Atomic Structure III: Quantum Mechanics

1. Consider a hydrogen atom which has been electrically excited into emission. What is the energy of the light emitted when the electron falls from the $n = 4$ state to the $n = 2$ state?

$$\Delta E_{\text{energy levels}} = E_{\text{photon}} = -R_{\text{H}}\left(\frac{1}{n_{\text{f}}^2} - \frac{1}{n_{\text{i}}^2}\right)$$

$$E = -2.179\times10^{-18}\,\text{J}\left(\frac{1}{2^2} - \frac{1}{4^2}\right) = -4.086\times10^{-19}\,\text{J}$$

2. What is the wavelength of the light produced in question 1? What is the color of the photon?

$$E = h\nu = \frac{hc}{\lambda} \quad \text{so...} \quad \lambda = \frac{hc}{E} = \frac{(6.626\times10^{-34}\,\text{J}\cdot\text{s})(3.00\times10^{8}\,\text{m/s})}{4.086\times10^{-19}\,\text{J}} \times \frac{1\text{ nm}}{10^{-9}\text{m}} = 486\text{ nm}$$

3. What region of the electromagnetic radiation spectrum is a photon produced by hydrogen atom in which the electron falls from $n = 7$ to $n = 6$?

$$\Delta E_{\text{energy levels}} = E_{\text{photon}} = -R_{\text{H}}\left(\frac{1}{n_{\text{f}}^2} - \frac{1}{n_{\text{i}}^2}\right)$$

$$E = -2.179\times10^{-18}\,\text{J}\left(\frac{1}{6^2} - \frac{1}{7^2}\right) = -1.606\times10^{-20}\,\text{J}$$

$$\lambda = \frac{hc}{E} = \frac{(6.626\times10^{-34}\,\text{J}\cdot\text{s})(3.00\times10^{8}\,\text{m/s})}{1.606\times10^{-20}\,\text{J}} \times \frac{1\text{ nm}}{10^{-9}\text{m}} = 12,400\text{ nm}$$

4. The ionization energy of hydrogen atom is 2.179×10^{-18} J. When an electron recombines with an ionized hydrogen, it emits a continuum of radiation rather than a line spectrum. Explain this observation.

The electron can posses any energy when approaching from outside the quantized energy levels, thus the light given off does not have to be at specific energies.

5. What is the wavelength of light emitted by a hydrogen atom when an electron at the ionization potential (*i.e.*, the electron is just beyond the $n = 7$ energy level) recombines with the hydrogen $n = 7$ energy level?

$$E_{\text{photon}} = R_{\text{H}}\left(\frac{1}{n_{\text{f}}^2} - \frac{1}{n_{\text{i}}^2}\right)$$

$$E = 2.179\times10^{-18}\,\text{J}\left(\frac{1}{7^2} - \frac{1}{\infty^2}\right) = 4.447\times10^{-20}\,\text{J}$$

$$\lambda = \frac{hc}{E} = \frac{(6.626\times10^{-34}\,\text{J}\cdot\text{s})(3.00\times10^{8}\,{}^{\text{m}}\!/_{\text{s}})}{4.447\times10^{-20}\,\text{J}}\times\frac{1\text{ nm}}{10^{-9}\text{m}} = 4{,}470\text{ nm}$$

6. Explain the observation that, in the solar blackbody spectrum, dark lines are seen at exactly the same wavelengths as the emission lines for hydrogen.

7. What are the allowed quantum numbers for a ground-state electron in the outer-most orbital of magnesium metal?

The two electrons in the valence are 3s so the allowed quantum numbers are:

***n* =**	**3**	**3**
***l* =**	**0**	**0**
***m_l* =**	**0**	**0**
***m_s* =**	**+$\frac{1}{2}$**	**-$\frac{1}{2}$**

9. Write the full electron configuration for ground-state

nitrogen atom $1s^2\ 2s^2\ 2p^3$

vanadium atom $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^3$

chromium atom $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^1\ 3d^5$

10. Write the abbreviated electron configuration for ground-state

oxygen atom [He] $2s^2\ 2p^4$

zirconium atom [Kr] $5s^2\ 4d^2$

copper atom [Ar] $4s^1\ 3d^{10}$

11. What are one possible set of quantum numbers for an excited-state electron of magnesium metal in the which the electron has been promoted to a *d*-orbital in the fifth principle quantum shell?

***n* =**	**5**	**5**	**5**	**5**	**5**
***l* =**	**2**	**2**	**2**	**2**	**2**
***m*$_l$ =**	**-2**	**-1**	**0**	**1**	**2**
***m*$_s$ =**	$\pm\frac{1}{2}$	$\pm\frac{1}{2}$	$\pm\frac{1}{2}$	$\pm\frac{1}{2}$	$\pm\frac{1}{2}$

12. When gaseous lithium metal is excited to emission in a flame, it produces a striking and beautiful red emission. One of the emission lines of lithium is 610.4 nm and is due to the excited state electron falling from a 3*d* orbital to a 2*p* orbital.

What is the energy difference between the lithium 3*d* and 2*p* orbital?

$$\Delta E = \frac{hc}{\lambda} = \frac{(6.626\times10^{-34}\ \mathrm{J\cdot s})(2.9997\times10^{8}\ \frac{\mathrm{m}}{\mathrm{s}})}{610.4\times10^{-9}\ \mathrm{m}} = 3.257\times10^{-19}\ \mathrm{J}$$

After the transition, is lithium at ground state?

No. The ground-state valence shell is 2*s*.