1. Answer the following questions as concisely as possible, using words, diagrams, or both. (You may use the back of this sheet for any of the questions if necessary.)

a. **Define** a nodal surface, and **give examples** of **two** different kinds of nodal surface.

   A nodal surface is a region of space in which the probability of finding an electron is zero.
   
   Nodal spheres are found within 2s, 3s, … 3p, 4p… 4d, 5d… orbitals.
   
   Nodal planes are found within any p,d,f … orbital.

b. Most textbooks depict orbitals by showing “balloon” shapes that have sharply defined borders. Explain how one should interpret such diagrams in the context of the Schroedinger theory.

   The probability of finding the electron within the volume enclosed by the balloon is 90%.

c. Draw an electron dot diagram for the 3s orbital of hydrogen. Clearly **depict and label** any nodal surface(s).

   See orbitron web site.
2. Some questions on light emission:

a. A laser used for surgical procedures has a wavelength of 532 nm. Calculate the frequency of this light.

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

\[ = \frac{3.00 \times 10^8 \text{ m/s}}{532 \times 10^{-9} \text{ m}} \]

\[ = 5.64 \times 10^{14} \text{ Hz} \]

b. Calculate \( \Delta E \) and the wavelength of light is that is emitted when the electron in hydrogen makes a transition from \( n = 6 \) to \( n = 4 \).

\[ \Delta E = -2.18 \times 10^{-18} \text{ J} \times \left[ \frac{1}{36} - \frac{1}{16} \right] \]

\[ = -7.57 \times 10^{-20} \text{ J} \]

\[ |\Delta E| = E \text{ (photon)} = \frac{hc}{\lambda} = (6.63 \times 10^{-34} \text{ Js})(3 \times 10^8 \text{ m/sec})/\lambda \]

\[ \lambda = 2630 \text{ nm} \]

c. For ions containing only 1 electron, the energy-level formula is the same as for hydrogen, except the constant is multiplied by \( Z^2 \), where \( Z \) is the number of protons. Calculate \( \Delta E \) when the electron in Li\(^{2+}\) makes a transition from \( n = 6 \) to \( n = 4 \).

\[ \Delta E = -7.57 \times 10^{-20} \text{ J} \times 9 = -6.81 \times 10^{-19} \text{ J} \]

\[ \lambda = 2630 \text{ nm} \] (from above) / 9 = 292 nm
3. Some questions on the photoelectric effect:

   a. You are performing an experiment in which you shine light on a silver surface, and observe whether or not electrons are ejected from the surface. You have two sources of light (A and B), each of a different wavelength. The first light source has wavelength \( \lambda_A \), and the second has wavelength \( \lambda_B \). You observe that **electrons are ejected** when \( \lambda_A \) is used, but **no electrons are ejected** when \( \lambda_B \) is used. Use these observations to deduce whether \( \lambda_A \) or \( \lambda_B \) is the longer wavelength. Explain your reasoning.

   \( \lambda_B \) is the longer wavelength because it corresponds to the smaller photon energy. The photon with the lower energy would not be able to eject an electron from the surface.

   b. Predict how your observation would be affected if you increased the intensity (brightness) of light source A. Explain your reasoning.

   More electrons would be ejected because more photons strike the silver surface.

   c. Predict how your observation would be affected if you increased the intensity (brightness) of light source B. Explain your reasoning.

   The observation would not change; *i.e.*, even with more photons from source B, an individual photon would still not have sufficient energy to eject an electron.
4. In an absorption experiment, a source of photons (such as a laser) provides the energy to make electrons go from a low energy level to a higher one. This question involves an absorption experiment using a sample of hydrogen atoms. All the atoms are in the $n=1$ level before the experiment begins. A laser beam of a certain wavelength causes every hydrogen atom to be excited to the $n=5$ level. (Assume that only one photon can interact with each hydrogen atom.) During the course of the experiment, the total laser energy entering the hydrogen sample is $1.258 \text{ J}$, and none is wasted on processes other than absorption.

a. Determine the wavelength of the laser.

\[
\Delta E = -2.18 \times 10^{-18} \text{ J} \quad [1 - \frac{1}{25}]
\]

\[
= -2.09 \times 10^{-18} \text{ J}
\]

\[
|\Delta E| = E (\text{photon}) = \frac{hc}{\lambda} = (6.63 \times 10^{-34} \text{ Js})(3 \times 10^8 \text{ m/sec})/\lambda
\]

\[
\lambda = 95.2 \text{ nm}
\]

b. Determine the number of photons that entered the hydrogen sample.

\[
(1.258 \text{ J})/(2.09 \times 10^{-18} \text{ J/photons}) = 6.02 \times 10^{17} \text{ photons}
\]

c. Determine the number of H atoms in the sample, and then determine the mass of the sample.

$6.02 \times 10^{17}$ H atoms are in the sample, because 1 photon excites one H atom.

$6.02 \times 10^{17}$ H atoms $\times (1 \text{ mol}/6.02 \times 10^{23} \text{ atoms}) \times 1.01 \text{ g/mol} = 1.01 \times 10^{-6} \text{ g}$
Potentially Useful Information

<table>
<thead>
<tr>
<th>Category</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>speed of light</td>
<td>c = 3.00 × 10^8 m/s</td>
</tr>
<tr>
<td>Planck constant</td>
<td>h = 6.63 × 10^{-34} J s</td>
</tr>
<tr>
<td>Hydrogen ionization energy</td>
<td>2.18 × 10^{-18} J</td>
</tr>
<tr>
<td>Avogadro’s number</td>
<td>N = 6.02 × 10^{23} particles/mole</td>
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</tbody>
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