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 of the following statement(s) is/are true?

I) Classical mechanics accurately predicted the behavior of blackbody radiators.
II) The failure of classical mechanics to predict the behavior of blackbody radiators is called the ultraviolet catastrophe.
III) A minimum frequency of light is required to eject an electron from a metal surface.
IV) The emission spectra of gases are continuous rather than discrete.

1. II, III, and IV

2. I and III

3. II and III **correct**

4. III and IV

5. I, II and IV

Explanation:

Classical mechanics predicted that the power radiated by a blackbody radiator would be proportional to the square of the frequency at which it emitted radiation, and thus approach infinity as the frequency increased. This was false, since at higher frequencies blackbody radiators emit less, not more power. This was termed the ultraviolet catastrophe. Classical mechanics also predicted that the energy (velocity) of electrons emitted from a metal surface is proportional to the intensity of light. In reality, the energy (velocity) is only dependent upon the frequency of light. Once the threshold frequency is reached, however, the number of emitted electrons is proportional to the intensity of light. Classical mechanics also fails in explaining the discrete lines in absorption/emission spectrum, which are due to discrete energy levels of atoms.

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002 10.0 points

What is the correct electronic configuration for a ground-state Gold atom (Au)?

1. [Rn] $6s^1\,4f^{14}\,5d^{10}$

2. [Xe] $6s^2\,4f^{14}\,5d^9$

3. [Rn] $6s^2\,4f^{14}\,5d^9$

4. [Rn] $6s^1\,5d^{10}$

5. [Xe] $6s^1\,4f^{14}\,5d^{10}$ **correct**

6. [Xe] $6s^1\,5d^{10}$

Explanation:

The Aufbau order of electron filling is $1s$, $2s$, $2p$, $3s$, $3p$, $4s$, $3d$, $4p$, $5s$, $4d$, $5p$, $6s$, $4f$, $5d$, $6p$, *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 in the case of gold you need to account for this by 'shuffling' an electron from the $6s$ orbital into the $5d$ orbital. Finally use noble gas shorthand to get the answer: [Xe] $6s^1\,4f^{14}\,5d^{10}$.

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003 10.0 points

What is the correct electronic configuration for a ground-state Antimony(V) ion (Sb^{5+})?

1. [Kr] $5s^0\,3f^{14}\,4d^{10}$

2. [Kr] $5s^1\,4d^{10}$

3. [Kr] $5s^0\,4d^{10}$ **correct**

4. [Kr] $5s^2\,4d^{10}$

5. [Kr] $5s^2\,4d^8$

Explanation:

The Aufbau order of electron filling is $1s$, $2s$, $2p$, $3s$, $3p$, $4s$, $3d$, $4p$, $5s$, $4d$, $5p$, $6s$, $4f$, $5d$, $6p$, *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 ions of main group metals (such as Antimoy). When forming an ion from a main group metal, electrons are removed first from the highest energy p orbital followed by the highest energy s orbital. Finally use noble gas shorthand to get the answer: [Kr] $5s^0\,4d^{10}$.

004 10.0 points

Rank the following from least to greatest ionization energy: silicon (Si), phosphorous (P), sulfur (S).

1. P < S < Si

2. Si < P < S

3. Si < S < P **correct**

4. S < Si < P

5. P < Si < S

6. S < P < Si

Explanation:

Ionization energy increases increases across a given row, but because of the added stability of a half-filled p subshell, sulfur has a lower ionization energy than would be simply predicted based on effective nuclear charge arguments.

005 10.0 points

Rank the following species in terms of decreasing atomic radius: Chlorine (Cl), Thallium (Tl), Arsenic (As), Tin (Sn), Lead (Pb)

1. Cl > As > Pb > Sn > Tl

2. Tl > Pb > Sn > As > Cl **correct**

3. Cl > As > Sn > Tl > Pb

4. Cl > As > Sn > Pb > Tl

5. Tl > Sn > Pb > As > Cl

6. Not enough information

Explanation:

The atomic radius trend is very smooth. Elements' atomic radii decrease to the right across a given period and up a given group. Therefore Pb is smaller than Tl, Sn is smaller than Pb, As is smaller than Sn, and lastly Cl is smaller than As.

006 10.0 points

Which of the following sets of quantum numbers are **valid**, i.e. don't violate any boundary conditions?

I) $n = 3, \ell = 2, m_\ell = -2, m_s = +\frac{1}{2}$

II) $n = 9, \ell = 5, m_\ell = 6, m_s = +\frac{1}{2}$

III) $n = 2, \ell = 1, m_\ell = 0, m_s = +1$

IV) $n = 2, \ell = 0, m_\ell = 0, m_s = +\frac{1}{2}$

1. I only

2. I, III, IV

3. II only

4. III only

5. II, III

6. I, II, IV

7. IV only

8. I, IV **correct**

Explanation:

Set II and III are invalid. For II, $m_{ell} = 6$ is disallowed because $\ell = 5$. For III, $m_s = +1$ is disallowed because m_s may only be $+\frac{1}{2}$ or $-\frac{1}{2}$.

007 10.0 points

What is the shortest-wavelength line in the emission spectrum of the hydrogen atom?

1. 100 nm

2. 122 nm

3. 1.00 nm

4. 182 nm

5. 91.2 nm **correct**

Explanation:
The Rydberg formula gives the frequencies of the emission lines in the hydrogen atom:

$$\nu = R\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right).$$

The wavelengths would be given by

$$\lambda = \frac{c}{\nu} = \frac{c}{R\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)}$$

The smallest value of λ would have the largest value of ν and the largest value of $\frac{1}{n_1^2} - \frac{1}{n_2^2}$. This will happen when $n_1 = 1$ and $n_2 = \infty$, giving

$$\begin{aligned}\lambda &= \frac{3 \times 10^8 \text{ m/s}}{(3.29 \times 10^{15} \text{ Hz})\left(1 - \frac{1}{\infty^2}\right)} \\ &= \frac{3 \times 10^8 \text{ m/s}}{(3.29 \times 10^{15} \text{ Hz})\,(1)} \\ &= 9.11854 \times 10^{-8} \text{ m}\end{aligned}$$

because $\frac{1}{\infty^2} = \frac{1}{\infty} = 0$.

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008 10.0 points

How many electrons can possess this set of quantum numbers: principal quantum number $n = 4$, magnetic quantum number $m_\ell = 0$?

1. 6

2. 8 **correct**

3. 12

4. 18

5. 2

6. 10

7. 14

8. 0

9. 16

10. 4

Explanation:
$m_\ell = 0$ represents one orientation of each orbital with the principal quantum number 4. At the principle level 4, there exists the 4s, 4p, 4d, and 4f orbitals. Each orbital will have one orientation with $m_\ell = 0$. Two electrons can exist in each of these orbitals, thus there can be a total of 8 electrons (4 orbitals with 2 electrons per orbital). Note that 4p, 4d, and 4f also have there orientations where m_ℓ is $+1$ and -1 for p, $+2$, $+1$, -1 and -2 for d, and $+3$, $+2$, $+1$, -1, -2, and -3 for f.

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009 10.0 points

Which of the following *valence-shell configurations*

	4s	4p		
I)	↑↓	↑	↓	__
II)	↑↓	↑	↑	__
III)	↑↓	↑↓	__	__
IV)	↑	↑	↑	↑

could describe a neutral atom in its ground state?

1. I only

2. None of the configurations

3. II only **correct**

4. IV only

5. III only

6. More than one of the configurations

Explanation:

The atom with a $4s^2\,4p^2$ valence-shell configuration is germanium (Ge). The ground-state configuration is given by

$$\underline{\uparrow\downarrow}\quad \underline{\uparrow}\ \underline{\uparrow}\ \underline{\ \ \ }$$

The other configurations represent excited states.

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010 10.0 points

Fill in the blanks: chlorine is one of the most well-known elements in the halogen ______. It belongs to ______17 which makes it a ______element. Its valence electrons belong to the $n = 3$ ______, and it has a nearly-filled $3p$ ______, making it very reactive. Cl^- is a very stable anion because it is isoelectronic to a ______.

1. family, group, main group, shell, subshell, noble gas **correct**

2. group, column, non-metal, shell, orbital, metal

3. row, group, main group, shell, orbital, noble gas

4. series, family, reactive, row, subshell, noble gas

5. family, column, common, row, shell, anion

Explanation:

Family refers to the common name of a group or groups of similar elements, e.g. rare earth, coinage metal, halogen. The number (1-18) of the column of an element is the group. All elements in rows 3-12 are called d-block elements, while the rest of the rows are called main group elements. Chlorine is on row 3, but the principal quantum number n always refers to an electron shell. The $3p$ orbitals of Cl form a subshell of the $n = 3$ shell, along with the $3s$ orbital. Cl^- is isoelectronic to group 18 which are called the noble gases.

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011 10.0 points

When dealing with electrons in atoms and molecules, the electrons that are not considered as valence electrons (can, cannot) effectively shield the nucleus and thereby (decrease, increase) the effective nuclear charge.

1. cannot; increase

2. can; increase

3. cannot; decrease

4. The non-valence electrons do nothing.

5. can; decrease **correct**

Explanation:

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012 10.0 points

Given the elements Cl, Ge, and K and the values 418, 1255, and 784 kJ/mol of possible first ionization energies, match the atoms with their first ionization energies.

1. Cl: 1255 kJ/mol; Ge: 784 kJ/mol; and K: 418 kJ/mol **correct**

2. Cl: 784 kJ/mol; Ge: 1255 kJ/mol; and K: 418 kJ/mol

3. Cl: 418 kJ/mol, Ge: 1255 kJ/mol; and K: 784 kJ/mol

4. Cl: 1255 kJ/mol; Ge: 418 kJ/mol; and K: 784 kJ/mol

5. Cl: 418 kJ/mol; Ge: 784 kJ/mol; and K: 1255 kJ/mol

Explanation:

Cl is a Group 7 non-metal and will tend to form a -1 ion, so it will be very reluctant to give up an electron and will have a very high first ionization energy. K is a group 1 metal and will readily lose an electron to form a $+1$ ion so the first ionization energy will be very low. Ge will form positive ions and be intermediate in its first ionization energy.

013 10.0 points

Which of the following concepts best describes the reason that atoms are larger and electron energies are weaker as you go down the periodic table?

1. increased proton density

2. Aufbau Principle

3. electronegativity

4. shielding **correct**

5. stable filled shells

Explanation:

As you go down the periodic table the number of shells increases, thus increasing shielding effects and decreasing effective nuclear charge. The outer shell electrons experience a decreased effective nuclear charge and are held less tightly to the nucleus than inner shell electrons. The electron energy is the energy needed to remove an electron. If the energy is small the electron can be easily removed. This weak attraction of the electron to the nucleus is due to shielding.

014 10.0 points

Which of the following atoms would have the smallest size (atomic radius)?

1. S

2. N

3. Li

4. O **correct**

5. B

Explanation:

Atomic radii become smaller as you move from left to right across a row, and also smaller as you move *up* a column. Diagonal relationships can be tricky, especially when you have to decide which of the two relationships will be the most important. Here, luckily, the comparison works well. The smallest radius here would then belong to the element which sits closest to the top right corner of the periodic table, which is O in this example.