Unit 2 Structures and Properties of Matter

Solutions to Practice Problems in
Chapter 3 Atomic Models and Properties of Atoms

Determining Quantum Numbers
(Student textbook page 179)

1. For the quantum number $n = 3$, what values of l are allowed, what values of m_l are possible, and how many orbitals are there?

What Is Required?
You need to determine the allowed values of l and m_l when the value of n is given.

What Is Given?
You are given the value of the principle quantum number, $n = 3$.

Plan Your Strategy	Act on Your Strategy
Use the rules that give the relationships among the quantum numbers: Allowed values for l are 0 to (n - 1).	When $n = 3$, l can be 0, 1, or 2.
Allowed values for m_l are all integers from $-l$ to $+l$.	When $l = 0$, $m_l = 0$ (one orbital). When $l = 1$, m_l can be -1, 0, or +1. When $l = 2$, m_l can be -2, -1, 0, 1, or 2.
To find the number of orbitals, count the total number of possible values for combinations of l and m_l.	There are 9 orbitals.

Check Your Solution
The total number of orbitals for any given value for n is n^2.
Thus, when $n = 3$, the number of orbitals is $3^2 = 9$.

2. If $n = 5$ and $l = 2$, what orbital type is this, what are the possible values for m_l, and how many orbitals are there?

What Is Required?
You need to determine the type of orbital (*s, p, d, f*) when n and l are given.
You need to determine the possible values of m_l when n and l are given.
You need to determine the number of orbitals.

What Is Given?
You are given the values for the principle quantum number and the orbital shape quantum numbers: $n = 5$ and $l = 2$

Plan Your Strategy	Act on Your Strategy
The value of l determines the shape. When $l = 0$, the orbital shape is *s*. When $l = 1$, the orbital shape is *p*. When $l = 2$, the orbital shape is *d*. When $l = 3$, the orbital shape is *f*. The value of n is written before the shape symbol.	When $n = 5$ and $l = 2$, the orbital is a 5*d* orbital.
The value for l also determines the allowed values for m_l, according to the rule that m_l can be any integer from $-l$ to $+l$.	Since $l = 2$, m_l can be -2, -1, 0, +1, or +2.
The number of orbitals is the number of allowed values for m_l. Count the number of values of m_l.	There are five allowed m_l values, so there are five orbitals.

Check Your Solution
For any given value of l there are $2l + 1$ allowed values of m_l and thus $2l + 1$ orbitals.
When $l = 2$, the number of allowed m_l values $= 2l + 1 = 2(2) + 1 = 5$. This is in agreement with the answers determined.

3. What are the n, l, and possible m_l values for the following orbital types?

a. $2s$
b. $3p$
c. $5d$
d. $4f$

What Is Required?
You need to determine the values of n and l and all of the possible values for m_l for the given orbital types.

What Is Given?
The orbital types $2s$, $3p$, $5d$, and $4f$ are given.

Plan Your Strategy	Act on Your Strategy
The number is the n value and the letter is the symbol for the l value.	**a.** $2s$: $n = 2$ **b.** $3p$: $n = 3$ **c.** $5d$: $n = 5$ **d.** $4f$: $n = 4$
Use the rules for writing orbital types. The $l = 0$ orbital has the symbol s. The $l = 1$ orbital has the symbol p. The $l = 2$ orbital has the symbol d. The $l = 3$ orbital has the symbol f.	**a.** $2s$: $l = 0$ **b.** $3p$: $l = 1$ **c.** $5d$: $l = 2$ **d.** $4f$: $l = 3$
Use the relationship between l and m_l to determine the possible values for m_l. Allowed m_l values are all integers from $-l$ to $+l$.	**a.** $2s$: $m_l = 0$ **b.** $3p$: $m_l = -1, 0, +1$ **c.** $5d$: $m_l = -2, -1, 0, +1, +2$ **d.** $4f$: $m_l = -3, -2, -1, 0, +1, +2, +3$

Check Your Solution
The results are in agreement with all of the rules.

4. What orbital type can be described by the following sets of quantum numbers?
a. $n = 2, l = 0, m_l = 0$
b. $n = 5, l = 3, m_l = -2$

What Is Required?
You need to determine all possible orbital types for the given principal, orbital-shape, and magnetic quantum numbers.

What Is Given?
You are given the combinations of quantum numbers:
a. $n = 2, l = 0, m_l = 0$
b. $n = 5, l = 3, m_l = -2$

Plan Your Strategy	Act on Your Strategy
Write the value of n and then write the symbol for the value of l. The values of m_l are not written into the symbols for orbital types because they only affect the orientation in space, not the shape of the orbitals.	**a.** 2*s* **b.** 5*f* The values of m_l are not written into the symbols for orbital types because they only affect the orientation in space, not the shape of the orbitals.

Check Your Solution
The symbols for the orbital types agree with the given values of the quantum numbers.

5. How many orbitals are associated with each of the following types?

a. 1*s*
b. 5*f*
c. 4*f*
d. 2*p*

What Is Required?
You need to determine the number of orbitals associated with the given orbital types.

What Is Given?
You are given the orbital types:
a. 1*s*
b. 5*f*
c. 4*f*
d. 2*p*

Plan Your Strategy	Act on Your Strategy
Determine the value for n. The first symbol is the n value.	**a.** 1*s*: $n = 1$ **b.** 5*f*: $n = 5$ **c.** 4*f*: $n = 4$ **d.** 2*p*: $n = 2$
Determine the value for l. Allowed l values are 0 to (n - 1).	**a.** 1*s*: $n = 1$; $l = 0$ **b.** 5*f*: $n = 5$; $l = 3$ **c.** 4*f*: $n = 4$; $l = 3$ **d.** 2*p*: $n = 2$; $l = 1$
Determine the value for m_l. Allowed m_l values are all integers from $-l$ to $+l$.	**a.**1*s*: $n = 1$; $l = 0$; $m_l = 0$ **b.** 5*f*: $n = 5$; $l = 3$; m_l = -3, -2, -1, 0, +1, +2, +3 **c.** 4*f*: $n = 4$; $l = 3$; m_l = -3, -2, -1, 0, +1, +2, +3 **d.** 2*p*: $n = 2$; $l = 1$; m_l = -1, 0, +1
Count the number values for m_l to determine the total number of orbitals.	**a.** 1 possible orbital **b.** 7 possible orbitals **c.**7 possible orbitals **d.** 3 possible orbitals

Check Your Solution
The number of orbitals for a given l value is $2l + 1$.
a. $l = 0$: $2(0) + 1 = 1$
b. $l = 3$: $2(3) + 1 = 7$
c. $l = 3$: $2(3) + 1 = 7$
d. $l = 1$: $2(1) + 1 = 3$
These values are all in agreement with the answers.

6. What sets of quantum numbers are possible for a 4*d* orbital? List them.

What Is Required?
You need to list all of the possible sets of quantum numbers for a given orbital type.

What Is Given?
The given orbital type is 4*d*.

Plan Your Strategy	Act on Your Strategy
Assign values for n and l based on the orbital type symbol 4*d*.	For orbital type 4*d*, $n = 4$ and $l = 2$.
List the possible values for m_l based on the value for l, given that allowed m_l values are all integers from $-l$ to $+l$.	$n = 4$, $l = 2$, and $m_l = -2$ $n = 4$, $l = 2$, and $m_l = -1$ $n = 4$, $l = 2$, and $m_l = 0$ $n = 4$, $l = 2$, and $m_l = +1$ $n = 4$, $l = 2$, and $m_l = +2$

Check Your Solution
The values of n and l agree with the orbital type 4*d*. For any l value, the number of possible orbitals is $2l + 1$. Thus, for $l = 2$, there would be $2(2) + 1 = 5$ orbital types. This agrees with the number of orbital types.

7. What is one possible value for the missing number in each of the following sets?

a. $n = 3$, $l = 1$, $m_l = ?$

b. $n = 2$, $l = ?$, $m_l = -3$

What Is Required?

You need to fill numbers into the two sets of quantum numbers that will create allowed sets of quantum numbers.

What Is Given?

You are given the partial sets of quantum numbers:

a. $n = 3$, $l = 1$, $m_l = ?$

b. $n = 2$, $l = ?$, $m_l = -3$

Plan Your Strategy	Act on Your Strategy
a. Determine the allowed values for m_l when $l = 1$ and choose one.	**a.** When $l = 1$, m_l can be -1, 0, or +1. Choose -1. The set of quantum numbers is: $n = 3$, $l = 1$, $m_l = -1$ Sample: $n = 3$, $l = 1$, $m_l = -1$
b. Determine the allowed values for l when $n = 2$ and $m_l = -3$ and choose one.	**b.** When $n = 2$, l must be 0 or 1. When $m_l = -3$, l must be 3 or greater. Therefore, there is no allowed number for l, given that $n = 2$ and $m_l = -3$. The values $n = 2$ and $m_l = -3$ are not compatable. Therefore, there is no solution.

Check Your Solution

a. The set of quantum numbers are allowed because when $n = 3$, l can be 0, 1, or 2.So, $l = 1$ is allowed. The allowed values for m_l are $-l$ to $+l$. So, the value of $m_l = -1$ is allowed.

b. When $n = 2$, l can be 0 or 1 because the allowed values for l are 0 to (n - 1). Allowed m_l values are all integers from -l to +l, which means that for $l = 0$, m_l must be 0. For $l = 1$, m_l must be -1, 0, or +1. Therefore, m_l cannot be -3 making $n = 2$ incompatible with $m_l = -3$.

8. Write two possible sets of quantum numbers for a 6*p* orbital.

What Is Required?
You need to determine two sets of quantum numbers that correspond to the given orbital type.

What Is Given?
You are given the orbital type 6*p*.

Plan Your Strategy	Act on Your Strategy
Determine possible combinations of n and l that correspond to the orbital type 6*p*.	For orbital type 6*d*, $n = 6$ and $l = 1$.
Determine the possible values for m_l that will correspond to the values for n and l that you determine.	The value of m_l can be any integer from -3 to +3. The possible sets of quantum numbers are: $n = 6, l = 1, m_l = -1$; $n = 6, l = 1, m_l = 0$; $n = 6, l = 1, m_l = +1$;
Write at least two sets of these quantum numbers.	Sample answer: $n = 6, l = 1, m_l = -1$; $n = 6, l = 1, m_l = 0$; $n = 6, l = 1, m_l = +1$

Check Your Solution
All of the possible sets of answers are in agreement with the rules for determining allowed values for m_l given l.

9. The following sets of quantum numbers are not allowed. Identify the problem and change one number to give an allowed set.
a. $n = 1$, $l = 2$, $m_l = -2$
b. $n = 4$, $l = 1$, $m_l = -2$

What Is Required?
For each set of quantum numbers, determine which values do not obey the rules. Change one of the numbers in each set so that the set of numbers will be allowed.

What Is Given?
You are given the sets of quantum numbers:
a. $n = 1$, $l = 2$, $m_l = -2$
b. $n = 4$, $l = 1$, $m_l = -2$

a. $n = 1$, $l = 2$, $m_l = -2$

Plan Your Strategy	Act on Your Strategy
Analyze the given sets of quantum numbers in light of the rules for allowed values of l given n, and allowed values for m_l given l. Determine the values that do not conform to the rules.	Given that $n = 1$, the value of l must be 0 since it has to be a positive integer less than 1. However, if $l = 0$, m_l cannot be -2 since m_l has to be between $-l$ and $+l$. So, if $l = 0$, m_l must be 0.
Change one value to create an allowed set of quantum numbers.	The only way to change one value is by setting $n = 3$ or higher. Sample answer: $n = 3$, $l = 2$, $m_l = -2$

b. $n = 4$, $l = 1$, $m_l = -2$

Plan Your Strategy	Act on Your Strategy
Analyze the given sets of quantum numbers in light of the rules for allowed values for l given n and allowed values for m_l given l. Determine the values that do not conform to the rules.	The values of $n = 4$ and $l = 1$ are allowed but m_l cannot be -2 since the magnitude of m_l cannot be greater than l.
Change one value to create an allowed set of quantum numbers.	You could change m_l to -1, 0, or +1 to create an allowed set of quantum numbers. Or, you could change l to 2 or 3, each of which is compatible with $n = 4$, and you would not have to change m_l. Sample answers: $n = 4$, $l = 2$, $m_l = -2$; $n = 4$, $l = 3$, $m_l = -2$; $n = 4$, $l = 1$, $m_l = -1$; $n = 4$, $l = 1$, $m_l = 0$ $n = 4$, $l = 1$, $m_l = +1$

Check Your Solution
All of the examples are in agreement with the rules that describe allowed sets of quantum numbers.

10. Label each of the following sets of quantum numbers as *allowed* or *not allowed*. Identify the problem for each of the *not allowed* sets.
a. $n = 3, l = 2, m_l = 0$
b. $n = 1, l = 1, m_l = -1$
c. $n = 0, l = 0, m_l = 0$
d. $n = 5, l = 1, m_l = 3$

What Is Required?
Determine whether each of four sets of quantum numbers is allowed or not allowed.

What Is Given?
You are given the four sets of quantum numbers:
a. $n = 3, l = 2, m_l = 0$
b. $n = 1, l = 1, m_l = -1$
c. $n = 0, l = 0, m_l = 0$
d. $n = 5, l = 1, m_l = 3$

a. $n = 3, l = 2, m_l = 0$

Plan Your Strategy	Act on Your Strategy
Analyze the set of quantum numbers against the rules for allowed quantum numbers.	allowed
If the set is not allowed, explain why it does not obey the rules.	

b. $n = 1, l = 1, m_l = -1$

Plan Your Strategy	Act on Your Strategy
Analyze the set of quantum numbers against the rules for allowed quantum numbers.	not allowed
If the set is not allowed, explain why it does not obey the rules.	The value of l must be a positive integer that is less than n. Therefore, when $n = 1$, l cannot be 1. In addition, if $l = 0$, then m_l must also be zero.

c. $n = 0, l = 0, m_l = 0$

Plan Your Strategy	Act on Your Strategy
Analyze the set of quantum numbers against the rules for allowed quantum numbers.	not allowed
If the set is not allowed, explain why it does not obey the rules.	The principle quantum number must be a positive integer greater than 0. Thus, n cannot be 0.

d. $n = 5$, $l = 1$, $m_l = 3$

Plan Your Strategy	Act on Your Strategy
Analyze the set of quantum numbers against the rules for allowed quantum numbers.	not allowed
If the set is not allowed, explain why it does not obey the rules.	The value for m_l must be between $-l$ and $+l$. So, when $l = 1$, m_l cannot be 3. It must be -1, 0, or +1.

Check Your Solution

The answers are all in agreement with the rules.