Dr. Zellmer | Chemistry 1210 | All Sections
Time: 7 PM Sun. | Autumn Semester 2022 | October 23, 2022
30 min | Quiz VII

Name ______________KEY__________________ Rec. TA/time ______________________________________

1. (5 pts) Calculate the de Broglie wavelength (in nm) for $H_2$ molecule moving at 1.50 m/s? If this wavelength corresponded to a photon of light would we be able to see it in the visible portion of the electromagnetic spectrum (and how do you know)? **(Show work and explain your answers.)**

$\lambda = \dfrac{h}{mv}$ where h = Planck's constant ($6.626 \times 10^{-34}$ J•s), m = mass and v = velocity

Need the mass of 1 $H_2$ molecule (2.016 amu) in kg, (1 J = 1 kg•m$^2$•s$^{-2}$)

$$? \text{ kg} = 2.016 \text{ amu} \times \frac{1.66 \times 10^{-24} \text{ g}}{1 \text{ amu}} \times \frac{1 \text{ kg}}{10^3 \text{ g}} = 3.3\underline{4}65 \times 10^{-27} \text{ kg}$$

$$\lambda = \frac{h}{mv} = \frac{(6.626 \times 10^{-34} \text{ J•s})[(1 \text{ kg•m}^2\text{•s}^{-2})/1\text{J}]}{(3.3\underline{4}65 \times 10^{-27} \text{ kg})(1.50 \text{ m/s})}$$

$$\lambda = 1.3\underline{1}99 \times 10^{-7} \text{ m} = 1.3\underline{1}99 \text{ x } \times 10^{2} \text{ nm} = 132 \text{ nm}$$

This would **NOT** be in the **visible** region of the spectrum. The visible region is 400-750 nm. This would be in the **UV** region.

2. (2 pts) Identify the correct quantum numbers for a 4*d* electron.

a) $n = 4$, $\ell = 1$, $m_\ell = -1$
b) $n = 3$, $\ell = 1$, $m_\ell = +2$
c) $n = 4$, $\ell = 0$, $m_\ell = 0$
d)* $n = 4$, $\ell = 2$, $m_\ell = -1$
e) $n = 4$, $\ell = 3$, $m_\ell = +1$

The rules for the values for the quantum numbers is given in section 6.5 (and 6.7 concerning the spin q.n.).

$n = 1, 2, 3, ..., \infty$ (integer values starting at 1) principal quantum number (shell number)

$\ell = 0, 1, 2, ..., (n-1)$ angular momentum (azimuthal) q.n. (subshell q.n. and defines shape of orbitals w/in a subshell)

$m_\ell = -\ell, ..., 0, ..., +\ell$ (values increase by 1) magnetic q.n. (describes orientation of orbital in space - orbitals are degenerate unless in an applied magnetic field)

$m_s = +\frac{1}{2}$ and $-\frac{1}{2}$ (only one with non-integer values) spin magnetic q.n. (electrons "spin" around an axis, only has two directions of spin, "up" or "down")

when n = 4 and $\ell = 0, 1, 2, 3$
s, p, d, f

For a "d" orbital $\ell = 2$ and the possible values of $m_\ell$ are $m_\ell = -2, -1, 0, 1, 2$

3. (2 pts) Which of the following sets of quantum numbers are **NOT** allowed for an electron in an atom?

**1)*** $n = 2$ $\ell = 2$ $m_\ell = -1$ $m_s = +1/2$
**2)*** $n = 3$ $\ell = 1$ $m_\ell = +2$ $m_s = +1$
3) $n = 4$ $\ell = 3$ $m_\ell = -2$ $m_s = -1/2$
4) $n = 8$ $\ell = 6$ $m_\ell = 0$ $m_s = +1/2$

See #11 above for a description of the quantum numbers.

$n = 1, 2, 3, ..., \infty$ $\ell = 0, 1, 2, ... , (n\text{-}1)$ $m_\ell = -\ell, ..., 0, ..., +\ell$ $m_s = + ½$ and $- ½$

Correct q.n.:

For (3) when $n = 4$ and $\ell = 3$ the possible values of $m_\ell$ are $m_\ell = -3, -2, -1, 0, 1, 2, 3$ and $m_s = - ½$ ok

For (4) when $n = 8$ and $\ell = 6$ the possible values of $m_\ell$ are $m_\ell = -6, ..., 0, ..., 6$ and $m_s = + ½$ ok

Incorrect q.n.:

For (1) when $n = 2$ and $\ell = 0, 1$ ($\ell$ can't be 2 when $n = 2$)

For (2) when $n = 3$ and $\ell = 1$ can't have $m_\ell = + 2$ or $m_s = 1$ ($m_s$ can be only + ½ and −½)

4. (4 pts) Fill in the blanks with the correct answer to each of the following.

(a) Which has the **smaller** ionization energy, $_{32}Ge$ or $_{15}P$? $_{32}Ge$ ↑ → I.E. inc

(b) Which is **largest** (size): $_{35}Br^-$, $_{34}Se^{2-}$ or $_{33}As^{3-}$?
anions larger than cations in isoelectronic series (same # $e^-$); $_{33}As^{3-}$ has higher (−) charge (fewer protons for the same # of electrons - things spread out)

$_{33}As^{3-}$ has 36 $e^-$ (like other two) but 33 protons (fewer protons)

(c) Which reacts **more readily** with chlorine, $_{37}Rb$ or $_{55}Cs$?
(i.e. lose an $e^-$ more easily)
These metals would lose e− to Cl (more metallic react faster)

$_{55}Cs$ ↓ ← metallic character inc (loses e− more easily)

(d) Which has the **more** negative electron affinity, $_{34}Se$ or $_{17}Cl$?(several exceptions)

$_{17}Cl$ ↑ → more neg. EA

5. (3 pts) Explain how the effective nuclear charge, $Z_{eff}$, changes going across a row from left to right in the periodic table and why?

Going left to right across a row the $Z_{eff}$ increases (rather rapidly). We are using the following for $Z_{eff}$,

$Z_{eff} = Z - S$ $Z = \#$ protons $S =$ Shielding factor

There are many ways to determine S. We're using the simplest one, S equals the number of core electrons. Going across a row the number of core electrons remains constant. However, the # protons increases by 1 each time you move one column to the right. Since S is constant and Z inc. by 1 when moving over 1 column the Zeff increases by 1 each time you move one column to the right. For example, in row 2 the core electrons are the two electrons in the 1s (He core). As you move over one column to the right Z inc. by 1 but the # of core electrons, S, stays constant at 2 and thus the $Z_{eff}$ inc. by 1. By the time you get to fluorine the $Z_{eff}$ is +7. This has big effects on the size and I.E.

6. (3 pts) Explain how and why the size, (radius), changes going across a row from left to right in the periodic table?

Going left to right in a row in the periodic table the size for a neutral atom tends to decrease. The major factor influencing this trend is the inc. in effective nuclear charge, $Z_{eff}$. The inc. in $Z_{eff}$ draws the valence shell electrons closer to the nucleus, thus causing the radius to dec. Looking at the representative elements within a row as one moves left to right the electrons are going into the s and p subshells of the same valence shell. The valence shell e- are shielded by the core electrons but don't shield each other to a great extent (the s $e^-$ do shield the p $e^-$ slightly). The number of protons inc. by one each type we move to the right one group. The $Z_{eff}$ inc. rapidly (by about 1 unit) each time we move to the right one group. However, the electrons are going into the same shell and don't shield each other very well. Thus the shell is pulled closer to the nucleus due to the inc $Z_{eff}$ and the electrons go into this shell which gets pulled in closer so the size dec.

7. (3 pts) Explain how the ionization energy, IE, changes going across a row from left to right in the periodic table and why?

IE is the energy required to remove an electron from a gaseous neutral atom or ion. This depends on the size of the atom (or ion). The energy needed to remove an $e^-$ from the outermost occupied shell depends on both the $Z_{eff}$ and average distance of the $e^-$ from the nucleus (size). The greater the $Z_{eff}$ and smaller the atom increases the attraction between the $e^-$ and the nucleus. As the attraction inc. it becomes more difficult to remove the $e^-$ and the I.E. inc. Going left to right across a row the $Z_{eff}$ increases (rather rapidly) and the size decreases (because $Z_{eff}$ inc. and the outer electrons are in the same shell). Thus the I.E. inc.

8. (3 pts) Explain why the electron affinity for Beryllium is positive while that for Boron is negative.

EA is the energy which occurs when an electron is added to a gaseous atom. Look at the $e^-$ configurations for each atom.

B: [He] $2s^2\ 2p^1$ Be: [He] $2s^2$

In Be the 2s subshell is filled. A filled subshell is pretty stable. The added $e^-$ must be put in a previously empty p subshell that is higher in energy. Also, the e- which would go into the 2p is shielded a little by the existing 2s electrons and there would be electron repulsion between the added electron and the electrons in the 2s subshell. All this requires energy. In B the extra $e^-$ goes in an empty 2p orbital in the 2p subshell which already has 1 $e^-$ to begin with and there is no extra shielding due to the existing $e^-$ in the 2p subshell.

9. (2 pts) Write the equation corresponding to the first electron affinity of Oxygen.

**Electron affinity**: **energy change which occurs when an electron is added to a gaseous neutral atom or anion**. The first EA is for the first electron being added. For most neutral atoms energy is released (negative EA) when an electron is added. There are a few cases when the energy change is positive (such as the noble gases, Be, Mg and N, the reasons for this were discussed in lecture and the textbook).

$$O\ (g) + e^- \rightarrow O^-\ (g)$$ first E.A. (First electron being added.)

10. (2 pts) Write the equation corresponding to the second ionization energy of Ca.

Ionization: losing one or more electron from a gaseous atom or ion.

**Ionization energy**: **energy required** to remove an electron from a gaseous neutral atom or ion.

$$Ca\ (g) \rightarrow Ca^+\ (g) + e^-$$ first I.E.

$$Ca^+\ (g) \rightarrow Ca^{2+}\ (g) + e^-$$ second I.E.

11. (3 pts) Write the electron configuration for the following ion by starting with the electron configuration for the neutral atom and then the ion given. **Show work.**

$Fe^{2+}$

Fe:

Shorthand config: $[Ar]4s^2 3d^6$ Use noble gas from previous period to represent the core (inner) $e^-$.

or

$[Ar]3d^6 4s^2$ is okay <- shows val. shell orbitals together on "outside"

Orbital diagram: [Ar]

| ↑↓ | ↑↓ | ↑ | ↑ | ↑ | ↑ |
|---|---|---|---|---|---|
| 4s | | | 3d | | |

In forming ions for transition metals electrons come out of the ns orbital before the (n-1)d orbitals. Remove the two electrons in the 4s. For $Fe^{3+}$ remove one electron from the 3d.

$Fe^{2+}$ $[Ar]3d^6$

Orbital diagram: [Ar]

| ↑↓ | ↑ | ↑ | ↑ | ↑ |
|---|---|---|---|---|
| | | 3d | | |

12. (3 pts) The electrons that are removed from ${}_{48}Cd$ to form the $Cd^{2+}$ ion are from the ___ subshell and the electrons that are removed from ${}_{83}Bi$ to form the $Bi^{2+}$ ion are from the ____ subshell.

Need to write out the e- configuration for each atom and then look at which electrons will come out when it forms an ion. Remember, the **valence** $e^-$ come out first when forming ions.

| | | |
|---|---|---|
| Cd | $[Kr]\ 5s^2\ 4d^{10}$ | |
| $Cd^{2+}$ | $[Kr]\ 4d^{10}$ | electrons come out of the 5s (valence shell) first |
| Bi | $[Xe]\ 6s^2\ 4f^{14}\ 5d^{10}\ 6p^3$ | |
| $Bi^{2+}$ | $[Xe]\ 6s^2\ 4f^{14}\ 5d^{10}\ 6p^1$ | electrons come out of the 6p (valence shell) first |