A SINGLE ONE SIDED 8.5x11” page of notes is allowed
- YOU MUST SIT IN YOUR ASSIGNED SEAT TO RECEIVE CREDIT FOR THE EXAM
- ALL ANSWERS MUST BE IN THE ANSWER BOX WHEN PROVIDED
- CROSSED OUT/PARTIALLY ERASED WORK WILL BE IGNORED
- NO PARTIAL CREDIT ON NUMERICAL PROBLEMS WITHOUT A FORMULA
- NO PARTIAL CREDIT ON “PHYSICALLY IMPLAUSIBLE” ANSWERS UNLESS THE ERROR IS RECOGNIZED

Your name:____________________________________________

Student ID#:___________________________________________

I have neither received nor provided external assistance of any kind on this exam.
I understand that doing so is serious academic misconduct.

Signature:___________________________________________

In the following, u and v are functions of x, and a and n and m are real numbers

\[ \frac{d}{dx}(uv) = u'v + uv' \]
\[ \int x^2 \, dx = \frac{x^3}{3} \]
\[ \int e^x \, dx = e^x \]
\[ \int \cos ax \, dx = \frac{\sin ax}{a} \]
\[ \int \sin ax \, dx = -\frac{\cos ax}{a} \]
\[ \int e^{ax} \, dx = \frac{e^{ax}}{a} \]
\[ \int \cos ax \, dx = \frac{\sin ax}{a} \]
\[ \int \sin ax \, dx = -\frac{\cos ax}{a} \]
\[ \int e^{ax} \, dx = \frac{e^{ax}}{a} \]

Some H-Atom wave functions:

\[ \psi_{1s}(r, \theta, \phi) = \frac{1}{\sqrt{\pi}} \left( \frac{1}{a_0} \right)^{3/2} e^{-r/a_0} \]
\[ \psi_{2s}(r, \theta, \phi) = \frac{1}{4\sqrt{2\pi}} \left( \frac{1}{a_0} \right)^{3/2} \left( 2 - \frac{r}{a_0} \right)^{3/2} e^{-r/2a_0} \]
\[ \psi_{3s}(r, \theta, \phi) = \frac{1}{8\sqrt{3\pi}} \left( \frac{1}{a_0} \right)^{3/2} \left( 6 - \frac{r^2}{a_0^2} \right)^{3/2} e^{-r/3a_0} \cos(\theta) \]

Some H-Atom radial wave functions:

\[ R_0(r) = \left( \frac{1}{a_0} \right)^{3/2} e^{-r/a_0} \]
\[ R_2(r) = \frac{1}{\sqrt{8}} \left( 2 - \frac{r}{a_0} \right)^{3/2} e^{-r/2a_0} \]
Total Points: 200

Question 1:_________/20
Question 2:_________/20
Question 3:_________/35
Question 4:_________/30
Question 5:_________/20
Question 6:_________/30
Question 7:_________/30
Question 8:_________/35

Total: _____________/200

Potentially Useful Information:

Workfunctions of Metals:

<table>
<thead>
<tr>
<th>Metal</th>
<th>Workfunction (eV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Li</td>
<td>2.3</td>
</tr>
<tr>
<td>Ca</td>
<td>2.87</td>
</tr>
<tr>
<td>Al</td>
<td>4.28</td>
</tr>
<tr>
<td>Au</td>
<td>5.1</td>
</tr>
</tbody>
</table>

The First Few Spherical Harmonics

\[
Y_0^0 = \frac{1}{(4\pi)^{1/2}}
\]
\[
Y_1^0 = \left( \frac{3}{4\pi} \right)^{1/2} \cos \theta
\]
\[
Y_1^1 = \left( \frac{3}{8\pi} \right)^{1/2} \sin \theta e^{i\phi}
\]
\[
Y_1^{-1} = \left( \frac{3}{8\pi} \right)^{1/2} \sin \theta e^{-i\phi}
\]
\[
Y_2^0 = \left( \frac{5}{16\pi} \right)^{1/2} (3\cos^2 \theta - 1)
\]
\[
Y_2^1 = \left( \frac{15}{8\pi} \right)^{1/2} \sin \theta \cos \theta e^{i\phi}
\]
\[
Y_2^{-1} = \left( \frac{15}{8\pi} \right)^{1/2} \sin \theta \cos \theta e^{-i\phi}
\]
\[
Y_2^2 = \left( \frac{15}{32\pi} \right)^{1/2} \sin^2 \theta e^{2i\phi}
\]
\[
Y_2^{-2} = \left( \frac{15}{32\pi} \right)^{1/2} \sin^2 \theta e^{-2i\phi}
\]

Values of Some Physical Constants

<table>
<thead>
<tr>
<th>Constant</th>
<th>Symbol</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atomic mass constant</td>
<td>(m_u)</td>
<td>1.660 5402 x 10^{-27} kg</td>
</tr>
<tr>
<td>Avogadro constant</td>
<td>(N_A)</td>
<td>6.022 137 x 10^{23} mol^{-1}</td>
</tr>
<tr>
<td>Bohr magneton</td>
<td>(\mu_B)</td>
<td>9.274 0154 x 10^{-24} J x T^{-1}</td>
</tr>
<tr>
<td>Bohr radius</td>
<td>(a_0)</td>
<td>5.291 772 49 x 10^{-10} m</td>
</tr>
<tr>
<td>Boltzmann constant</td>
<td>(k_B)</td>
<td>1.380 658 x 10^{-23} J x K^{-1}</td>
</tr>
<tr>
<td>Electron rest mass</td>
<td>(m_e)</td>
<td>0.910 9389 x 10^{-31} kg</td>
</tr>
<tr>
<td>Gravitational constant</td>
<td>(G)</td>
<td>6.672 59 x 10^{-11} m^3 kg^{-1} x s^{-2}</td>
</tr>
<tr>
<td>Molar gas constant</td>
<td>(R)</td>
<td>8.314510 x J x K^{-1} x mol^{-1}</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.083 1451 dm^3 x bar x K^{-1} x mol^{-1}</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.082 0578 dm^3 x atm x K^{-1} x mol^{-1}</td>
</tr>
</tbody>
</table>

Molar volume, ideal gas

<table>
<thead>
<tr>
<th>(one bar, 0°C)</th>
<th>(one atm, 0°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>22.711 06 L x mol^{-1}</td>
<td>22.414 09 L x mol^{-1}</td>
</tr>
</tbody>
</table>

Nuclear magneton | \(\mu_N\) | 5.050 7866 x 10^{-27} J x T^{-1} |

Permittivity of vacuum | \(\varepsilon_0\) | 8.854 187 816 x 10^{-12} C^2 x N^{-1} x m^{-1} |
| \(4\pi\varepsilon_0\) | 1.112 605 x 10^{-9} C^2 x N^{-1} x m^{-1} |

Planck constant | \(h\) | 6.626 0755 x 10^{-34} J x s |
| h | 1.054 572 66 x 10^{-27} J x s |

Proton charge | \(e\) | 1.602 177 33 x 10^{-19} C |

Proton magnetogonic ratio | \(\gamma_p\) | 2.675 221 28 x 10^{6} s^{-1} x T^{-1} |

Proton rest mass | \(m_p\) | 1.672 6231 x 10^{-27} kg |

Rydberg constant (Bohr) | \(R_H\) | 2.179 8736 x 10^{20} J |

Rydberg constant for H | \(R_0\) | 109 737.31534 cm^{-1} |

Speed of light in vacuum | \(c\) | 299 792 458 m x s^{-1} (defined) |

Stefan-Boltzmann constant | \(\sigma\) | 5.670 51 x 10^{-8} J x m^{-2} x K^{-4} x s^{-1} |