

Atomic Structure and the Periodic Table - Self-Test Review Sheet for AP Chemistry

Multiple Choice

- What is the most likely electron configuration for a sodium ion in its ground state?
 - $1s^2 2s^2 2p^5$
 - $1s^2 2s^2 2p^6$
 - $1s^2 2s^2 2p^6 3s^1$
 - $1s^2 2s^2 2p^5 3s^2$
 - $1s^2 2s^2 2p^6 3s^2$
- Which of the following statements is true regarding sodium and chlorine?
 - Sodium has greater electronegativity and a larger first ionization energy
 - Sodium has a larger first ionization energy and a larger atomic radius
 - Chlorine has a larger atomic radius and a greater electronegativity
 - Chlorine has greater electronegativity and a larger first ionization energy
 - Chlorine has a larger atomic radius and a larger first ionization energy
- Which of the following could be the quantum numbers (n , l , m_l , m_s) for the valence electron in a potassium atom in its ground state?
 - 3, 0, 0, $\frac{1}{2}$
 - 3, 1, 1, $\frac{1}{2}$
 - 4, 0, 0, $\frac{1}{2}$
 - 4, 1, 1, $\frac{1}{2}$
 - 4, 2, 1, $\frac{1}{2}$
- Which of the following elements is diamagnetic?
 - H
 - Li
 - Be
 - B
 - C
- Which of the following ions has the smallest ionic radius?
 - O^{2-}
 - F^-
 - Na^+
 - Mg^{2+}
 - Al^{3+}
- When an electron in a hydrogen atom makes the transition from the $n = 4$ state to the $n = 2$ state, blue light is emitted. Which of the following expressions gives the energy released by the transition?
 - $\frac{(6.63 \times 10^{-34})(3.00 \times 10^8)}{(4.34 \times 10^{-7})}$ Joules
 - $\frac{(6.63 \times 10^{-34})(4.34 \times 10^{-7})}{(3.00 \times 10^8)}$ Joules
 - $\frac{(6.63 \times 10^{-34})}{(4.34 \times 10^{-7})(3.00 \times 10^8)}$ Joules
 - $\frac{(4.34 \times 10^{-7})}{(6.63 \times 10^{-34})(3.00 \times 10^8)}$ Joules
 - $(6.63 \times 10^{-34})(4.34 \times 10^{-7})$ Joules
- The ionization energies for an element are listed below.

IE_1	IE_2	IE_3	IE_4
578 kJ/mol	1820 kJ/mol	2750 kJ/mol	11,600 kJ/mol

Based on these values, the element is most likely to be

- Sodium
- Magnesium
- Aluminum

- d) Silicon
- e) Phosphorus

Essay Questions

1. Explain the following in terms of atomic and molecular structures and/or forces.
 - a) The first ionization energy for magnesium is greater than the first ionization energy for calcium.
 - b) The first and second ionization energies for calcium are comparable, but the third ionization energy is much greater.
 - c) The second ionization energy for sodium is much greater than the first ionization energy, but the second ionization energy for magnesium is comparable to its first ionization energy.

2. Silicon is a non-metal with four valence electrons.
 - a) Write the ground state electron configuration for silicon
 - b) Which fundamental atomic theory is violated by the following list of quantum numbers representing silicon's valence electrons?

n	l	m _l	m _s
3	0	0	-1/2
3	0	0	-1/2
3	1	1	-1/2
3	1	1	-1/2

- c) Which fundamental atomic theory is violated by the following list of quantum numbers representing silicon's valence electrons?

n	l	m _l	m _s
3	0	0	-1/2
3	0	0	+1/2
3	1	-1	-1/2
3	1	-1	+1/2

- d) Will a lone silicon atom be diamagnetic or paramagnetic?
3. Use your knowledge of the periodic table to answer the following questions.
 - a) Explain the trend in electronegativity from P to S to Cl.
 - b) Explain the trend in electronegativity from Cl to Br to I.
 - c) Explain the trend in atomic radius from Li to Na to K.
 - d) Explain the trend in atomic radius from Al to Mg to Na.
4. When an electron in a hydrogen atom makes the transition from the n = 4 state to the n = 1 state,
 - a) What is the energy of the emitted light?
 - b) What is the wavelength of the emitted light?
 - c) If the electron has a wavelength of 0.122 nm, what is its velocity (the mass of an electron is 9.11×10^{-28} g)?

Answers:

Multiple Choice

1. b – Neutral sodium in its ground state has the electron configuration shown in (c). Sodium forms an ion by giving up one valence electron and in this form it has the same electron configuration as neon.
2. d – As we move from left to right across the periodic table within a single period (from sodium to chlorine), we add protons to the nuclei, which progressively increases the pull of each nucleus on its electrons. So chlorine will have a higher first IE, greater electronegativity, and a smaller atomic radius.
3. c – Potassium's valence electron is in the 4s orbital. That means that n = 4, l = 0, m_l = 0, and m_s = -1/2 or +1/2.
4. c – Beryllium's electrons are paired up in the completed 1s and 2s orbitals. e is wrong because, according to Hund's rule, carbon's two 2p electrons must be placed in different orbitals.
5. e – All of the ions listed have the same electron configuration as neutral neon. Al³⁺ has the most protons, so its electrons will experience greater attractive force from the nucleus, resulting in the smallest ions.
6. a – When you know the wavelength emitted, the formula for the energy of an electron transition is shown below.

Remember that 1 nm = 1×10^{-9} m.
$$E_n = \frac{hc}{\lambda}$$

7. c – The ionization energy will show a large jump when enough electrons have been removed to leave a stable shell. Aluminum has 3 valence electrons, so we would expect to see a large jump in ionization energy after the third electron has been removed.

Essays

1.

- Ionization energy is the energy required to remove an electron from an atom. The outermost electron in Ca is at the 4s energy level. The outermost electron in Mg is at the 3s level. The outermost electron in Ca is at a higher energy level and is more shielded from the nucleus, making it easier to remove.
- Calcium has two electrons in its outer shell. The second ionization energy will be larger than the first, but still comparable because both electrons are being removed from the same energy level. The third electron is much more difficult to remove because it is being removed from a lower energy level, so it will have a much higher ionization energy than the other two.
- Sodium has one electron in its outer shell, while magnesium has two. After sodium's one valence electron has been removed, the second electron must be removed from a much lower energy level, requiring a much larger ionization energy. Magnesium's two electrons are removed from the same energy level, so while the second ionization energy will be larger than the first, it will not be very much larger.

2.

- $1s^2 2s^2 2p^6 3s^2 3p^2$
- The Pauli Exclusion Principle is violated. The Pauli Exclusion Principle states that no two electrons can have the same set of quantum numbers.
- Hund's rule is violated. Hund's rule states that within an energy level, electrons will be placed in empty orbitals while they are available, and will only start to pair up in orbitals when no more empty orbitals are available.
- A lone silicon atom will be paramagnetic and will be affected by a magnetic field. If all the electrons in an atom are spin-paired, the atom is diamagnetic. If *any* of the electrons are not spin-paired, the atom is paramagnetic. Silicon has two electrons in the 3p subshell. They will be placed in different orbitals, so they will not be spin-paired.

3.

- Electronegativity is the pull of the nucleus of one atom on the electrons of other atoms; it increases from P to Cl because nuclear charge increases; this is because as you move left to right across the periodic table, atomic radii decrease in size. Increasing nuclear charge means that Cl has the most positively charged nucleus of the three and will exert the greatest pull on the electrons of other atoms.
- Electronegativity is the pull of the nucleus of one atom on the electrons of other atoms; it decreases from Cl to I because electron shells are added. The added electron shells shield the nucleus, causing it to have less effect on the electrons of other atoms. So iodine will exert the least pull on the electrons of other atoms.
- Atomic radius increases from Li to Na to K because electrons are being added in higher energy levels, which are farther away from the nucleus, therefore, the K atom is the largest of the three.
- Atomic radius increases from Al to Mg to Na because protons are being removed from the nucleus while the energy level of the valence electrons remains unchanged. If there are fewer positive charges in the nucleus, the electrons of Na will be less attracted to the nucleus and will remain farther away.

4.

a) $E_4 = -1.36 \times 10^{-19} \text{ J}$ $E_1 = -2.18 \times 10^{-18} \text{ J}$

$$\Delta E = -2.18 \times 10^{-18} \text{ J} - (-1.36 \times 10^{-19} \text{ J}) = -2.044 \times 10^{-18} \text{ J}$$

$$\text{energy of emitted light} = -2.044 \times 10^{-18} \text{ J}$$

b) Frequency, $\nu = E/h$ $\nu = (2.044 \times 10^{-18} \text{ J}) / (6.63 \times 10^{-34} \text{ Js}) = 3.083 \times 10^{15} \text{ s}^{-1}$

$$\text{wavelength, } \lambda = c/\nu \quad \lambda = (3 \times 10^8 \text{ ms}^{-1}) / (3.083 \times 10^{15} \text{ s}^{-1}) = 9.73 \times 10^{-8} \text{ m} = 97.3 \text{ nm}$$

c) Wavelength, $\lambda = 0.122 \text{ nm} = 1.22 \times 10^{-10} \text{ m}$

$$\lambda = h / (m\nu) \text{ relates the velocity and wavelength of an electron}$$

Note that when mixing energy and mass units, you must use kg for mass if you use J for energy, so mass of electron = $9.11 \times 10^{-28} \text{ g} = 9.11 \times 10^{-31} \text{ kg}$

$$\text{rearranging gives } \nu = h / (m\lambda)$$

$$\nu = (6.63 \times 10^{-34} \text{ Js}) / (9.11 \times 10^{-31} \text{ g} \times 1.22 \times 10^{-10} \text{ m})?$$
$$\nu = 5.97 \times 10^6 \text{ ms}^{-1}$$