2. Which of the following statements is/are **CORRECT**.

(i) The lowest energy electron configuration for degenerate orbitals maximizes the number of unpaired electrons.

(ii) All d orbitals have the same shape.

(iii) Electrons in s orbitals have a higher probability of being close to the nucleus than do the p electrons in the same shell.

(iv) According to Heisenberg's principle, the positional uncertainty of an electron and the uncertainty in its momentum are directly proportional.

inversely

   A) i & ii   B) ii & iii   C) iii & iv   D) i & iii   E) i
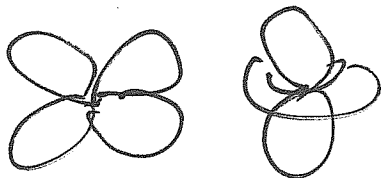
3. What is the uncertainty in the position of a fast moving electron if its velocity is 5.9×10^6 m s^{-1} and the uncertainty in the velocity is 1.2%? (You may wish to consult the data sheet.)

A) 4.6×10^{-21} m   B) 8.2×10^{-10} m   C) 9.8×10^{-12} m

D) 1.2×10^{-10} m   E) 1.2×10^{-8} m

$$0.012 \times 5.9 \times 10^6 = 70800 \text{ ms}^{-1}$$

uncertainty

$$\Delta x \cdot \Delta mv \geq h/4\pi$$

$$\Delta x = \frac{h}{4\pi \Delta mv}$$

$$= \frac{6.63 \times 10^{-34}}{4 \times \pi \times 9.109 \times 10^{-31} \times 70800}$$

$$= 8.2 \times 10^{-10}$$

4. An electron in a hydrogen atom undergoes a transition between principal energy level 3 and principal energy level 5, leading to an absorption in the infrared part of the spectrum. Calculate the energy change for this electron.

A) 2.91 x 10^{-19} J   B) -2.91 x 10^{-19} J   C) -1.55 x 10^{-19} J

D) 1.55 x 10^{-19} J   E) 2.34 x 10^{14} J

$$\Delta E = -2.18 \times 10^{-18} \left(\frac{1}{n_f^2} - \frac{1}{n_i^2} \right) J$$

$$= -2.18 \times 10^{-18} \left(\frac{1}{25} - \frac{1}{9} \right) J$$

$$= 1.55 \times 10^{-19} J$$

5. Four atoms are arbitrarily labeled Q, R, S, and T. Their electronegativities are as follows: Q = 3.8, R= 3.3, S = 2.8, T= 1.3. The atoms of these elements form the following compounds: QR, QT, RT, and QS. Arrange these molecules in DECREASING order of ionic character (*i.e.* most ionic first, most covalent last).

A) $RT > QT > QS > QR$ B) $QT > RT > QS > QR$ C) $QR > QS > RT > QT$

D) $RT > QR > QS > QT$ E) $QS > QR > QT > RT$

Diff. in EN: QR 0.5, QT 2.5, QS 1, RT 2

so QT > RT > QS > QR

6. What is the maximum number of electrons in an atom that can have the quantum numbers $n = 4$, $\ell = 3$?

A) 2   B) 6   C) 10   D) 14   E) 32

$\ell = 3$ so m_ℓ can take values

$-3, -2, -1, 0, 1, 2, 3$ m_s for each $+\frac{1}{2}, -\frac{1}{2}$

⇅ ⇅ ⇅ ⇅ ⇅ ⇅ ⇅ $= 14$

7. Identify the element which has exactly three unpaired $4d$ electrons in its ground state electron configuration.

A) V   B) Cr   C) As   D) Pr   E) Nb

8. Select the full set of quantum numbers for the electron gained when an S⁻ ion becomes an S²⁻ ion.

A) $n = 3$, $\ell = 2$, $m_l = -1$, $m_s = +1/2$

B) $n = 2$, $\ell = 1$, $m_l = 0$, $m_s = -1/2$

C) $n = 3$, $\ell = 1$, $m_l = +2$, $m_s = -1/2$

D) $n = 3$, $\ell = 1$, $m_l = +1$, $m_s = -1/2$

E) $n = 4$, $\ell = 3$, $m_l = -1$, $m_s = +1/2$

9. Which of the following statements about oxygen and fluorine are true?

(i) O has a larger atomic radius than F

(ii) O^{2-} has a larger ionic radius than F^-

(iii) O has a smaller first electron affinity than F

(iv) O and F have the same number of core electrons

A. all except (i)   B. all except (ii)   C. all except (iii)
D. all except (iv)   E. all of them

10. The possible numbers of orbitals in the shells (principal energy levels) having n = 1, 2, 3, 4 are, respectively:

A) 1, 3, 5, 7   B) 1, 2, 3, 4   C) 2, 4, 6, 8   D) 2, 8, 18, 32   E) 1, 4, 9, 16

$n = 1$ 1s   = 1

$n = 2$ 2s   and   2p   = 4

1   3

11. The electron configuration $[Kr]5s^24d^65p^26s^1$ is an excited state of which element?

A) Sb   B) Sn   C) Ag   D) Hg   E) Ru

12. For a bromine atom, in which orbital will an electron experience the greatest effective nuclear charge?

A) 3p orbital   B) 2p orbital   C) 3s orbital   D) 2s orbital   E) 3d orbital

13. Which will have the highest first ionization energy?

   A) O   B) Mg   C) Cs   D) Si   E) He

14. Which of the following is expected to be the correct order of atomic radii from smallest to largest?

A) $H < He < Li$ B) $P < Al < Na$ C) $C < O < N$

D) $P < As < Se$ E) $Si < N < Ge$

15. Which of the following elements is expected to have the largest (i.e. most negative) electron affinity?

A) Na   B) Mg   C) P   D) S   E) Ar

16. Which of the following statements is/are **CORRECT**?

i. The greater the difference in electronegativity between two atoms, the more polar their bond.

ii. The dipole moment of a molecule is measured by measuring its bond strength.

iii. Ionic bonds can be considered to be formed by the transfer of electrons between different atoms.

iv. Main group atoms tend to gain or lose or share electrons until they have eight valence electrons.

A) all are correct   B) ii & iii   C) iii & iv   D) i, ii, & iv   E) i, iii & iv

6. [3 Marks]

Write down three ions that have the condensed electron configuration [Ne], in order of decreasing size. (*i.e.* Largest first, smallest last.) Explain your reasoning concerning the relative sizes.

O^{2-}, F^-, [Ne] Na^+, Mg^{2+}

isoelectroic: same no. of electrons being attracted by more protons in nucleus

END

PART II – Written Answers to Questions. [Total Marks = 20]

Write your answers directly on this test paper. Show all your work. Hand in the <u>entire test paper</u> at the end of the test period.

1. [3 Marks]
a) Light shining on a clean metal surface can cause electrons to be emitted from the metal. This is the photoelectric effect. The minimum energy required to remove an electron from potassium metal is 3.7×10^{-19} J.
Will a photon of blue light ($\lambda = 451$ nm) cause the photoelectric effect? (Yes or no.) Show your work.

$$ \text{ln} \quad E = h\nu = \frac{hc}{\lambda} = \frac{6.63 \times 10^{-34} \times 3 \times 10^{8}}{451 \times 10^{-9}} \text{ J} $$

$$ = 4.4 \times 10^{-19} \text{ J} \quad \boxed{YES} $$

b) If you answered *no* to part a) how much more energy is required?
If you answered *yes* to part a), how much kinetic energy does the electron have upon leaving the metal surface?

$$ \left(4.4 - 3.7 \right) \times 10^{-19} \text{ J} = 7 \times 10^{-20} \text{ J} $$

2. **[5 Marks]**

An ion having a +4 charge has two electrons with n = 1, eight electrons with n = 2, and ten electrons with n = 3. Supply the following properties for the ion.

(a). the atomic number and chemical symbol 24 , Cr

(b) total number of s electrons 6

(c) total number of p electrons 12

(d) total number of d electrons 2

(e) number of unpaired electrons 2

$Cr = 1s^2 \ 2s^2 \ 2p^6 \ 3s^2 \ 3p^6 \ 4s^2 \ 3d^4$

$4s^1 \ 3d^5$

$Cr^{4+} = 1s^2 2s^2 \ 2p^6 \ 3s^2 \ 3p^6 \qquad 3d^2$

3. [4 Marks]

By using the positions of the elements in the periodic table (*i.e.* by using their electron configurations), give the formula of the most likely binary compound formed by each of the following pairs of elements. (*A binary compound is one formed of only two elements.*)
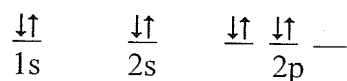
(a) Li and N Li_3N

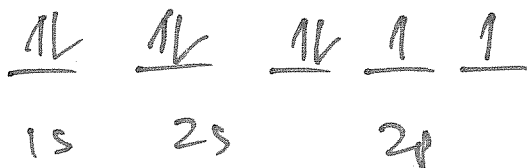(b) Na and I NaI

(c) Al and Cl $AlCl_3$

(d) K and S K_2S

4. [3 Marks]

The following orbital diagram applies to a certain electronic state of oxygen:

$\underset{\text{1s}}{\underline{\downarrow\uparrow}} \qquad \underset{\text{2s}}{\underline{\downarrow\uparrow}} \qquad \underset{\text{2p}}{\underline{\downarrow\uparrow}\ \underline{\downarrow\uparrow}\ \underline{}}$

(a) Using the **same kind of orbital notation**, show the electron configuration of the ground state of oxygen.

$\underset{\text{1S}}{\underline{\uparrow\downarrow}} \qquad \underset{\text{2S}}{\underline{\uparrow\downarrow}} \qquad \underset{\text{2p}}{\underline{\uparrow\downarrow}\ \underline{\uparrow}\ \underline{\uparrow}}$

(b) In going from the state given above to the ground state, would energy be released or absorbed? Explain.

ground state lowest in energy

5. [2 Marks]

The first ionization energy of Na is slightly less than that of Mg, but the second ionization energy of Na is about three times that of Mg. Why?

lower Z_{eff}

requires removal of core e^-