**Time : 50 minutes**

**Chemistry 201**
**Quiz 1**

**March 25, 2009**
*R. Sultan*

**Name :** KEY

**Signature :** ____________________

**Student Number :** ____________________

Circle your *recitation* **Section :**

| | |
|---|---|
| Sect.1 | 12 F |
| Sect. 2 | 9:30 T |
| Sect. 3 | 12:30 Th (Patra) |
| Sect. 4 | 12:30 Th (Sultan) |

## Useful Information

Planck's constant $h = 6.626 \times 10^{-34}$ Js

Speed of light $c = 2.998 \times 10^{8}$ m s$^{-1}$

Constant for the Bohr energy levels $R_H = 2.178 \times 10^{-18}$ J (Rydberg's constant)

1 nm = $10^{-9}$ m

1 eV = $1.602 \times 10^{-19}$ J

Mass of electron $m_e = 9.109 \times 10^{-31}$ kg

**There are 18 questions. In each question, only ONE of the proposed answers is right. Circle the letter corresponding to the right answer.**

- The 3*s* orbital is described by the following wave function:

$$\psi_{3,0,0} = C\left(4 - 4\rho + \frac{4}{9}\rho^2\right)\exp(\rho/3)$$

$4\rho^2 - 36\rho + 36 = 0$

$\hookrightarrow \rho^2 - 9\rho + 9 = 0$

$\Delta = 81 - 36 = 45$

Where *C* is a constant, and $\rho = r/a_0$, *r* being the radial spherical polar coordinate; $a_0$ is the Bohr radius. Find the location of the nodes.

$\rho' = \frac{9 - \sqrt{45}}{2} = 1.15$

$\rho'' = \frac{9 + \sqrt{45}}{2} = 7.85$

a. There are two radial nodes, one at the nucleus, and one at $r = 3a_0$.
[✓ b.] There are two radial nodes at $r = 0.608$ Å and $r = 4.15$ Å.
c. There are three radial nodes in the 3*s* orbital, at $r = a_0$, $2a_0$ and $3a_0$.
d. There are two radial nodes at $r = 1.15$ Å and $r = 7.85$ Å.
e. None of the above.

$\rho' = 1.15 \Rightarrow r' = 1.15\,a_0 = \underline{0.608\ \text{Å}}$

$\rho'' = 7.85 \Rightarrow r'' = 7.85\,a_0 = \underline{4.15\ \text{Å}}$

- Which of the following statements is true?

✓ a. The 4*p* orbital has three nodes overall. $4-1-1 = \underline{2}$ radial / $\underline{\text{one}}$ angular
✗ b. The 4*d* orbital has two radial nodes and two angular nodes. $4-2-1 = 1$ radial
✗ c. The 4s orbital has three radial nodes and four nodes overall. $4-0-1 = 3$ radial / 3 overall!
✗ d. The 4*f* orbital has zero radial node and two angular nodes. No three angular
✓ e. The 5*f* orbital has one radial node and three angular nodes. $5-3-1 = \underline{\text{one}}$ radial / 3 angular
✗ f. a) and c)
[✓ g.] a) and e)

- How many electrons can have $m_s = +1/2$, in the ground state electronic configuration of $_{24}$Cr?

$\underbrace{1s^2 2s^2 2p^6 3s^2 3p^6}_{\frac{1}{2}(18) = 9}\ 4s^1\ 3d^5$

$\boxed{\uparrow}\ \boxed{\uparrow|\uparrow|\uparrow|\uparrow|\uparrow}$

$+\ \underbrace{\qquad}_{6} = 15$

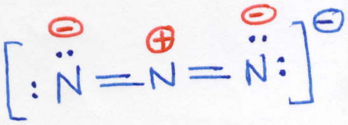
a. 9 electrons
b. 13 electrons
c. 12 electrons
d. 14 electrons
[✓ e.] 9 electrons or 15 electrons

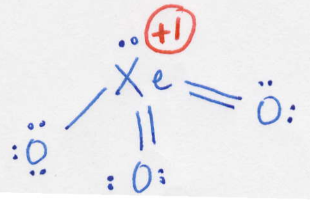
If $\boxed{\downarrow}\ \boxed{\downarrow|\downarrow|\downarrow|\downarrow|\downarrow}$

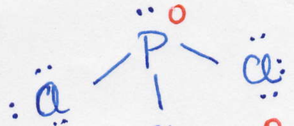
then only 9

- Which of the following statements is false?

✓ a. In the Lewis structure of $CO_2$, all atoms have a formal charge of zero.
✓ b. In the Lewis structure of the sulfate ion with four single bonds, Sulfur has a formal charge of +2.
✓ c. In the Lewis structure of $XeO_3$ with two double bonds and one single bond, Xe has a formal charge of +1.
✗ [✓ d.] In the best Lewis structure of $PCl_3$, Phosphorus has a formal charge of zero, and each chlorine atom has a formal charge of $\boxed{-1.}$ 0
✓ e. The best Lewis structure of the azide ion $N_3^-$, has two double bonds.







- Which of the following formulas does not correspond to the accompanying physical significance?

  ✓ a. Wavelength of a photon emitted as an electron in the H-atom relaxes from quantum energy level $n_2$ to quantum energy level $n_1$ : $\lambda = \dfrac{hc}{R_H\left(\dfrac{1}{n_1^2}-\dfrac{1}{n_2^2}\right)}$.

  ✓ b. Wavelength of an a~~e~~n electron scattered from a bloc of nickel at a speed $v_e$: $\lambda = \dfrac{h}{mv_e}$, where $m$ is the mass of the electron.

  ✓ c. Minimum uncertainty on velocity $\Delta v$ when position ($x$) is measured with uncertainty $\Delta x$ : $\dfrac{h}{4\pi\, m\,\Delta x}$.

  X [✓ d.] Quantization of angular momentum in the Bohr model: $m v r = n\dfrac{h}{2\pi}$, where $n = 0, 1, 2, 3,...$ n cannot be zero

  No e. None of the above.

- An electron in an $Li^{2+}$ ion relaxes from a certain energy level to the ground state, and emits a photon of wavelength 10.345 nm. In what level was the electron originally?

  a. Level 3
  b. Level 4
  c. Level 5
  d. Level 6
  [✓ e.] Level 7
  f. Level 8

$$E_n = -\frac{R_H Z^2}{n^2} \qquad \underbrace{\Delta E}_{\frac{hc}{\lambda}} = R_H Z^2\left(\frac{1}{n_1^2}-\frac{1}{n_2^2}\right)$$

$$\hookrightarrow \lambda = \frac{hc}{R_H Z^2\left(\frac{1}{1^2}-\frac{1}{n_2^2}\right)} \Rightarrow 1-\frac{1}{n_2^2} = \frac{hc}{\lambda R_H Z^2} = \frac{6.626\times10^{-34}\times2.998\times10^{8}}{2.178\times10^{-18}\times\boxed{9}\times10.345\times10^{-9}} = 0.9796$$

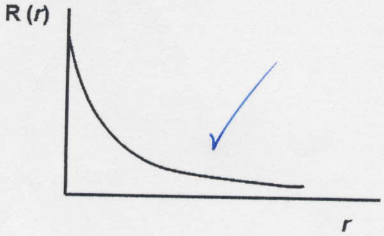
$$\Rightarrow n^2 = 49$$

$$\boxed{n = 7}$$

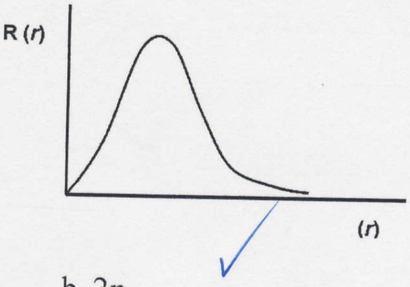
- What is the maximum number of electrons in the same atom, that can possess simultaneously the following quantum numbers? All propositions are correct but one. Choose the **incorrect** match.

  ✓ a. $n = 2$; $\ell = 1$; $m_\ell = -1$; $m_s = -1/2$. 1 electron.
  X [✓ b.] $n = 4$. 30 electrons. No! 32
  ✓ c. $n = 3$; $\ell = 2$; $m_\ell = +1$. 2 electrons.
  ✓ d. $n = 5$; $\ell = 3$. 14 electrons
  ✓ e. $n = 4$; $\underbrace{\ell = 2; m_\ell = -3}_{!!}$; $m_s = -1/2$. zero electron. ✓ $m_\ell$ cannot be $-3$ if $\ell = 0$
  f. b) and e)
  No!

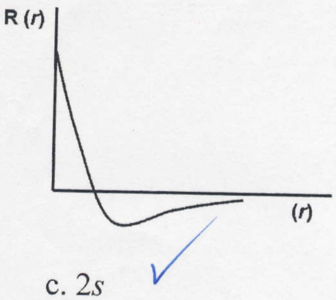
- Which of the following plots of $R(r)$ versus the radial coordinate $r$, <u>does not</u> represent the right orbital label?



a. 1s

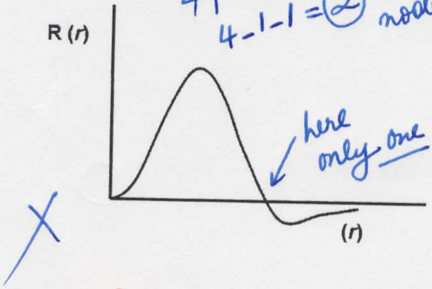


b. 2p

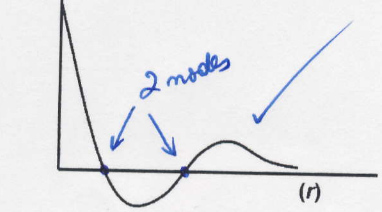


c. 2s ✓

4p has 4-1-1=② radial nodes!



[✓ d.] 4p



e. 3s

- Which of the following closed shell electronic configurations <u>does not</u> correspond to the accompanying element in the ground state?

✓ a. $_{47}$Ag: [Kr] $5s^1\ 4d^{10}$
✓ b. $_{82}$Pb: [Xe] $6s^2\ 4f^{14}\ 5d^{10}\ 6p^2$
✓ c. $_{65}$Tb: [Xe] $6s^2\ 4f^9$
X [✓ d.] $_{75}$Re: [Xe] $6s^1\ 4f^{14}\ 5d^5$ No $6s^2$!
✓ e. $_{71}$Lu: [Xe] $6s^2\ 4f^{14}\ 5d^1$ ✓

- The number of <u>unpaired</u> electrons in each of the following atoms (or ions) in the ground state is indicated. Which one is <u>wrong</u>?

✓ a. $O^+$: 3 electrons ✓ $1s^2 2s^2 2p^3$ ↑ | ↑ | ↑
X [✓ b.] $O^-$: 0 electron → $2s^2 2s^2 2p^5$ ↑↓ | ↑↓ | ↑ NO! one is unpaired.
✓ c. Gd: 8 electrons
✓ d. Os: 4 electrons $d^6$ ↑↓ | ↑ | ↑ | ↑ | ↑ 4 unpaired $e^-$s.
✓ e. Mo: 6 electrons ✓ like Cr
✓ f. Hg: 0 electron ✓

- Which of the following molecular forms (A central atom, B atom bonded to A, E lone pair) corresponds to the correct molecular shape according to VSEPR?

  a. $AB_4E$: Regular tetrahedron X irregular
  [✓ b.] $AB_3E_3$: T-shaped ✓
  c. $AB_5E$: Trigonal bipyramidal X square pyramidal
  d. $AB_2E_4$: V-shaped X linear
  e. $AB_4E_2$: Tetrahedral X square planar

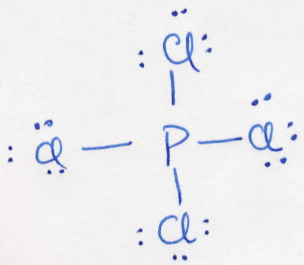
- Which of the following statements is true?

  X a. An NaI crystal is a good electrical conductor.
  X b. Molten NaI would not be a good conducting liquid.
  ✓ [✓ c.] The inter-ionic distance in MgO is 0.398 nm. The lattice energy (energy of interaction between a pair of oppositely charged ions) is –14.5 eV ($C = 2.31 \times 10^{-19}$ J•nm).
  X d. The calculated dipole moment of KI in the gas phase is 14.85 Debye. The measured dipole moment is 10.82 Debye. The % ionic character in KI is thus 62.9%. No! 72.9 ≡ (10.82/14.85) × 100
  X e. The energy of an NaI aggregate is ~~equal~~ to that of the separate atoms. less than!

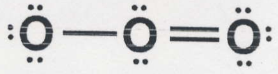
- According to VSEPR theory, the shape of $PCl_4^+$ is

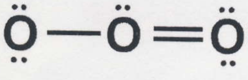
  ✓ [✓ a.] Tetrahedral
  b. See-saw
  c. Square planar
  d. Square pyramidal
  e. Trigonal pyramidal

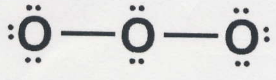
$PCl_4^+$ $5 + 28 - 1 = 32$ $\bar{e}s$
$-8$
$24$

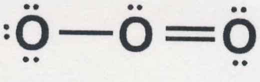


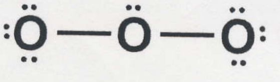
- Which one is a correct Lewis structure for ozone, $O_3$?

a.

X

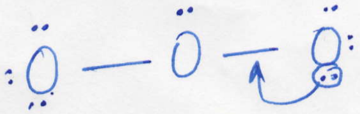
b.

X

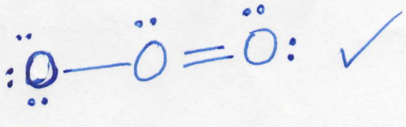
c.

X

[✓ d.]

✓

e.

X

$O_3$ : $6 \times 3 = 18$
4
14





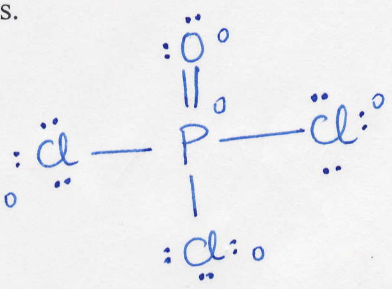
Stern & Gerlach! (sorry)

- In the experiment of ~~Davisson and Germer~~, which of the following statements is false?

✓ a. The Ag atoms possess angular momentum only due to spin.
X [✓ b.] The beam of Ag atoms splits exactly into two, because an *s* orbital can accommodate a maximum of two electrons.
✓ c. The contribution to the orbital angular momentum of the atom comes only from one electron in an *s* orbital.
✓ d. The beam of Ag atoms splits exactly into two, because an electron has half-integer spin, and hence $2s + 1 = 2$ orientations.
✓ e. The net orbital angular momentum of the atom is zero.

- The best Lewis structure for the compound $POCl_3$, has __3__ single bonds, __1__ double bonds and __11__ lone pairs.

a. 4, 0, 12
b. 0, 4, 8
[✓ c.] 3, 1, 11
d. 2, 2, 10
e. 1, 3, 9



- In the derivation of the Bohr Theory, the total energy of the electron is given by the relation:

a. $\frac{1}{4\pi\varepsilon_0}\frac{e^2}{2r}$

b. $\frac{1}{4\pi\varepsilon_0}\frac{e^2}{r}$

[✓ c.] $-\frac{1}{4\pi\varepsilon_0}\frac{e^2}{2r}$

d. $-\frac{1}{4\pi\varepsilon_0}\frac{e^2}{r}$

e. $-\frac{1}{4\pi\varepsilon_0}\frac{e^2}{3r}$

Forces: $\frac{1}{4\pi\varepsilon_0}\frac{e^2}{r^{\cancel{2}}} = m\frac{v^2}{\cancel{r}} \Rightarrow mv^2 = \frac{e^2}{4\pi\varepsilon_0}$

$P.E = -\frac{1}{4\pi\varepsilon_0}\frac{e^2}{r}$

Total Energy $E_T = K.E + P.E$

$= \frac{1}{2}mv^2 - \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r}$

$= \frac{1}{2}\times\frac{e^2}{4\pi\varepsilon_0} - \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r}$

$= -\frac{1}{2}\frac{1}{4\pi\varepsilon_0}\frac{e^2}{r}$

- Calculate the wavelength of the lowest energy transition in the Paschen series of the hydrogen atom.

a. 121.6 nm
b. 656.7 nm
c. 820.8 nm
[✓ d.] 1,876 nm
e. 4,054 nm

Paschen

$$\begin{array}{c} n_2 \\ \downarrow \\ n_1 = 3 \end{array}$$

lowest energy transition :

4 ⟶ 3

$$\lambda = \frac{hc}{R_H\left(\frac{1}{9} - \frac{1}{16}\right)}$$

$$= \frac{6.626\times10^{-34} \times 2.998\times10^{8}}{2.178\times10^{-18}(0.048611)}$$

$$= 1.876\times10^{-6}\ m = 1,876\ nm$$