Section 3.4: Quantum Numbers

Research This: Magnetic Fields and Sunspots, page 157

A. Answers may vary. Sample description: My image chows a cluster of sunspots interacting. One of the sunspots was described using a spectrograph. The spectrograph shows the splitting pattern generated by iron. The amount of splitting that occurs can be used to determine the strength of the associated magnetic field caused by the sunspot. This allows scientists to predict and characterise solar radiation that is produced by sunspots. It is important because the magnetic fields caused by solar flares associated with the sunspots can interfere with communications technologies on Earth.

B. Answers may vary. Sample answer: This technology could be used to determine the character of an unidentified compound. An example of this technology is nuclear magnetic resonance (NMR) spectroscopy that analyzes the effects of magnetic fields on the absorbance patterns of the molecule.

Tutorial 1: Working with Quantum Numbers, page 158

1. For $n = 7$, the possible values for the quantum numbers are $l = 0, 1, 2, 3, 4, 5, 6$ and $m_l = -6, -5, -4, -3, -2, -1, 0, 1, 2, 3, 4, 5, 6$.

2. The orbital designations 1*p*, 3*f,* and 2*d*, do not exist because the *l* value given does not occur in the energy level *n* provided.

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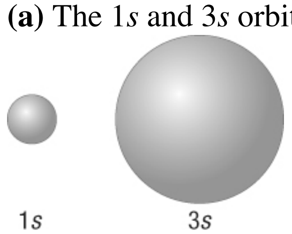
1. Quantum numbers are numbers that describe the quantum mechanical properties of orbitals. Charts may vary. Charts should include that the principal quantum number, *n,* describes the size and energy of an atomic orbital; the second quantum number, *l,* describes small energy level steps within the main energy level corresponding to different shapes of orbitals; the magnetic quantum number, m_l, describes the orientation in space of the orbitals; and the spin quantum number, m_S, describes the "spin" of electrons.

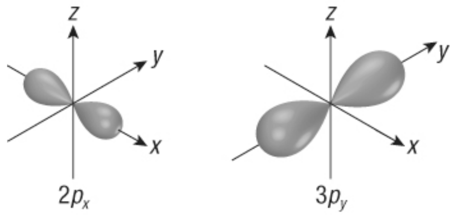
2. Answers may vary. Sample answer: The quantum numbers of an atom are like a family over several generations where each family member represents an electron. The principal quantum number, *n,* is like a family member's generation. The second quantum number is like the position of the family member in the family, e.g., grandfather, father, son. The magnetic quantum number, m_l, is like siblings or cousins of the same generation. The spin quantum number, m_S, represents the siblings or cousins of the same generation that are either male or female.

3. The three 2*p* orbitals have different magnetic quantum numbers, m_l, so they have different orientations in space. The 3*p* orbitals have more energy and are bigger than 2*p* orbitals.

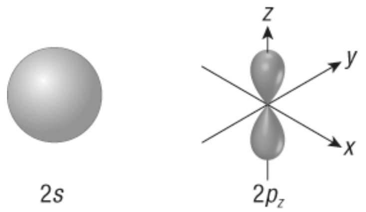
4. (a) The 1*s* and 3*s* orbitals are both spherical, but the 3*s* orbital is larger than the 1*s* orbital.



(b) The $2p_x$ and $3p_y$ orbitals are both lobed. The lobes of the $2p_x$ orbital are smaller and are centred along the *x*-axis. The lobes of the $3p_y$ orbital are larger and are centred along the *y*-axis.



(c) The 2*s* orbital is spherical. The $2p_z$ orbital is lobed, with its lobes centred along the *z*-axis.



5. The possible quantum numbers for the first three shells are as follows: first shell, $n = 1$, $l = 0$, $m_l = 0$, $m_s = ½$ or $– ½$; second shell, $n = 2$, $l = 0$ or 1, $m_l = 0, +1$, or $−1$, $m_s = ½$ or $– ½$; third shell, $n = 3$, $l = 0$, 1, or 2, $m_l = −2, −1, 0, 1$, or 2, $m_s = ½$ or $– ½$.

6. (a) An electron in the 2*s* orbital may have the following quantum number: $n = 2$, $l = 0$, $m_l = 0$, $m_s = ½$ or $– ½$.

(b) An electron in the 6*s* orbital may have the following quantum number: $n = 6$, $l = 0$, $m_l = 0$, $m_s = ½$ or $– ½$.

(c) An electron in the 5*f* orbital may have the following quantum number: $n = 5$; $l = 4$; $m_l = –4$, $–3, –2, –1, 0, 1, 2, 3$, or 4; $m_s = ½$ or $– ½$.

7. (a) The 1*d* orbital designation does not exist because the first set of no *d* orbitals occur in the third energy level, *n*=3.

(b) The 0*p* orbital designation does not exist because the first set of *p* orbitals occur in the second energy level, *n=2*.

(c) The 4*g* orbital designation does not exist because there are no *g* orbitals in the fourth energy level, *n*=4.

(d) There is a 5*s* orbital designation.

(e) The 2*f* orbital designation does not exist because the first set of *f* orbitals occur in the fourth energy level, *n*=4.

8. (a) The set of quantum numbers $n = 3$, $l = 2$, $m_l = 2$ is allowed.

(b) The set of quantum numbers $n = 4$, $l = 3$, $m_l = 4$ is not allowed because m_l cannot be greater than *l*.

(c) The set of quantum numbers $n = 0$, $l = 0$, $m_l = 0$ is not allowed because *n* must equal 1 or greater.

(d) The set of quantum numbers $n = 2$, $l = –1$, $m_l = 0$ is not allowed because *l* cannot be less than 0.

(e) The set of quantum numbers $n = 1$, $l = 1$, $m_l = 2$ is not allowed because *l* cannot equal *n* and m_l range is $+l$ to $–l$.

9. (a) The set of quantum numbers $n = 3$, $l = 3$, $m_l = 0$, $m_S = –½$ is not allowed because *l* cannot equal *n*.

(b) The set of quantum numbers $n = 4$, $l = 3$, $m_l = 2$, $m_S = –½$ is allowed.

(c) The set of quantum numbers $n = 4$, $l = 1$, $m_l = 1$, $m_S = +½$ is allowed.

(d) The set of quantum numbers $n = 2$, $l = 1$, $m_l = -1$, $m_S = -1$ is not allowed because m_s cannot be -1.
(e) The set of quantum numbers $n = 5$, $l = -4$, $m_l = 2$, $m_S = +½$ is not allowed because l cannot be less than 0.
(f) The set of quantum numbers $n = 3$, $l = 1$, $m_l = 2$, $m_S = -½$ is not allowed because m_l range is $-l$ to $+l$.
10. The fourth quantum number, m_S, is needed to account for spectral data showing that atoms have magnetic moments. The opposite spin states allow two electrons to be introduced into each orbital.
11. The second energy shell (n = 2) cannot hold more than 8 electrons because it has 4 orbitals (an *s* orbital and three *p* orbitals), each with the ability to contain two electrons.
12. For $n = 1$: l = 0; $m_i = 0$; $m_s = -½, +½$. This can result in 2 different sets of quantum numbers:
$n = 1$, l = 0, *mi* = 0, $m_s = -½$; and $n = 1$, l = 0, *mi* = 0, $m_s = +½$
For $n = 2$: l = 0, or 1; $m_i = -1, 0,$ or 1; $m_s = -½, +½$. This can result in 8 different sets of quantum numbers:
$n = 2$; $l = 0$, $m_i = 0$, $m_s = -½$;
$n = 2$, $l = 0$, $m_i = 0$, $m_s = +½$;
$n = 2$; $l = 1$, $m_i = -1$, $m_s = -½$;
$n = 2$, $l = 1$, $m_i = -1$, $m_s = +½$;
$n = 2$, $l = 1$, $m_i = 0$, $m_s = -½$;
$n = 2$, $l = 1$, $m_i = 0$, $m_s = +½$;
$n = 2$, $l = 1$, $m_i = 1$, $m_s = -½$;
$n = 2$, $l = 1$, $m_i = 1$, $m_s = +½$.