantum number $n = 3$.

(b) Name all the corresponding orbitals for the quantum numbers listed in part (a).

(c) For each one-electron orbital with n =3, plot the radial probability density ($r^2[R_{nl}(r)]^2$) as a function of the distance from the nucleus.

(d) Determine the number of radial nodes and angular nodes for each of the orbitals listed in part b.

(e) Compare the energy-level diagrams of all orbitals for a one-electron atom with those for a many-electron atom.

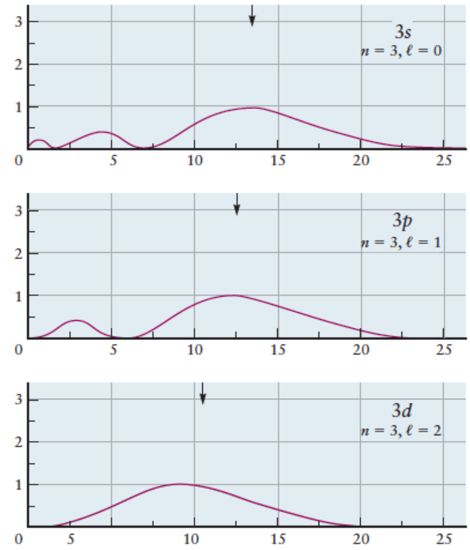
(answer)

(a) (2 pt)

n	3		
ℓ	0	1	2
m_l	0	-1, 0, +1	-2, -1, 0, +1, +2

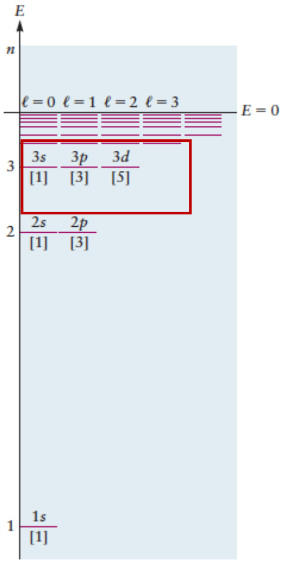
(b) (2 pt) *3s, 3p, 3d*

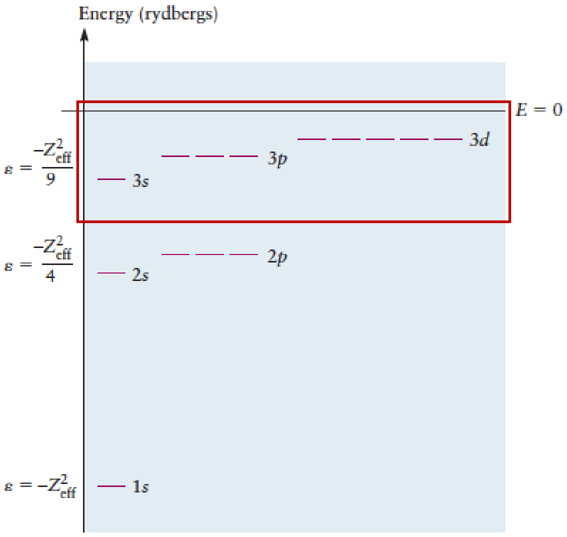
(c) (2 pts)



(d) (2 pts)
3s: 2 radial and 0 angular *3p*: 1 radial and 1 angular *3d*: 0 radial and 2 angular

(e) (2 pts)
(left) one-electron atom (contribution of n for energy level)
(right) many-electron atom (contribution of n and ℓ for energy level)


E
n
ℓ = 0
ℓ = 1
ℓ = 2
ℓ = 3
E = 0
3
3s
[1]
3p
[3]
3d
[5]
2
2s
[1]
2p
[3]
1
1s
[1]


Energy (rydbergs)
E = 0
$\varepsilon = \frac{-Z_{\text{eff}}^2}{9}$
3s
3p
3d
$\varepsilon = \frac{-Z_{\text{eff}}^2}{4}$
2s
2p
$\varepsilon = -Z_{\text{eff}}^2$
1s

Physical Constants

Avogadro’s number	N_A = 6.02214179 x 10^{23} mol^{-1}
Bohr radius	a_0 = 0.52917720859 Å = 5.2917720859x10^{-11} m
Boltzmann’s constant	K_B = 1.3806504 x 10^{-23} J K^{-1}
Electronic charge	e = 1.602176487 x 10^{-19} C
Faraday constant	F = 96485.3399 C mol^{-1}
Masses of fundamental particles:	
Electron	m_e = 9.10938215 x 10^{-31} kg
Proton	m_P = 1.672621637 x 10^{-27} kg
Neutron	m_n= 1.674927211 x 10^{-27} kg
Permittivity of vacuum	ε_o = 8.854187817 x 10^{-12} C^{-2} J^{-1} m^{-1}
Planck’s constant	h = 6.62606896 x 10^{-34} J s
Ratio of proton mass to electron mass	m_P / m_e = 1836.15267247
Speed of light in a vacuum	c = 2.99792458 x 10^{8} m s^{-1} (exactly)
Standard acceleration of terrestrial gravity	g = 9.80665 m s^{-2} (exactly)
Universal gas constant	R = 8.314472 J mol^{-1} K^{-1}
	= 0.0820574 L atm mol^{-1} K^{-1}

Values are taken from the 2006 CODATA recommended values,
as listed by the National Institute of Standards and Technology.

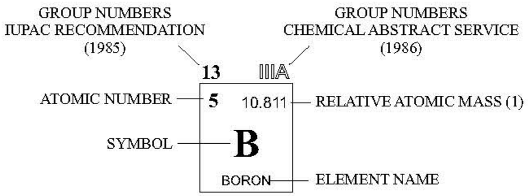
Conversion factors

Ångström	1 Å= 10^{-10} m
Atomic mass unit	1 u = 1.660538782 x 10^{-27} kg
	1 u = 1.492417830 x 10^{-10} J = 931.494028 MeV (energy equivalent form $E = mc^2$)
Calorie	1 cal = 4.184 J (exactly)
Electron volt	1 eV = 1.602177 x 10^{-19} J = 96.485335 kJ mol^{-1}
Foot	1 ft = 12 in = 0.3048 m (exactly)
Gallon (U. S.)	1 gallon = 4 quarts = 3.785412 L (exactly)
Liter	1 L = 10^{-3} m^3 = 10^3 cm^3 (exactly)

Liter-atmosphere	1 L atm = 101.325 J (exactly)
Metric ton	1 t = 1000 kg (exactly)
Pound	1 lb = 16 oz = 0.4539237 kg (exactly)
Rydberg	1 Ry = 2.17987197 x 10^{-18}J = 1312.7136 kJ mol^{-1} = 13.60569193 eV
Standard atmosphere	1 atm = 1.01325 x 10^5 Pa = 1.01325 x 10^5 kg m^{-1} s^{-2} (exactly)
Torr	1 torr = 133.3224 Pa

PERIODIC TABLE OF THE ELEMENTS

http://www.ktf-split.hr/periodni/en/



PERIOD \ GROUP	1 IA	2 IIA	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8	9 VIIIB	10	11 IB	12 IIB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA
1	1 1.0079 **H** HYDROGEN																	2 4.0026 **He** HELIUM
2	3 6.941 **Li** LITHIUM	4 9.0122 **Be** BERYLLIUM											5 10.811 **B** BORON	6 12.011 **C** CARBON	7 14.007 **N** NITROGEN	8 15.999 **O** OXYGEN	9 18.998 **F** FLUORINE	10 20.180 **Ne** NEON
3	11 22.990 **Na** SODIUM	12 24.305 **Mg** MAGNESIUM											13 26.982 **Al** ALUMINIUM	14 28.086 **Si** SILICON	15 30.974 **P** PHOSPHORUS	16 32.065 **S** SULPHUR	17 35.453 **Cl** CHLORINE	18 39.948 **Ar** ARGON
4	19 39.098 **K** POTASSIUM	20 40.078 **Ca** CALCIUM	21 44.956 **Sc** SCANDIUM	22 47.867 **Ti** TITANIUM	23 50.942 **V** VANADIUM	24 51.996 **Cr** CHROMIUM	25 54.938 **Mn** MANGANESE	26 55.845 **Fe** IRON	27 58.933 **Co** COBALT	28 58.693 **Ni** NICKEL	29 63.546 **Cu** COPPER	30 65.39 **Zn** ZINC	31 69.723 **Ga** GALLIUM	32 72.64 **Ge** GERMANIUM	33 74.922 **As** ARSENIC	34 78.96 **Se** SELENIUM	35 79.904 **Br** BROMINE	36 83.80 **Kr** KRYPTON
5	37 85.468 **Rb** RUBIDIUM	38 87.62 **Sr** STRONTIUM	39 88.906 **Y** YTTRIUM	40 91.224 **Zr** ZIRCONIUM	41 92.906 **Nb** NIOBIUM	42 95.94 **Mo** MOLYBDENUM	43 (98) Tc TECHNETIUM	44 101.07 **Ru** RUTHENIUM	45 102.91 **Rh** RHODIUM	46 106.42 **Pd** PALLADIUM	47 107.87 **Ag** SILVER	48 112.41 **Cd** CADMIUM	49 114.82 **In** INDIUM	50 118.71 **Sn** TIN	51 121.76 **Sb** ANTIMONY	52 127.60 **Te** TELLURIUM	53 126.90 **I** IODINE	54 131.29 **Xe** XENON
6	55 132.91 **Cs** CAESIUM	56 137.33 **Ba** BARIUM	57-71 **La-Lu** **Lanthanide**	72 178.49 **Hf** HAFNIUM	73 180.95 **Ta** TANTALUM	74 183.84 **W** TUNGSTEN	75 186.21 **Re** RHENIUM	76 190.23 **Os** OSMIUM	77 192.22 **Ir** IRIDIUM	78 195.08 **Pt** PLATINUM	79 196.97 **Au** GOLD	80 200.59 **Hg** MERCURY	81 204.38 **Tl** THALLIUM	82 207.2 **Pb** LEAD	83 208.98 **Bi** BISMUTH	84 (209) **Po** POLONIUM	85 (210) **At** ASTATINE	86 (222) **Rn** RADON
7	87 (223) **Fr** FRANCIUM	88 (226) **Ra** RADIUM	89-103 **Ac-Lr** **Actinide**	104 (261) Rf RUTHERFORDIUM	105 (262) Db DUBNIUM	106 (266) Sg SEABORGIUM	107 (264) Bh BOHRIUM	108 (277) Hs HASSIUM	109 (268) Mt MEITNERIUM	110 (281) Uun UNUNNILIUM	111 (272) Uuu UNUNUNIUM	112 (285) Uub UNUNBIUM		114 (289) Uuq UNUNQUADIUM				

LANTHANIDE

6	57 138.91 **La** LANTHANUM	58 140.12 **Ce** CERIUM	59 140.91 **Pr** PRASEODYMIUM	60 144.24 **Nd** NEODYMIUM	61 (145) Pm PROMETHIUM	62 150.36 **Sm** SAMARIUM	63 151.96 **Eu** EUROPIUM	64 157.25 **Gd** GADOLINIUM	65 158.93 **Tb** TERBIUM	66 162.50 **Dy** DYSPROSIUM	67 164.93 **Ho** HOLMIUM	68 167.26 **Er** ERBIUM	69 168.93 **Tm** THULIUM	70 173.04 **Yb** YTTERBIUM	71 174.97 **Lu** LUTETIUM

ACTINIDE

7	89 (227) **Ac** ACTINIUM	90 232.04 **Th** THORIUM	91 231.04 **Pa** PROTACTINIUM	92 238.03 **U** URANIUM	93 (237) Np NEPTUNIUM	94 (244) Pu PLUTONIUM	95 (243) Am AMERICIUM	96 (247) Cm CURIUM	97 (247) Bk BERKELIUM	98 (251) Cf CALIFORNIUM	99 (252) Es EINSTEINIUM	100 (257) Fm FERMIUM	101 (258) Md MENDELEVIUM	102 (259) No NOBELIUM	103 (262) Lr LAWRENCIUM

(1) Pure Appl. Chem., **73**, No. 4, 667-683 (2001)
Relative atomic mass is shown with five significant figures. For elements have no stable nuclides, the value enclosed in brackets indicates the mass number of the longest-lived isotope of the element.
However three such elements (Th, Pa, and U) do have a characteristic terrestrial isotopic composition, and for these an atomic weight is tabulated.

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