

This print-out should have 14 questions. Multiple-choice questions may continue on the next column or page – find all choices before answering.

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**001 10.0 points**

Which phenomenon provides the best evidence that light can have particle properties?

1. Electromagnetic radiation
2. Electron diffraction
3. Photoelectric effect **correct**
4. Interference of light in thin films
5. X-ray diffraction

**Explanation:**

Interference of light in thin films and electromagnetic radiation are generally used to show the wavelike properties of light. Electron diffraction is used to show the wavelike properties of matter. X-ray diffraction is a result of the wave properties of light.

The photoelectric effect supports the idea that light is quantized, or carries discrete amounts of energy. This is a property of particles manifested by light.

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**002 10.0 points**

Which of the following is not a permitted combination of quantum numbers?

1.  $n = 6, \ell = 5, m_\ell = -5, m_s = -\frac{1}{2}$
2.  $n = 5, \ell = 3, m_\ell = -2, m_s = \frac{1}{2}$
3.  $n = 3, \ell = 2, m_\ell = -2, m_s = \frac{1}{2}$
4.  $n = 8, \ell = 0, m_\ell = 0, m_s = \frac{1}{2}$
5.  $n = 4, \ell = 0, m_\ell = -2, m_s = -\frac{1}{2}$

**correct**

**Explanation:**

For  $\ell = 0$ ,  $m_\ell$  can only have a value of 0.

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**003 10.0 points**

How many electrons are in principle energy level 7 ( $n = 7$ )?

1. 28
2. 14
3. 98 **correct**
4. 196
5. 49

**Explanation:**

the number of electrons in a given principle energy level is equal to  $2n^2$ .

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**004 10.0 points**

What is the correct electronic configuration for a ground-state divalent Barium cation ( $\text{Ba}^{2+}$ )?

1.  $[\text{Rn}]$
2.  $[\text{Rn}] 6s^2 5d^2$
3.  $[\text{Xe}] 6s^1$
4.  $[\text{Rn}] 6s^1$
5.  $[\text{Xe}]$  **correct**
6.  $[\text{Xe}] 6s^2 4f^2$

**Explanation:**

The Aufbau order of electron filling is  $1s, 2s, 2p, 3s, 3p, 4s, 3d, 4p, 5s, 4d, 5p, 6s, 4f, 5d, 6p, \text{etc.}$

$s$  orbitals can hold 2 electrons,  $p$  orbitals 6 electrons, and  $d$  orbitals 10 electrons. Note some exceptions do occur in the electron configuration of atoms because of the stability of either a full or half-full outermost  $d$ -orbital, so you may need to account for this by ‘shuffling’ an electron from the  $(n - 1)s$  orbital. Finally use noble gas shorthand to get the answer:  $\text{Ba}^{2+}$  has 54 electrons all of which are accounted for by the shorthand notation,  $[\text{Xe}]$ .

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**005 10.0 points**

Which of the following elements is not correctly paired with its group (family) name?

1. Radon (Rn), Noble gases
2. Bismuth (Bi), Halogens **correct**
3. Lithium (Li), Alkali metals
4. Strontium (Sr), Alkaline earth metals

**Explanation:**

The pnictogens are the family containing nitrogen through bismuth. The halogens are fluorine through astatine.

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**006 10.0 points**

Which of the following BEST describes the purpose of effective nuclear charge?

1. It is a measure of the effect of filled and half-filled subshells on the stability of atoms and ions.
2. It exists only to torture foolish CH 301 students who did not study.
3. It is used to determine the number of valence electrons of a given species.
4. It is used to rationalize chemical bonding in covalently bonded molecules.
5. It is a measure of how many protons a given atom has which is useful because of variations from isotope to isotope.
6. It is a method to evaluate how much attraction a given electron “feels” from the nucleus so that periodic trends can be predicted and rationalized. **correct**

**Explanation:**

Inner shell electrons “shield” the outer shell electrons from the full attraction of the nucleus. An electron in a higher shell, farther from the nucleus, feels much less attraction, for example; in other words the effective nu-

clear charge it experiences is smaller. This is used to rationalize the periodic trends.

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**007 10.0 points**

Rank the following isoelectronic species from smallest to largest ionic radius:  $\text{Ca}^{2+}$ ,  $\text{S}^{2-}$ ,  $\text{Cl}^-$ ,  $\text{Ga}^{3+}$ .

1.  $\text{Cl}^- < \text{S}^{2-} < \text{Ca}^{2+} < \text{Ga}^{3+}$
2.  $\text{S}^{2-} < \text{Cl}^- < \text{Ca}^{2+} < \text{Ga}^{3+}$
3.  $\text{Ga}^{3+} < \text{Ca}^{2+} < \text{Cl}^- < \text{S}^{2-}$  **correct**
4.  $\text{Ga}^{3+} < \text{S}^{2-} < \text{Ca}^{2+} < \text{Cl}^-$
5.  $\text{Ca}^{2+} < \text{Ga}^{3+} < \text{S}^{2-} < \text{Cl}^-$

**Explanation:**

The ionic radius trend is very smooth. For a given set of isoelectronic species, the one with most protons is the smallest and the one with the least protons is the largest.

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**008 10.0 points**

Rank the following species in terms of increasing electron affinity: Sulfur (S), Rubidium (Rb), Germanium (Ge), Krypton (Kr), Fluorine (F)

1.  $\text{Kr} < \text{Rb} < \text{Ge} < \text{S} < \text{F}$  **correct**
2.  $\text{F} < \text{Ge} < \text{S} < \text{Rb} < \text{Kr}$
3.  $\text{Ge} < \text{Rb} < \text{S} < \text{F} < \text{Kr}$
4. Not enough information
5.  $\text{Rb} < \text{Ge} < \text{S} < \text{F} < \text{Kr}$
6.  $\text{Kr} < \text{Ge} < \text{Rb} < \text{S} < \text{F}$

**Explanation:**

Elements’ electron affinities increase across a given period and up and given group. Noble gases (*i.e.* Kr) have an electron affinity of essentially zero. Rb is greater than zero, Ge is greater than Rb, S is greater than Ge, and F is greater than P.

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**009 10.0 points**

What is the electronic configuration of a Copper atom (Cu)?

1. [Ar]  $4s^1 4d^9$
2. [Ne]  $4s^1 4d^{10}$
3. [Ar]  $4s^2 3d^5 4p^3$
4. [Ar]  $4s^2 3d^9$
5. [Ar]  $4s^1 3d^{10}$  **correct**

**Explanation:**

The enhanced stability afforded by a filled  $d$  subshell results in a single  $4s$  electron being “borrowed” to fill Copper’s  $3d$  subshell; therefore, Cu is [Ar]  $4s^1 3d^{10}$ .

**010 10.0 points**

The ionization energy of an Oxygen atom (O) is (equal to/greater than/less than) what you would predict based on simple effective nuclear charge arguments because the half-filled  $2p$  orbital for  $O^+$  is (more/less) stable.

1. greater than, more
2. equal to, less
3. less than, more **correct**
4. greater than, less
5. less than, less
6. equal to, more

**Explanation:**

$O^+$ ’s  $2p$  subshell is half-filled, affording additional stability. As a consequence, less energy is required to remove an electron from O than one would predict simply based on effective nuclear charge and Oxygens’s place in the IE trend reflects this with a diminished ionization energy.

**011 10.0 points**

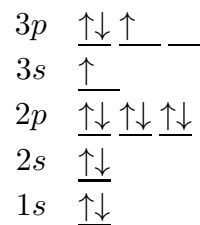
Which of the following types of electromag-

netic radiation has the shortest wavelength?

1.  $3.12 \times 10^{-19}$  J
2.  $2.74 \times 10^{-19}$  J
3.  $3.57 \times 10^{-19}$  J **correct**
4.  $3.05 \times 10^{-19}$  J
5.  $2.83 \times 10^{-19}$  J

**Explanation:**

Higher energies correspond to shorter wavelengths, from the equation  $E = \frac{hc}{\lambda}$ .

**012 10.0 points**

Consider the electron filling diagram for a ground state atom illustrated above. Which of the following does it violate?

- I) The Aufbau principle
- II) Hund’s rule
- III) The Pauli exclusion principle

1. I, II **correct**
2. III only
3. I only
4. II, III
5. I, III
6. II only
7. I, II, III

**Explanation:**

Aufbau’s principle says you must fill the orbitals in order from lowest energy to high-

est. Putting electrons in the  $3p$  orbitals before filling the  $3s$  orbital violates that.

Hund's rule says that orbitals in the same subshell must each have an unpaired electron before any of them can have a pair. This is violated in the  $3p$  subshell.

The Pauli exclusion principle says that no two electrons can have the same four quantum numbers, which the given configuration does not violate.

feel an effective nuclear charge ( $Z_{\text{eff}}$ ) of +2.

Effective nuclear charge:

$$Z_{\text{eff}} = \# \text{ of protons in the nucleus} \\ - \# \text{ of lower energy electrons} \\ \text{(not in the outer shell).}$$

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### 013 10.0 points

The transition metals are elements with partially filled

1.  $s$  subshells.
2.  $p$  subshells.
3.  $f$  subshells.
4.  $d$  subshells. **correct**

#### Explanation:

In transition metals,  $d$  orbitals are being filled.

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### 014 10.0 points

Due to the screening effect, the  $3s$  electrons of magnesium (Mg) feel an effective nuclear charge ( $Z_{\text{eff}}$ ) of

1. +1
2. +12
3. -2
4. +4
5. +2 **correct**

#### Explanation:

The two  $3s$  electrons are partially shielded from the 12 protons in the nucleus by the 10 electrons in the lower energy orbitals. The lower energy electrons cancel out 10 of the positive charges from the protons in the nucleus, leaving only two positive charges to act on the two  $3s$  electrons. Thus the  $3s$  electrons