GENSET EDUCATION ACADEMY

CHEMISTRY 1000

ASSIGNMENT (2) TWO SOLUTIONS

(*Atomic Structure and Periodicity*)

COMPILED BY TUTOR POUL

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THE UNIVERSITY OF ZAMBIA
SCHOOL OF NATURAL SCIENCES
DEPARTMENT OF CHEMISTRY
ACADEMIC YEAR 2022
TERM 1
CHE 1000: INTRODUCTORY CHEMISTRY

ASSIGNMENT SHEET 2 **3rd May 2023**

Answer all the problems in a HARD COVER book and submit in ROOM 124 before 10:00 hrs on Monday, 7th May 2023

1. What is a wave? Explain the following terms associated with waves: wavelength, frequency, amplitude.
2.
   a. List the types of electromagnetic radiation in descending order with respect to energy and frequency.
   b. The following are representative wavelengths in the infrared, ultraviolet, and x-ray regions of the electromagnetic spectrum, respectively: 1.0×10^{-6} m, 1.0×10^{-8} m, and 1.0×10^{-10} m. What is the energy of a photon of each radiation? Which has the greatest amount of energy per photon? Which has the least?
3.
   a. What is the wavelength (in nanometers) of blue light having a frequency of 8.6×10^{13} Hz?
   b. What is the frequency (in Hz) of blue light having a wavelength of 566 nm?
4.
   a. A photon has a wavelength of 624 nm. Calculate the energy of the photon in electron volts (ev).
   b. Calculate the wavelength of light emitted when each of the following transitions occur in the hydrogen atom. What type of electromagnetic radiation is emitted in each transition? $n = 3$ and $n = 2$
5. The first line of the Balmer series occurs at a wavelength of 656.3 nm. What is the energy difference between the two energy levels involved in the emission that results in this spectral line?
6. Calculate the wavelength (in nanometers) of a photon emitted by a hydrogen atom when its electron drops from the n = 6 state to the n = 4 state.
7.
   a. Explain the statement, Matter and radiation have a "dual nature."
   b. What is the de Broglie wavelength (in nm) associated with a 2.5-g Ping-Pong ball traveling 35 m/s?
8.
   a. How is the concept of electron density used to describe the position of an electron in the quantum mechanical treatment of an atom?

b. An electron in a certain atom is in the n = 2 quantum level. List the possible values of l and ml that it can have.

c. List all the possible subshells and orbitals associated with the principal quantum number n, if n = 6.

9.

a. Explain the meaning of diamagnetic and paramagnetic. Give an example of an element that is diamagnetic and one that is paramagnetic. What does it mean when we say that electrons are paired?

b. The ground-state electron configurations listed here are incorrect. Explain what mistakes have been made in each and write the correct electron configurations.

i. Al: $1s^2 2s^2 2p^4 3s^2 3p^3$

ii. B: $1s^2 2s^2 2p^5$

iii. F: $1s^2 2s^2 2p^6$

10. Draw atomic orbital diagrams representing the ground-state electron configuration for each of the following elements

i. Nickel metal

ii. cobalt

iii. chromium

11.

a. Why is the first ionization energy of sulphur smaller than the first ionization energy of phosphorus?

b. Why are ionization energies always positive quantities?

c. Why does the fluorine atom have a larger first ionization energy than the oxygen atom?

12. From their positions in the periodic table, arrange the atoms in each of the following series in order of increasing electronegativity.

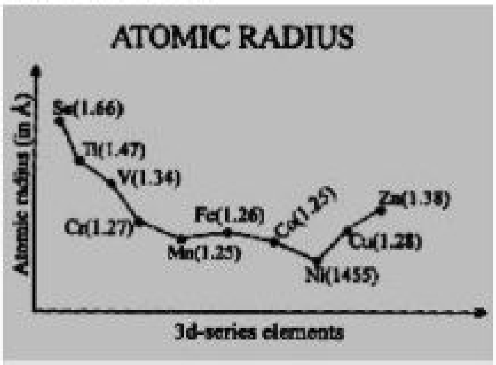
a. C, F, H, N, O

b. Br, Cl, F, H, I

c. F, H, O, P, S

13. Arrange the species in each group in order of increasing ionization potential, and explain in each case the reason for the sequence: Fe, Fe^{2+}, Fe^{3+}

14. Explain why atomic radius in d block initially decreases then remains constant and finally increases at the end.



15. Why zirconium and Hafnium have nearly same atomic sizes?

16.

a. Base on their positions in the periodic table, list the following atoms in order of increasing radius: Cs, Ca, Rb, Mg

b. The ionic radii of the ions S^{2-}, Cl^{-}, and K^{+} are 184, 181, 138 pm respectively. Explain why these ions have different sizes even though they contain the same number of electrons.

CHE1000 ASSIGNMENT 2 SOLUTIONS

QUESTION 1

=> A WAVE is a propagating disturbance in a medium that carries energy from one place to another.

=> WAVELENGTH is the distance between two successive crests or troughs of a wave. You can also say that it's the distance over which the wave's shape repeats. It's measured in meters.

=> FREQUENCY is the number of complete oscillations per second. In terms of waves you can say that it is the number of waves that pass a fixed point in a unit time. It is measured in Hertz or per seconds.

=> AMPLITUDE is the maximum displacement of a particle from it's mean position of a propagating or moving wave. It's the height of a crest or trough. Amplitude is measured in meters.

QUESTION 2

(a) There is a a memory Aid that helps remember all the electromagnetic waves and their order.

* Receiving Maize Is a Very Unusual Xmas Gift.

R for Radio waves
I for infrared radiation
U for Ultra violet radiation
G for Gamma rays.

M for Micro waves
V for visible light
X for X-rays

⇒ So from Gamma rays to Radio Waves its in order of increasing wavelength.
⇒ Then from Gamma rays to Radio waves its in order of decreasing frequency.

⇒ Then we all know that frequency is directly proportional to energy. As frequency reduces Energy also reduces.

LISTING THEM ACCORDING TO DECREASING ENERGY

Gamma rays → X-rays → ultra violet radiation → visible light → infra-red radiation → micro waves → Radio waves

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(b)

* He we use plank's equation and the equation relating speed, frequency and wavelength. First find the frequencies and then the energy.

$$c = 3.0 \times 10^{8}\, m/s$$

$\lambda_I = 1.0 \times 10^{-6}\, m$

$\nu = c/\lambda$

$= \dfrac{3.0 \times 10^{8}}{1.0 \times 10^{-6}}$

$\nu_I = 3.0 \times 10^{14}\,/s$ #

$\lambda_u = 1.0 \times 10^{-8}\, m$

$\nu = c/\lambda$

$= \dfrac{3.0 \times 10^{8}}{1.0 \times 10^{-8}}$

$\nu_u = 3.0 \times 10^{16}\,/s$ #

$\lambda_x = 1.0 \times 10^{-10}\, m$

$\nu = c/\lambda$

$= \dfrac{3.0 \times 10^{8}}{1.0 \times 10^{-10}}$

$\nu_x = 3.0 \times 10^{18}\,/s$ #

NOW FIND ENERGY.

E_{photon} (infrared) $= h\nu$

$= 6.63 \times 10^{-34} \times 3.0 \times 10^{14}$

$= 19.878 \times 10^{-20}$

$= 1.99 \times 10^{-20}\, J$ #

E_{photon} (ultraviolet) $= h\nu$

$= 6.63 \times 10^{-34} \times 3.0 \times 10^{16}$

$= 19.878 \times 10^{-18}$

$= 1.99 \times 10^{-18}\, J$ #

E_{photon} (X-ray) $= h\nu$

$= 6.63 \times 10^{-34} \times 3.0 \times 10^{18}$

$= 19.878 \times 10^{-16}$

$= 1.99 \times 10^{-16}\, J$ #

∴ Infrared has the ~~greatest~~ least energy per photon
X-ray has the ~~least~~ greatest energy per photon

QUESTION 3

(a)

- To solve this, you have to know the formula that associates speed of light, wavelength and frequency.

* speed of light = frequency × wavelength

$$C = V\lambda$$

- speed of light is always $C = 3.0 \times 10^{8}$ m/s.

$C = 3.0 \times 10^{8}$ m/s $\quad V = 8.6 \times 10^{13}$ Hz $\quad \lambda = ?$

$$C = V\lambda$$

$$\lambda = C/V$$

$$= \frac{3.0 \times 10^{8}}{8.6 \times 10^{13}}$$

$$= 0.34884 \times 10^{-5}$$

$$= 3.49 \times 10^{-6} \text{ m}$$

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- Now convert to nano-meters by multiplying by 10^{+9}.

$$\lambda = 3.49 \times 10^{-6} \times 10^{9}$$

$$= 3.49 \times 10^{-6+9}$$

$$= 3.49 \times 10^{3} \text{ nm}$$

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(b) * Still using the same principle here as the previous question.
* Convert nm to meters before dividing

$C = 3.0 \times 10^8 m/s$ $\quad V = ?$ $\quad \lambda = 566 nm$

$= 566 \times 10^{-9}$

$= 5.66 \times 10^{-7} m$

$$C = V\lambda$$

$$V = C/\lambda$$

$$= \frac{3.0 \times 10^8}{5.66 \times 10^{-7}}$$

$$= 0.530035335 \times 10^{8-(-7)}$$

$$= 5.30 \times 10^{14} Hz$$

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QUESTION 4

(a)

* Here we use Planck's equation and the equation for speed of light.

$\mathcal{E} = hv$ $\quad$ but $V = C/\lambda$

$\therefore \mathcal{E} = hv$

$= h(C/\lambda)$

$\mathcal{E} = hc/\lambda$

//

$\mathcal{E}$ = Energy

h = Planck's Constant

C = speed of light

λ = wavelength

$h = 6.626 \times 10^{-34}$ $\quad C = 3.0 \times 10^8 m/s$ $\quad \lambda = 624 nm$

$= 6.24 \times 10^{-7} m$

$$\mathcal{E} = hc/\lambda$$

$$= \frac{(6.626 \times 10^{-34})(3.0 \times 10^8)}{6.24 \times 10^{-7}}$$

$$= \frac{19.878 \times 10^{-26}}{6.24 \times 10^{-7}}$$

$$= 3.185576923 \times 10^{-26-(-7)}$$

$$= 3.19 \times 10^{-19} J$$

//

* Convert the energy to electron volts Now.

$$1\ eV = 1.602 \times 10^{-19}\ J$$
$$x\ eV = 3.19 \times 10^{-19}\ J$$

$$x = \frac{3.19 \times 10^{-19}}{1.602 \times 10^{-19}}$$
$$= 1.991260924 \times 10^{-19-(-19)}$$
$$= 1.99\ eVolts$$

(b)

- Here we use Rydberg's equation to Calculate Wavelength.
- Since the final energy level is not stated in the question, we assume that final energy level is one for both 3 and 2.

$$\frac{1}{\lambda} = 1.097 \times 10^7 \left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$$

For the transition $n_i = 3 \longrightarrow n_f = 1$

$$\frac{1}{\lambda} = 1.097 \times 10^7 \left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$$
$$= 1.097 \times 10^7 \left(\frac{1}{1^2} - \frac{1}{3^2}\right)$$
$$= 1.097 \times 10^7 \left(1 - \frac{1}{9}\right)$$
$$\frac{1}{\lambda} = 1.097 \times 10^7 \left(\frac{8}{9}\right)$$
$$\frac{1}{\lambda} = 9.751111111 \times 106$$
$$\lambda = \frac{1}{9.75111111 \times 106}$$
$$\lambda = 1.025524157 \times 10^{-7}\ m$$

$\lambda = 1.03 \times 10^{-7}$ m

* Convert to nano-meters

$\lambda = 1.03 \times 10^{-7} \times 10^{9}$

$= 1.03 \times 10^{2}$

$= 103$ nm

* This electromagnetic wave is Ultra-violet

for the transition $n_i = 2 \longrightarrow n_f = 1$

$1/\lambda = 1.097 \times 10^{7} \left(1/n_f^2 - 1/n_i^2 \right)$

$= 1.097 \times 10^{7} \left(1/1^2 - 1/2^2 \right)$

$= 1.097 \times 10^{7} (3/4)$

$1/\lambda = 8.227500 \times 10^{6}$

$\lambda = 1 \div 8.227500 \times 10^{6}$

$= 1.215486083 \times 10^{-7}$

$\lambda = 1.22 \times 10^{-7}$ m

* Convert to nano-meters

$\lambda = 1.22 \times 10^{-7} \times 10^{9}$

$= 1.22 \times 10^{2}$

$= 122$ nm

* This electromagnetic wave is ultra-violet

QUESTION 5

* Here you have to know how to handle questions dealing with transition series. The first line of Balmer series of hydrogen occurs when a electron moves from $n = 3$ to $n = 2$.

=> we have a wavelength = 656.3 nm

$= 656.3 \times 10^{-9}$ m

$= 6.563 \times 10^{-7}$ m

*

We Calculate the energy using the formular

$$E = -2.178 \times 10^{-18} [1/n_i^2 - 1/n_f^2]$$

$n_i = 3$ $n_f = 2$

$$E = -2.178 \times 10^{-18} [1/3^2 - 1/2^2]$$

$$= -2.178 \times 10^{-18} [-5/36]$$

$$= 0.3025 \times 10^{-18}$$

$$= 3.025 \times 10^{-19} J$$

∴ The energy between two energy levels in the balmer Series is 3.025×10^{-19} J

QUESTION 6

* Here we will use Rybergs equation. The only equation that relates wavelength directly to energy levels.

$n_i = 6$ $n_f = 4$

$$\frac{1}{\lambda} = 1.097 \times 10^7 \left[\frac{1}{n_f^2} - \frac{1}{n_i^2} \right]$$

$$= 1.097 \times 10^7 \left[\frac{1}{4^2} - \frac{1}{6^2} \right]$$

$$= 1.097 \times 10^7 \left[\frac{5}{144} \right]$$

$$= 0.038090277 \times 10^7$$

$$\frac{1}{\lambda} = 3.8090277 \times 10^5$$

$$\lambda = \frac{1}{3.8090277 \times 10^5}$$

$$\lambda = 2.63 \times 10^{-6} m$$

* Convert to nano-memeters.

$$\lambda = 2.63 \times 10^{-6} \times 10^9$$

$$= 2.63 \times 10^3 \text{ nm}$$

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QUESTION 7

(a) The Statement means that matter exhibits both particulate and wave properties. In short, it means that a particle can be treated as a wave and a wave can show proporties of a particle.

(b)

* To find the wavelength, we use the formula

$$\lambda = h/mv$$

λ = wavelength h = Planks constant m = mass in kg V = speed

$h = 6.626 \times 10^{-34}$ $m = 2.5g$ $V = 35 m/s$

$= (2.5 \div 1000)$

$= 0.0025 kg$

$$\lambda = h/mv$$

$= (6.626 \times 10^{-34}) \div (0.0025 \times 35)$

$= 6.626 \times 10^{-34} \div 0.0875$

$= 7.57 \times 10^{-33} m$

* Convert to nano-meters

$\lambda = 7.57 \times 10^{-33} \times 10^{9}$

$= 7.57 \times 10^{-24} nm$

//

QUESTION 8

(a) The concept of electron density gives the probability that an electron will be found in a particular region of an atom reffered to as an electron cloud.

We can also say that it's a number that tells us how much charge is located at each point in the cloud.

(b) n = principal quantum number
l = Angular momentum quantum number
m_l = magnetic quantum number

from 0 to
l = n − 1

m_l = −l to +l

* For n = 2
l = 2 − 1 = 1
l = 2 − 2 = 0
m_l = −1, 0, 1

∴ l = 0, 1
m_l = −1, 0, 1

//

(c) For n = 6

* l from 0 to n − 1
l = 0, 1, 2, 3, 4, 5

* m_l from −l to +l
m_l = −5, −4, −3, −2, −1, 0, 1, 2, 3, 4, 5

//

QUESTION 9

(a) Diamagnetic means that all electrons in a compound are paired. On the other hand, paramagnetic means that not all electrons in a compound are paired.

⇒ Copper, mercury and gold are examples of Diamagnetic elements

⇒ Magnesium and Lithium are examples of paramagnetic elements.

⇒ Paired electrons are the electrons in an atom that occur in an orbital as pairs. These alway occur as a Couple of electrons.

(b)

<i> Al : $1s^2 2s^2 2p^4 3s^2 3p^3$

Mistake : 2p should be filled first before filling of 3S starts.

CORRECT ; Al : $1s^2 2s^2 2p^6 3s^2 3p^1$

<ii> B : $1s^2 2s^2 2p^5$

Mistake : We have more than 5 electrons. Boron has 5 $\bar{E}s$

CORRECT: $1s^2 2s^2 2p^1$

<iii> F : $1s^2 2s^2 2p^6$

Mistake : we have more than 9 electrons. Florrine has 9 electrons

CORRECT ; $1s^2 2s^2 2p^5$

QUESTION 10

*Find the atomic number and follow the rules below to fill electrons in its orbitals.

⇒ Aufbau principle : Energy levels with lower energy fill first

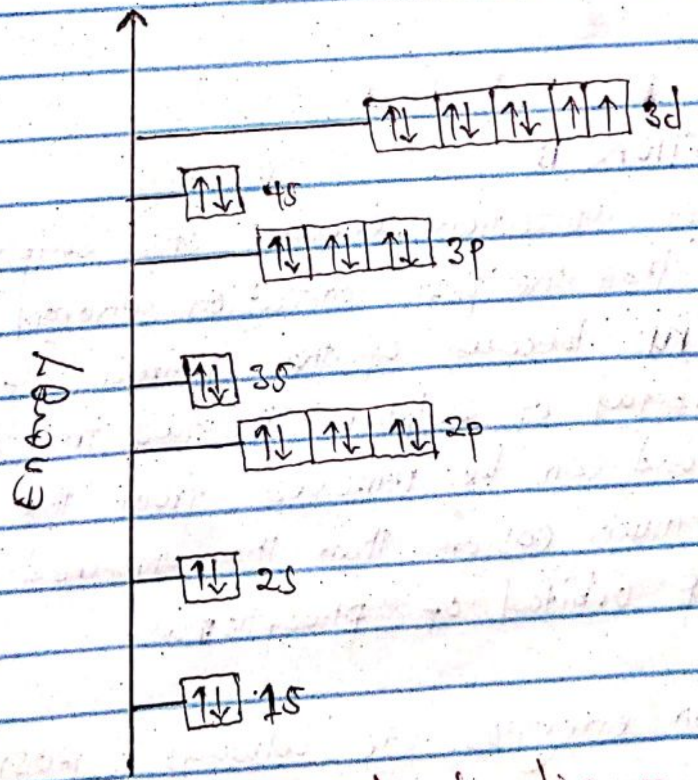
⇒ Pauli Exclusion Principle : Only 2 electrons must fill an orbital and have opposite spins.

⇒ Hund's Rule : Singly fill the orbitals before doubly filling them.

(i) Nickel metal

Atomic Number = 28, meaning we have 28 electrons.

electronic Configuration : $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^8$



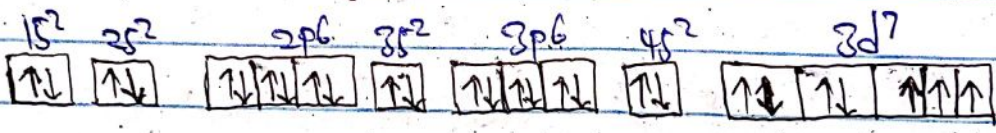
Atomic Orbital diagram.

(ii) Cobalt

Atomic number = 27, meaning we have 27 electro

Electronic Configuration. ⇒ $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^7$

Atomic Orbital diagram



(iii) Chromium.

- This one you can write on your own follow the same procedure. Peace! lol

QUESTION 11

(a) The first ionization energy of sulphur is smaller than the first ionization energy of phosphorus because of the paired electrons in 3p orbital of sulphur. The two try to repel each other and can be removed from the sulphur atom much easier than the unpaired electrons in 3p orbital of phosphorus.

(b) Ionization energies are always positive because energy must be supplied to separate electrons from atoms. An endothermic energy change is required.

(c) Flourine has a larger ionisation energy than oxygen because flourine is more electronegative than oxygen. The outermost electrons of flourine are more tightly held by the nucleus than oxygen.

QUESTION 12

* Electro-negativity is the tendency of an atom to attract electrons to itself.

(a) Hydrogen ⟶ Carbon ⟶ Nitrogen ⟶ Oxygen ⟶ Flourine
increasing electro-negativity.

(b) Hydrogen ⟶ Iodine ⟶ Bromine ⟶ Chlorine ⟶ Flourine
increasing electro-negativity

(c) Hydrogen ⟶ Phosphorus ⟶ Sulphur ⟶ Oxygen ⟶ Flourine
increasing electro-negativity

QUESTION 13

The correct order is ;

$Fe \longrightarrow Fe^{2+} \longrightarrow F^{3+}$

This is because in the formation of a cation, electrons are removed. As a result, the effective nuclear charge increases and so does the ionisation potential. The greater the positive charge of the ion, the more the ionisation potential.

QUESTION 14

Yes, atomic radius in d block initially decreases then remains constant and finally increases at the end. This can be explained based on nuclear attraction and inter-electronic repulsions. Nuclear attractions supports decrease in atomic radii while electronic repulsions increase atomic radii.

As we move from Sc to Zn, nuclear charge increases as new electrons are coming and entering into the same orbital. Electronic repulsions in the inner shell are less. This results in decrease in atomic radii.

In the middle, nuclear charge and electronic repulsions are almost equal which results in a consistant size.

At the end, electronic repulsions increase as the outer electrons are pushed away making the atomic radii increase.

QUESTION 15

Zr and Hf have almost identical atomic radii due to lanthanoid contractions. This is the poor filling of the 4f orbitals. which have a poor shielding effect as they are far away from the nucleus.

QUESTION 16

* The radius increases down the group

(a)

Mg ⟶ Ca ⟶ Rb ⟶ Cs

increasing radius

(b) These have gained or lost electrons.

S^{2-} = 184 pm Cl^{-} = 181 pm K^{+} = 138 pm

⇒ They have different size because they contain different number of protons which determines their size.

This is simple ai? YES!

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