Question #: 1

For each blank, give the **number of electrons** in an atom that can have the given value of quantum numbers:

\[ n = 3, l = 1 : \underline{1} \]

\[ n = 3, m_l = 1 : \underline{2} \]

Report each answer as an integer.

1. \underline{1}
2. \underline{2}

Question #: 2

Consider the orbital diagram below and select the statement that describes the degenerate orbitals in the diagram.

A. The three 2p orbitals are degenerate.
B. Only the two 2p orbitals that contain electrons are degenerate.
C. The 1s and 2s orbitals are degenerate.
D. None of the orbitals are degenerate.
Question #: 3

In the principle level with \( n = 3 \), what is the highest energy sublevel?

A. 3s  
B. 3p  
C. 3d  
D. 3f

Question #: 4

Select the statement that describes the error (if any) of a ground state helium atom that has quantum number \([n, l, ml, ms]\) as follows:
Electron 1: \([1, 0, 0, 1/2]\)  
Electron 2: \([1, 0, 0, 1/2]\)

A. There is no error. The two sets of quantum numbers are allowed.  
B. The Pauli exclusion principle is violated. The \( ms \) values must be different.  
C. Hund's rule is violated. The \( ml \) values must be different.  
D. The electrons must be in different shells. The \( n \) values must be different.

Question #: 5

The following are attempts at ground state orbital diagrams of a nitrogen atom. Which diagram violates Hund's Rule?

A.  
B.  
C.  
D. 
C.

\[
\begin{array}{ccc}
1s & 2s & 2p \\
\uparrow & \uparrow & \downarrow \\
\end{array}
\]

D. Both a) and c) violate Hund's rule.

---

**Question #: 6**

Provide the electron configuration of the element calcium.  
Put your answer in using a noble gas core in the format similar to \([\text{Ne}]\ 3s^2\ 3p^1\)

1. ______

---

**Question #: 7**

Write the electron configuration of silicon. How many valence electrons and core electrons are in the ground state atom?
Valence electrons = ______
Core electrons = ______

1. ______
2. ______
Question #: 8
How many elements in the 4th period have only five electrons in the d-subshell in the ground state configuration?

A. 0  
B. 1  
C. 2  
D. 5

Question #: 9
Consider the ground-state electron configurations of K, Ca, Sc and Ti. How many are paramagnetic?

A. 1  
B. 2  
C. 3  
D. 4

Question #: 10
Consider the orbital diagram below. Select the **false** statement concerning the electrons represented by the two red arrows.

A. The \( n \) values for the electrons are the same.  
B. The \( m_l \) values for the electron are the same.  
C. The \( m_s \) values for the electrons are the same.  
D. The \( l \) values for the electrons are the same.
Question #: 11

Below is a schematic of a beryllium atom. Consider the red electron that has an arrow pointing to it.
1) Which electron [A, B or C] has the least ability to shield the red electron from the positive charge of the nucleus? __1__
2) What is the effective nuclear charge, \( Z_{\text{eff}} \), of this electron? __2__

1. __________
2. __________

----------------------------------------------------------------------------------------------------------------------------------------
Question #: 12

Description of the above image. The blue spheres represent a diatomic molecule. The black dots are the atom’s nuclei. Line segment A reaches from outside edge of one atom to the outside edge of the other atom. Line segment B reaches from nucleus to nucleus.

How is atomic radius defined?

A. Length of line A.
B. $\frac{1}{2}$ the length of line A.
C. Length of line B.
D. $\frac{1}{2}$ the length of line B.

Question #: 13

Use increases or decreases to complete the sentence.
Across a period, from left to right, the atomic radius __1___ because the effective nuclear charge __2__.

1. __________ 
2. __________
Question #: 14

Fill in the blank with <, =, > to indicate the relative size of the radius of the ion to its parent atom.

Ca$^{2+}$ __ 1 __ Ca
O$^{2-}$ __ 2 __ O

1. __________
2. __________

Question #: 15

Consider an atom of Ca and an ion Ti$^{2+}$ and select the **true** statement.

A. The species are not isoelectronic because one is an atom and the other is an ion.
B. The species are isoelectronic because they have the same number of electrons.
C. The species are isoelectronic because they have the same electron configuration.
D. The species are not isoelectronic because they have different electron configurations.

_____

Question #: 16

Rank the species from smallest to largest. Enter each symbol with superscripts (i.e. Ca$^{2+}$ should be entered as Ca$^{2+}$)

$K^+$  Ca$^{2+}$  S$^{2-}$  Cl$^-$

1. __________
2. __________
3. __________
4. __________
**Question #**: 17

Ionization energy is the energy \(1\) [released, required] when \(2\) [adding, removing] an electron to/from a gaseous, ground-state atom.

1. __________
2. __________

---

**Question #**: 18

Rank the species from least to greatest ionization energy.

\[
\text{Cl} \quad \text{Sr} \quad \text{Se} \quad \text{Ca} \\
1 < 2 < 3 < 4
\]

1. __________
2. __________
3. __________
4. __________

---

**Question #**: 19

Select the group to which an element belongs if it has the following sequence of ionization energies (in kJ/mol).

\[
\text{IE}_1 = 738, \text{IE}_2 = 1450, \text{IE}_3 = 7730, \text{IE}_4 = 10500, \text{IE}_5 = 13600, \text{IE}_6 = 18000, \text{IE}_7 = 21700, \text{IE}_8 = 25700
\]

A. alkali metal
B. alkaline earth metal
C. halogen
D. noble gas
Question #: 20

What energy is associated with the following process?
\[ \text{F}(g) + e^- \rightarrow \text{F}^-(g) \]

A. first ionization energy
B. electron Affinity
C. electronegativity
D. lattice energy

Question #: 21

Place the element symbol **Cs, Ca** or **Al** in each blank.
The element with the greatest metallic character. 1
The element with the smallest ionization energy. 2
The element with the greatest reactivity. 3

1. ______
2. ______
3. ______

Question #: 22

Select the correct statement.

A. The compound CaCl$_2$ is ionic. The elements transfer electrons resulting in a bond formed by an electrostatic force.
B. The compound CaCl$_2$ is covalent. The bond is characterized by the sharing of electrons between atoms.
C. The compound SCl$_2$ is ionic. The bond is characterized by the sharing of electrons between atoms.
D. The compound SCl$_2$ is covalent. The elements transfer electrons resulting in a bond formed by electrostatic forces.
Question #: 23

Which reaction represents the process associated with lattice energy?

A. X(g) + e⁻ → X⁻(g)
B. M(s) → M⁺(g)
C. M⁺(g) + X⁻(g) → MX(s)
D. M(s) + ½X₂(g) → MX(s)

Question #: 24

Rank the ionic compounds in magnitude of the lattice energy from smallest to greatest. Enter formulas without subscripts (i.e. MgCl₂ should be entered as MgCl₂)

MgCl₂, CaS, KCl

1 < 2 < 3

1. ____________
2. ____________
3. ____________

Question #: 25

Select the compound with the greatest lattice energy

A. NaI
B. NaBr
C. LiBr
D. LiF
**Question #: 26**

The image below represents the _______ of O₂. The arrow is pointing to a _______ bond.

- A. Lewis structure, double
- B. ionic bonding, double
- C. Lewis structure, quadruple
- D. ionic bonding, quadruple

**Question #: 27**

Examine the Born-Haber Cycle for MgO. What is the missing reaction for the energy ΔH(4), indicated in the image with Q27?

- A. O(g) + e⁻ → O⁻(g)
- B. O(g) + 2 e⁻ → O²⁻(g)
- C. O(g) + e⁻ → O⁺(g)
- D. O(g) + 2e⁻ → O²⁺(g)
Question #: 28

Examine the Born-Haber Cycle for MgO. The concept of the Born-Haber Cycle allows for the calculation of ______ indicated as ______ in the image.

A. enthalpy of formation, ΔH(6)
B. enthalpy of formation, ΔH(5)
C. lattice energy, ΔH(5)
D. lattice energy, ΔH(6)
**Question #: 29**

Examine the Born-Haber Cycle for MgO. What is(are) the energies that are needed to obtain $\Delta H(3)$?

Note: In answers, EA = electron affinity, IE = ionization energy.

A. $2 \times EA_1$
B. $EA_1 + EA_2$
C. $2 \times IE_1$
D. $IE_1 + IE_2$
**Question #**: 30

**Bonus Question**
From the table of energies provided. Calculate the lattice energy of MgO.

<table>
<thead>
<tr>
<th>Enthalpy</th>
<th>Value (kJ/mol)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enthalpy of formation, MgO</td>
<td>−602</td>
</tr>
<tr>
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<td>146</td>
</tr>
<tr>
<td>First Ionization Energy, Mg</td>
<td>738</td>
</tr>
<tr>
<td>Second Ionization Energy, Mg</td>
<td>1450</td>
</tr>
<tr>
<td>First Electron Affinity, O</td>
<td>−142</td>
</tr>
<tr>
<td>Second Electron Affinity, O</td>
<td>844</td>
</tr>
<tr>
<td>First Ionization Energy, O</td>
<td>1314</td>
</tr>
<tr>
<td>Second Ionization Energy, O2</td>
<td>3389</td>
</tr>
<tr>
<td>Bond Dissociation Energy, O2</td>
<td>498</td>
</tr>
</tbody>
</table>

Lattice energy = ___1___ kJ/mol
Report your answer with **four** significant figures. Do **NOT** include units in your answer. Do **NOT** use scientific notation.

1. __________
For each blank, give the **number of electrons** in an atom that can have the given value of quantum numbers:

- \( n = 3, l = 1 \): ____

- \( n = 3, m_l = 1 \): ____

Report each answer as an integer.

1. 6[six]
2. 4[four]

---

Consider the orbital diagram below and select the statement that describes the degenerate orbitals in the diagram.
A. The three 2p orbitals are degenerate.
B. Only the two 2p orbitals that contain electrons are degenerate.
C. The 1s and 2s orbitals are degenerate.
D. None of the orbitals are degenerate.

Question #: 3

In the principle level with \( n = 3 \), what is the highest energy sublevel?

A. 3s
B. 3p
C. 3d
D. 3f

Question #: 4

Select the statement that describes the error (if any) of a ground state helium atom that has quantum number \([n, l, m_l, m_s]\) as follows:
Electron 1: \([1, 0, 0, 1/2]\)
Electron 2: \([1, 0, 0, 1/2]\)

A. There is no error. The two sets of quantum numbers are allowed.
B. The Pauli exclusion principle is violated. The \( m_s \) values must be different.
C. Hund’s rule is violated. The \( m_l \) values must be different.
D. The electrons must be in different shells. The \( n \) values must be different.

Question #: 5

The following are attempts at ground state orbital diagrams of a nitrogen atom. Which diagram violates Hund’s Rule?
A. 

B. 

C. ✓

D. Both a) and c) violate Hund’s rule.

Question #: 6

Provide the electron configuration of the element calcium. 
Put your answer in using a noble gas core in the format similar to [Ne] 3s2 3p1

1. [Ar] 4s2

Question #: 7

Write the electron configuration of silicon. How many valence electrons and core electrons are in the ground state atom?

Valence electrons = 
Core electrons = 

1. 4
2. 10
Question #: 8

How many elements in the 4th period have only five electrons in the d-subshell in the ground state configuration?

A. 0
B. 1
✓C. 2
D. 5

Question #: 9

Consider the ground-state electron configurations of K, Ca, Sc and Ti. How many are paramagnetic?

A. 1
B. 2
✓C. 3
D. 4

Question #: 10

Consider the orbital diagram below. Select the false statement concerning the electrons represented by the two red arrows.

A. The $n$ values for the electrons are the same.
✓B. The $m_l$ values for the electron are the same.
C. The $m_s$ values for the electrons are the same.
D. The $l$ values for the electrons are the same.
Question #: 11

Below is a schematic of a beryllium atom. Consider the red electron that has an arrow pointing to it.

1) Which electron [A, B or C] has the least ability to shield the red electron from the positive charge of the nucleus? 1
2) What is the effective nuclear charge, $Z_{\text{eff}}$, of this electron? 2

1. A
2. $2|+2|$
Description of the above image. The blue spheres represent a diatomic molecule. The black dots are the atom’s nuclei. Line segment A reaches from outside edge of one atom to the outside edge of the other atom. Line segment B reaches from nucleus to nucleus.

How is atomic radius defined?

A. Length of line A.
B. \( \frac{1}{2} \) the length of line A.
C. Length of line B.
✓D. \( \frac{1}{2} \) the length of line B.

Question #: 13

Use **increases** or **decreases** to complete the sentence.

Across a period, from left to right, the atomic radius **1** because the effective nuclear charge **2**.

1. decreases
2. increases

Question #: 14

Fill in the blank with <, =, > to indicate the relative size of the radius of the ion to its parent atom.

\[
\begin{align*}
\text{Ca}^{2+} & \quad 1 \quad \text{Ca} \\
\text{O}^{2-} & \quad 2 \quad \text{O}
\end{align*}
\]

1. <
2. >

Question #: 15

Consider an atom of Ca and an ion Ti\(^{2+}\) and select the **true** statement.

A. The species **are not** isoelectronic because one is an atom and the other is an ion.
B. The species **are** isoelectronic because they have the same number of electrons.
C. The species **are** isoelectronic because they have the same electron configuration.
✓D. The species **are not** isoelectronic because they have different electron configurations.
Question #: 16

Rank the species from smallest to largest. Enter each symbol with superscripts (i.e. Ca$^{2+}$ should be entered as Ca$^{2+}$)

\[ \text{K}^+ \quad \text{Ca}^{2+} \quad \text{S}^{2-} \quad \text{Cl}^- \]

\[
\begin{align*}
1 & \quad < \\ 2 & \quad < \\ 3 & \quad < \\ 4 &
\end{align*}
\]

1. Ca$^{2+}$
2. K$^+$
3. Cl$^-$
4. S$^{2-}$

Question #: 17

Ionization energy is the energy \[ \text{1} \] [released, required] when \[ \text{2} \] [adding, removing] an electron to/from a gaseous, ground-state atom.

1. required
2. removing

Question #: 18

Rank the species from least to greatest ionization energy.

\[ \text{Cl} \quad \text{Sr} \quad \text{Se} \quad \text{Ca} \]

\[
\begin{align*}
1 & \quad < \\ 2 & \quad < \\ 3 & \quad < \\ 4 &
\end{align*}
\]

1. Sr
2. Ca
3. Se
4. Cl

Question #: 19
Select the group to which an element belongs if it has the following sequence of ionization energies (in kJ/mol).

\[ \text{IE}_1 = 738, \text{IE}_2 = 1450, \text{IE}_3 = 7730, \text{IE}_4 = 10500, \text{IE}_5 = 13600, \text{IE}_6 = 18000, \text{IE}_7 = 21700, \text{IE}_8 = 25700. \]

A. alkali metal  ✓
B. alkaline earth metal
C. halogen
D. noble gas

Question #: 20

What energy is associated with the following process?

\[ \text{F(g)} + e^- \rightarrow \text{F}^-(g) \]

A. first ionization energy  ✓
B. electron Affinity
C. electronegativity
D. lattice energy

Question #: 21

Place the element symbol Cs, Ca or Al in each blank.
The element with the greatest metallic character. 1
The element with the smallest ionization energy. 2
The element with the greatest reactivity. 3

1. Cs
2. Cs
3. Cs

Question #: 22

Select the correct statement.
A. The compound CaCl₂ is ionic. The elements transfer electrons resulting in a bond formed by an electrostatic force.
B. The compound CaCl₂ is covalent. The bond is characterized by the sharing of electrons between atoms.
C. The compound SCl₂ is ionic. The bond is characterized by the sharing of electrons between atoms.
D. The compound SCl₂ is covalent. The elements transfer electrons resulting in a bond formed by electrostatic forces.

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Which reaction represents the process associated with lattice energy?

A. X(g) + e⁻ → X⁻(g)
B. M(s) → M⁺(g)
C. M⁺(g) + X⁻(g) → MX(s)
D. M(s) + ½X₂(g) → MX(s)

Question #: 24

Rank the ionic compounds in magnitude of the lattice energy from smallest to greatest. Enter formulas without subscripts (i.e. MgCl₂ should be entered as MgCl2)

\[
\begin{array}{ccc}
\text{MgCl}_2 & \text{CaS} & \text{KCl} \\
1 & 2 & 3 \\
\end{array}
\]

1. CaS
2. MgCl₂
3. KCl

Question #: 25

Select the compound with the greatest lattice energy

A. NaI
B. NaBr
C. LiBr
D. LiF
Question #: 26

The image below represents the _______ of O₂. The arrow is pointing to a _______ bond.

✓ A. Lewis structure, double
   B. ionic bonding, double
   C. Lewis structure, quadruple
   D. ionic bonding, quadruple

Question #: 27

Examine the Born-Haber Cycle for MgO. What is the missing reaction for the energy ΔH(4), indicated in the image with Q27?
A. $\text{O}(g) + e^- \rightarrow \text{O}^-(g)$

✓B. $\text{O}(g) + 2e^- \rightarrow \text{O}_2^-(g)$

C. $\text{O}(g) + e^- \rightarrow \text{O}^+(g)$

D. $\text{O}(g) + 2e^- \rightarrow \text{O}_2^+(g)$

Question #: 28

Examine the Born-Haber Cycle for MgO. The concept of the Born-Haber Cycle allows for the calculation of ______ indicated as ______ in the image.
Examine the Born-Haber Cycle for MgO. What is(are) the energies that are needed to obtain ΔH(3)?

Note: In answers, EA = electron affinity, IE = ionization energy.
A. $2 \times EA_1$
B. $EA_1 + EA_2$
C. $2 \times IE_1$
D. $IE_1 + IE_2$

**Bonus Question**

From the table of energies provided, calculate the lattice energy of MgO.

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</table>
Lattice energy = \( -3887 \) kJ/mol

Report your answer with \textbf{four} significant figures. Do \textbf{NOT} include units in your answer. Do \textbf{NOT} use scientific notation.

1. -3887