Name____________________________ SID____________________

1) Light irradiates a metal surface and ejects an electron. Compare the energy E_{photon} of the incoming photon to the kinetic energy $K_{electron}$ of the ejected electron.

- ● $E_{photon} > K_{electron}$
- ○ $E_{photon} = K_{electron}$
- ○ $E_{photon} < K_{electron}$
- ○ Not enough information

2) Select the appropriate number of nodes for a 3d orbital.

- ○ 1 radial, 1 angular
- ○ 2 radial, 0 angular
- ● 0 radial, 2 angular
- ○ No nodes

3) A compound strongly absorbs light between 300-650 nm. Light is transmitted between 650 -750 nm. What color is the compound?

- ○ Blue
- ○ Green
- ○ Yellow
- ● Red

4) Rank the following objects in order of their de Broglie wavelength (smallest to greatest).

- ○ 3 m/s baseball < 30 m/s baseball < 10^2 m/s electron < 10^4 m/s electron
- ● 30 m/s baseball < 3 m/s baseball < 10^4 m/s electron < 10^2 m/s electron
- ○ 10^2 m/s electron < 10^4 m/s electron < 3 m/s baseball < 30 m/s baseball
- ○ 3 m/s baseball < 10^2 m/s electron < 30 m/s baseball < 10^4 m/s electron

5) Select the appropriate electron configuration for Cl^-

- ○ [Ar] $3s^2\ 3p^5$
- ● [Ne] $3s^2\ 3p^6$
- ○ [Ne] $3s^2\ 3p^5$
- ○ [Ar] $3s^2\ 3p^6$

Name________________________ SID________________

6) Ozone molecules (O_3) can react with oxygen atoms (O) to produce diatomic oxygen (O_2).

i. Write a balanced reaction equation for this process.

$$O_3 + O \rightarrow 2O_2$$

The destruction of ozone is much more rapid in the presence of chlorine atoms, through a sequence of reactions

$$\mathrm{Cl} + \mathrm{O_3} \rightarrow \mathrm{ClO} + \mathrm{O_2}$$
$$\mathrm{ClO} + \mathrm{O} \rightarrow \mathrm{Cl} + \mathrm{O_2}$$

Consider a mixture that initially contains no O_2, no ClO, and the following masses of Cl, O_3, and O:

18 g Cl

48 g O_3

32 g O

ii. How many moles of Cl, O_3, and O are initially present? (Only one significant figure is needed for each species.)

$$18\text{ g Cl} \cdot \frac{1\text{ mol Cl}}{35.6\text{ g Cl}} = 0.5\text{ mol Cl}$$

$$48\text{ g } O_3 \cdot \frac{1\text{ mol } O_3}{48\text{ g } O_3} \cdot 1\text{ mol } O_3$$

$$32\text{ g O} \cdot \frac{1\text{ mol O}}{16\text{ g O}} \cdot 2\text{ mol O}$$

Final Answer

0.5 mol Cl

1 mol O_3

2 mol O

Name________________________ SID______________

iii. How many oxygen nuclei are initially present? (Your answer should be a number with no units.)

1 mol O_3 } 5 mol oxygen nuclei
2 mol O }

$5 \cdot 6.02 \cdot 10^{23} : 30.10 \cdot 10^{23}$

$3.01 \cdot 10^{24}$ Final Answer

iv. If the sequence of reactions proceeds as far as possible, which molecule or atom is the limiting reagent? Explain your reasoning.

Cl (0.5 mol) + O_3 (1 mol) → ClO (0.5 mol) + O_2 (0.5 mol) + O_3 (0.5 mol)

ClO (0.5 mol) + O (2 mol) → Cl (0.5 mol) + O_2 (0.5 mol) + O (1.5 mol)

O_3 is the limiting reagent. Cl product after the 2nd reaction can react w/ O_3 leftover in 1st rxn ∴ There is excess O compared to O_3 - more moles of O and 1:1 stoicheometry.

v. What is the system's total mass at the end of the reaction?

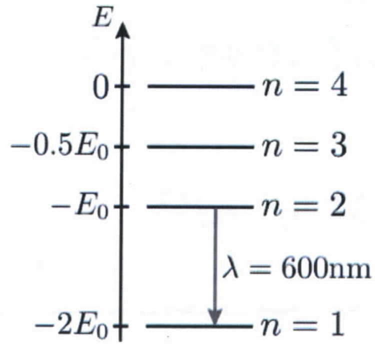
mass is conserved

18g + 48g + 32g

98g Final Answer

Name________________________________ SID____________________

7) The diagram below shows the allowed energy levels of a certain molecule.



i. A transition from $n = 2$ to $n = 1$ is accompanied by emission of a photon with wavelength $\lambda = 600$ nm, as shown in the energy level diagram. Using this information, calculate the value of E_0 in units of kJ/mol.

$\Delta E = -E_{photon}$: $\frac{-hc}{\lambda} = -1E_0$

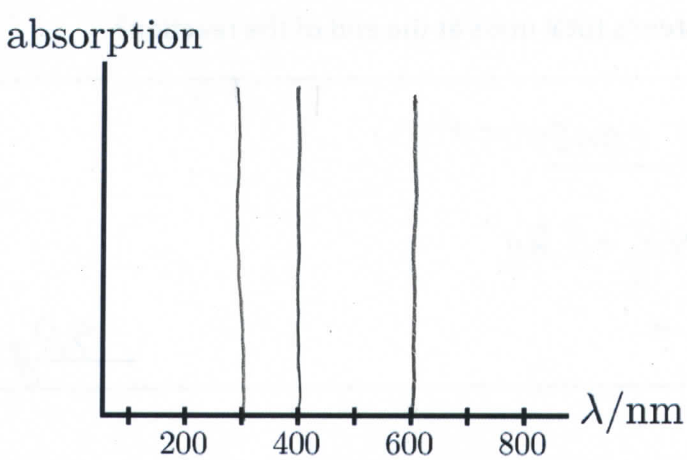
$$-\frac{(6.626\cdot10^{-34}\ \text{J}\cdot\text{s})(3.00\cdot10^{8}\ \frac{\text{m}}{\text{s}})}{6\cdot10^{-7}\ \text{m}} = -E_0$$

$E_0 = 3.313\cdot10^{-19}$ J per photon

$3.313\ \frac{\text{J}}{\text{photon}}\cdot\frac{1\text{ kJ}}{1000\text{ J}}\cdot\frac{6.02\cdot10^{23}\text{ photons}}{\text{mol}}$

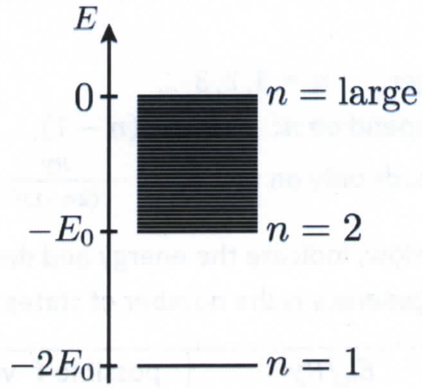
$200\ \frac{\text{kJ}}{\text{mol}}$ Final Answer

ii. When the molecule is in its ground state ($n = 1$), only certain colors of light can be absorbed. On the graph below sketch its absorption spectrum as a function of wavelength λ. Consider only transitions that begin from $n = 1$.

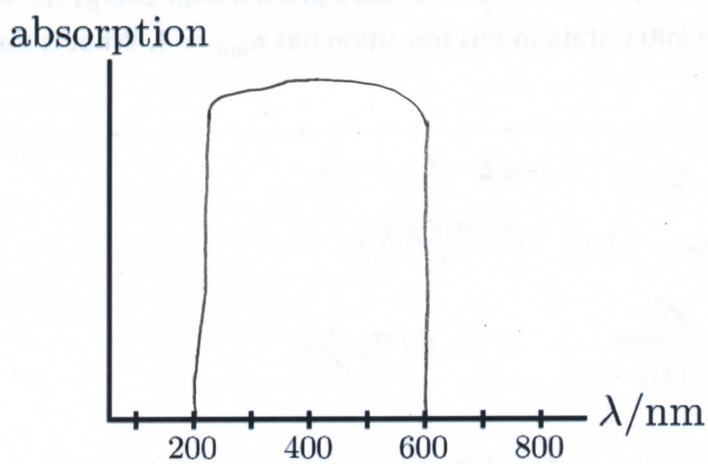


Name________________________ SID________________

iii. A different substance has many more energy levels in the range between $E = -E_0$ and $E = 0$, as shown below.



Considering only transitions that begin from $n = 1$, sketch the absorption spectrum of this substance on the graph below. (You may assume that excited states are so numerous that the spectrum is very smooth.)



iv. Based on the absorption spectrum you drew in part (iii), describe the appearance of this substance to the eye.

Red

Name________________________ SID________________

8) Consider a model of a hypothetical single-electron atom that is different from the hydrogen atom. This atom has two quantum numbers, n and ℓ. There is one orbital for each combination of n and ℓ.

n can be any positive integer: $n = 1, 2, 3, \ldots$

The possible values of ℓ depend on n: $\ell = -(n-1), \ldots, 0, \ldots, n-1$

The energy of a state depends only on n: $E_n = -\frac{Ry}{(2n-1)^2}$, where Ry is Rydberg's constant.

i. By filling in the table below, indicate the energy and degeneracy of each level, up to $n = 4$. (Recall that degeneracy is the number of states with the same energy.)

n	E_n/Ry	possible ℓ values	degeneracy
1	$-Ry$	0	1
2	$-Ry/9$	$-1, 0, 1$	3
3	$-Ry/25$	$-2, -1, 0, 1, 2$	5
4	$-Ry/49$	$-3, -2, -1, 0, 1, 2, 3$	7

ii. A certain transition of this atom causes a photon with energy $h\nu = 0.0196\ Ry$ to be emitted. The initial state in this transition has $n_{\text{init}} = 4$. What is the value of n in the final state?

$\Delta E = E_{fin} - E_{init}$ $\quad -\Delta E = E_{init} - E_{fin}$

$-\Delta E = E_{photon} = h\nu = 0.0196\ Ry$

$-\frac{Ry}{49} + \frac{Ry}{(2n_f - 1)^2} = 0.0196\ Ry$

$\frac{1}{(2n_f-1)^2} = 0.04$

$0.04(2n_f - 1)^2 = 1$

$(2n_f - 1)^2 = 25$

$2n_f - 1 = 5$

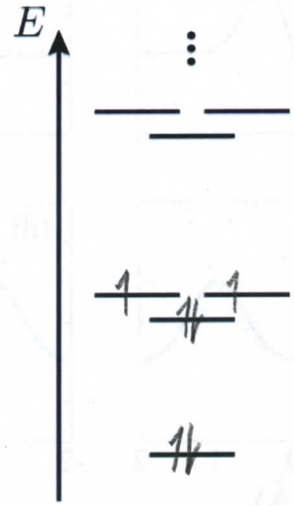
$2n_f = 6$

$n_f = 3$

$n_f = 3$ Final Answer

Name______________________________ SID__________________

The orbitals of this model can be filled with electrons to make hypothetical multi-electron atoms. Due to screening, the $\ell = 0$ orbitals have slightly lower energy than those with $\ell \neq 0$ for the same value of n. The energy level diagram below shows the positioning of these orbitals.



Aufbau, Pauli, and Hund's rules apply to the filling of these orbitals.

iii. Write the electronic configuration of an atom with 6 electrons. By analogy with the hydrogen atom, use "s" to refer to orbitals with $\ell = 0$, and use "p" to refer to orbitals with $\ell = \pm 1$.

$1s^2 2s^2 2p^2$

iv. For this model, an atom with 8 electrons is extremely stable and non-reactive. Explain this observation using its electron configuration.

full n=2 valence shell: 6 electrons in valence shell and all are paired.
next e⁻ would need to be added to an orbital w/ principle quantum number n=3.

Name_____________________________ SID__________________

9) Consider an electron in a potential energy $V(x)$ described by 4 different wavefunctions as shown in panels (a), (b), (c), and (d):

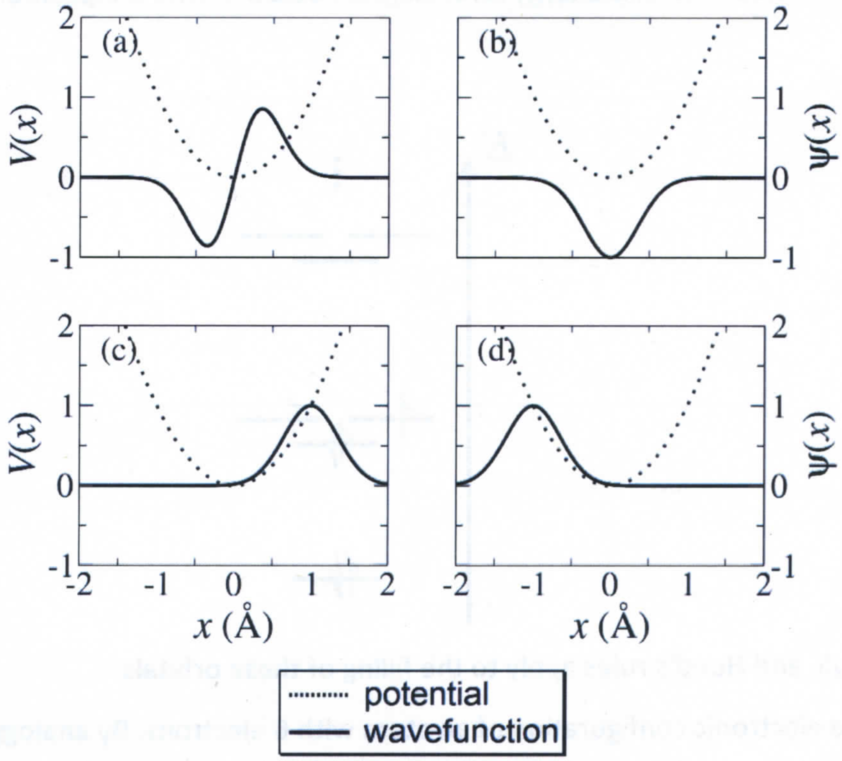


Figure 1: The potential energy ($V(x)$) is shown by the dotted curve and the electron wavefunction ($\psi(x)$) by the solid curve.

i. For each panel (b), (c), and (d) in Figure 1, where on the x-axis is the most probable location to find the electron? Explain your answer.

(b) 0 Å
(c) 1 Å
(d) −1 Å

$|\psi(x)|^2$ = probability
These are the positions where $\psi(x)$ is at an extreme and ∴ $|\psi(x)|^2$ is maximized

ii. Which wavefunction (or wavefunctions) has the highest kinetic energy? Please reason your answer.

(a) has the most nodes, highest curvature.

Name_________________________ SID_________________

iii. Which wavefunction (or wavefunctions) has the lowest kinetic energy? Please reason your answer.

(b), (c), (d) all have the same curvature, no nodes

iv. Which wavefunction (or wavefunctions) has the highest potential energy? Please reason your answer.

(c), (d) $\psi(x)$ has maximum in regions where $V(x)$ is large.

v. Which wavefunction (or wavefunctions) has the lowest potential energy? Please reason your answer.

(b) There is maximal density of the wavefunction at minimal values of $V(x)$

vi. True or false: For panel (a) in Figure 1, the probability of finding the electron in $x < 0$ is smaller than the probability of finding the electron in $x > 0$ because the wavefunction for $x < 0$ is negative. Explain your answer.

○ True ● False	Explain: Probability $\equiv |\psi(x)|^2$ The wave function is odd: $\psi(x) = -\psi(-x)$ for any x. ∴ There is equal probability of finding the e^- in $x > 0$ and $x < 0$.