Practice Test Questions 4
Electrons, Orbitals and Quantum Numbers

1. How did Heisenberg's uncertainty principle influence our understanding of the structure of an atom?

2. Briefly define the terms diamagnetic and paramagnetic, and describe an experiment that would demonstrate whether a substance was diamagnetic or paramagnetic.

3. Briefly explain what is meant by the term "Pauli exclusion principle". How does the Pauli exclusion principle apply to electron configurations?

4. For each of the following formulas, state whether it applies to:
   - light only,
   - ordinary particles only, or
   - both light and ordinary particles.

(a) $E_k = \frac{1}{2} mv^2$ (b) $E = h\nu$

(c) $p = h/\lambda$ (d) $p = mv$

5. A .22 caliber bullet weighs approximately 2.5 g. When fired from a rifle, this bullet travels at a speed of 1200 km/h.

(a) What is the wavelength of this bullet?

(b) Based on your calculation, do you think quantum mechanical effects will be important to understand the motion of bullets? Explain briefly.

6. In order to use waves to visualize something, whether those waves are particle waves or electromagnetic waves, the wavelength should be shorter than the features you want to detect. For example, bacteria typically have dimensions of the order of 1 μm, so if we want to be able to "see" bacteria in some kind of microscope, we need to use waves with a shorter wavelength. For example, 525 nm waves would do.

(a) Suppose that we were using light waves. Calculate the energy of a mole of photons of this wavelength.

(b) Suppose that we were using neutrons instead. Calculate the speed of the neutrons if the wavelength is 525 nm.

7. Fill in the blanks in the sentences below.

A 6f orbital corresponds to the quantum numbers n = ______, l = ______.

The possible values of m_l for an electron in a 6f orbital range from ______ to ______.

The possible values of m_s for an electron in a 6f orbital range from ______ to ______.

8. For each of the following pairs of electrons, indicate whether or not they could both be in the same orbital according to the Pauli exclusion principle. Explain each of your decisions in a few words.

Quantum Numbers of Two Electrons	Could this be a pair of electrons in the same orbital? Circle yes or no.	Briefly, justify your answer.
$n = 3, l = 1, m_l = 0, m_s = +½$ and $n = 3, l = 1, m_l = 0, m_s = -½$	YES / NO	
$n = 3, l = 2, m_l = 1, m_s = +½$ and $n = 3, l = 1, m_l = 1, m_s = -½$	YES / NO	
$n = 3, l = 1, m_l = 1, m_s = +½$ and $n = 3, l = 1, m_l = 1, m_s = +½$	YES / NO	
$n = 3, l = 2, m_l = 2, m_s = +½$ and $n = 3, l = 2, m_l = 1, m_s = -½$	YES / NO	

9. Give the orbital label (1s, 2p, 6f, etc.) for ***one*** orbital that corresponds to each set of quantum numbers. Also, sketch the orbital using Cartesian axes to show its orientation. *Note that you can rotate the axes if it makes your picture clearer/easier to draw.*

(a) $n = 4,\ l = 2,\ m_\ell = -2$

(b) $n = 6,\ l = 0,\ m_\ell = 0$

(c) $n = 3,\ l = 1,\ m_\ell = +1$

(d) $n = 2,\ l = 1,\ m_\ell = 0$

10. For each of the following sets of quantum numbers, indicate the maximum number of <u>electrons</u> allowed in a single atom.
If the answer is “none”, briefly explain why that is the case.

(a) $n = 4 \quad l = 2 \quad m_l = 2 \quad m_s = -½$

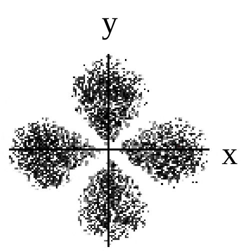
(b) $n = 2 \quad l = 2 \quad\quad m_s = -½$

(c) $n = 5 \quad l = 1$

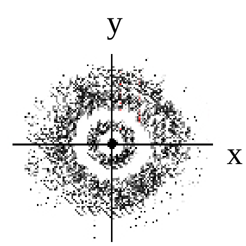
11. Each of the pictures below shows a cross-section of an electron ‘dot’ picture of an atomic orbital. For each picture, give the orbital label (e.g. $4p_z$) and provide the corresponding principal quantum number and angular momentum quantum number.

(a)

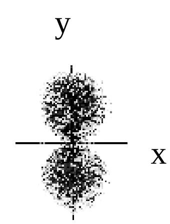
(i)



(ii)



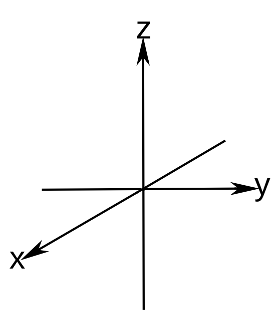
(iii)



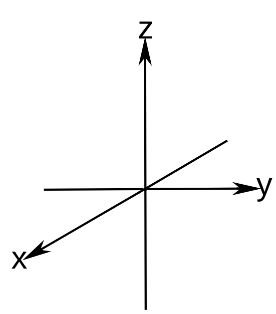
(b) Sketch the 95% probability surface for each of the orbitals in part (a). Clearly show phases as well as any nodal planes.

12. Sketch an outline diagram that clearly shows the shapes of (a) the p_y and (b) the d_{xz} orbital on the xyz grids provided. Pay attention to the labels on the axes. Shade the orbital lobes to indicate phase.

a)



b)



13. Sketch each of the orbitals listed below. For each orbital, use a set of axes to clearly show its orientation.

(a) $2p_z$ (b) $3d_{yz}$ (c) $3d_{z^2}$

14. Sketch all the atomic orbitals corresponding to $n = 2$ in a single atom.
Each sketch should include:
   i. a clearly labeled set of axes, and
   ii. the label for the orbital (its "name")

15. Each of the following sets of quantum numbers describes an orbital in the same atom. Draw one orbital that could be described by each set of quantum numbers.
Be sure to include labeled axes on your picture.

(a) $n = 3$ $l = 1$ $m_l = +1$

(b) $n = 3$ $l = 1$ $m_l = -1$

(c) $n = 3$ $l = 2$ $m_l = +1$

16. A hydrogen atom in an excited state has its electron in a 5*d* orbital.

(a) How many 5*d* orbitals are there in a single hydrogen atom?

(b) List all possible values for each of the four quantum numbers for the electron in this hydrogen atom.

(c) What wavelength of light will be emitted if this electron returns directly to the ground state? *Express your answer using an appropriate SI prefix so that the value is between 0.1 and 1000.*