PHY142: ATOMIC AND NUCLEAR PHYSICS

WAVE-PARTICLE DUALITY OF LIGHT
&
PHOTOELECTRICITY

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WAVE-PARTICLE DUALITY OF LIGHT

In 1924 Einstein wrote:- " There are therefore now two theories of light, both indispensable, and … without any logical connection."

Evidence for wave-nature of light

- Diffraction and interference

Evidence for particle-nature of light

- Photoelectric effect
- Compton effect

- Light exhibits diffraction and interference phenomena that are *only* explicable in terms of wave properties
- Light is always detected as packets (photons); if we look, we never observe half a photon
- Number of photons proportional to energy density (i.e. to square of electromagnetic field strength)

Consequence: Heisenberg uncertainty principle

MATTER WAVES

We have seen that light comes in discrete units (photons) with particle properties (energy and momentum) that are related to the wave-like properties of frequency and wavelength.

In 1923 Prince Louis de Broglie postulated that ordinary matter can have wave-like properties, with the wavelength λ related to momentum p in the same way as for light

de Broglie relation

$$\boxed{\lambda = \frac{h}{p}}$$

de Broglie wavelength

Planck's constant

$$h = 6.63 \times 10^{-34}\ \text{Js}$$

NB wavelength depends on momentum, not on the physical size of the particle

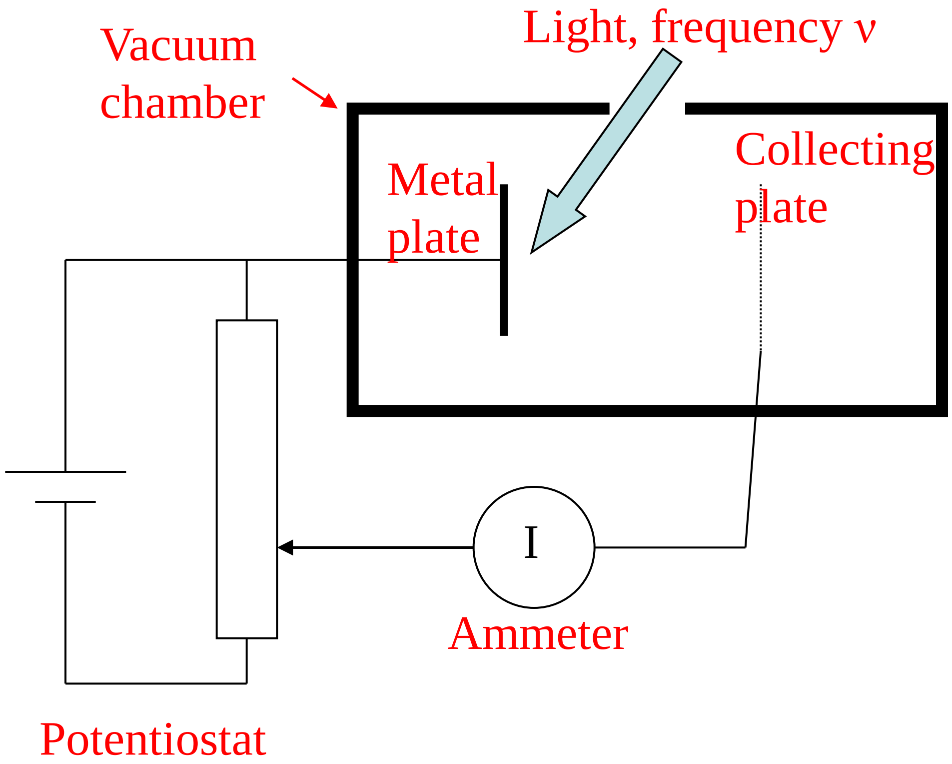
Prediction: We should see diffraction and interference of matter waves

PHOTOELECTRIC EFFECT

Hertz

J.J. Thomson

When UV light is shone on a metal plate in a vacuum, it emits charged particles (Hertz 1887), which were later shown to be electrons by J.J. Thomson (1899).



Classical expectations

Electric field E of light exerts force $\mathbf{F}=-e\mathbf{E}$ on electrons. As intensity of light increases, force increases, so KE of ejected electrons should increase.

Electrons should be emitted whatever the frequency ν of the light, so long as **E** is sufficiently large

For very low intensities, expect a time lag between light exposure and emission, while electrons absorb enough energy to escape from material

PHOTOELECTRIC EFFECT (cont)

Actual results:

Maximum KE of ejected electrons is independent of intensity, but dependent on ν

For $\nu<\nu_0$ (i.e. for frequencies below a cut-off frequency) no electrons are emitted

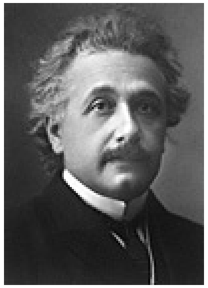
There is no time lag. However, rate of ejection of electrons depends on light intensity.

Einstein's interpretation (1905):

Light comes in packets of energy (*photons*)

$$E = h\nu$$

An electron absorbs a single photon to leave the material



Einstein

Millikan

The maximum KE of an emitted electron is then

$$K_{\max} = h\nu - W$$

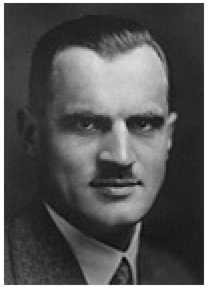
Planck constant: universal constant of nature

$$h = 6.63\times10^{-34}\,\mathrm{Js}$$

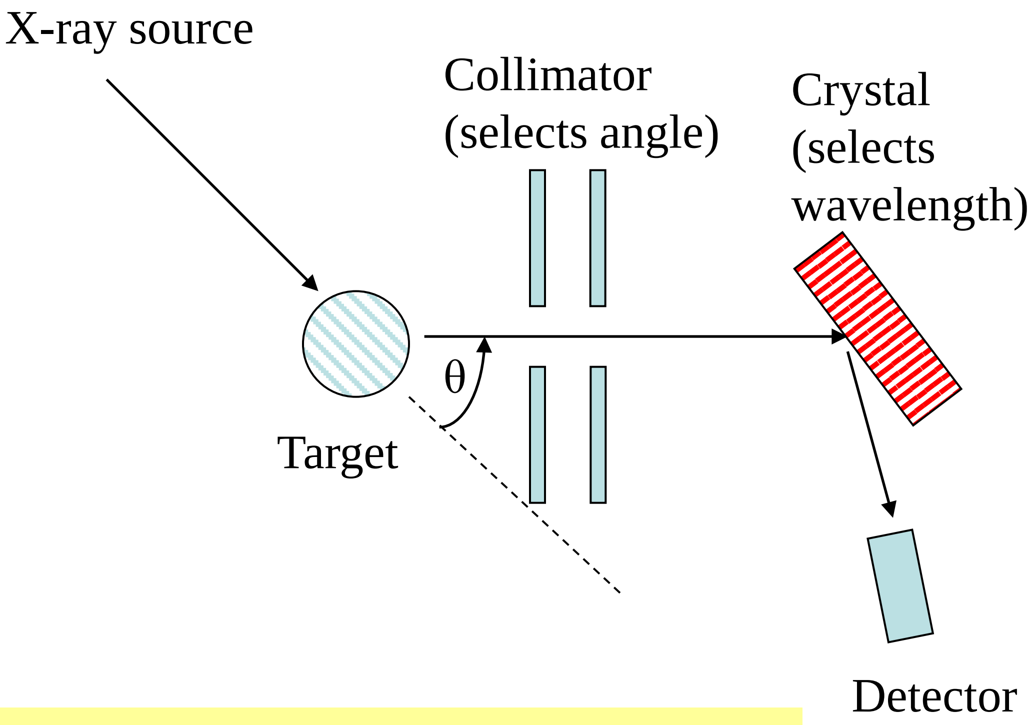
Work function: minimum energy needed for electron to escape from metal (depends on material, but usually 2-5eV)

Verified in detail through subsequent experiments by Millikan

COMPTON SCATTERING


Compton

Compton (1923) measured intensity of scattered X-rays from solid target, as function of wavelength for different angles. He won the 1927 Nobel prize.



Result: peak in scattered radiation shifts to longer wavelength than source. Amount depends on θ (but not on the target material).

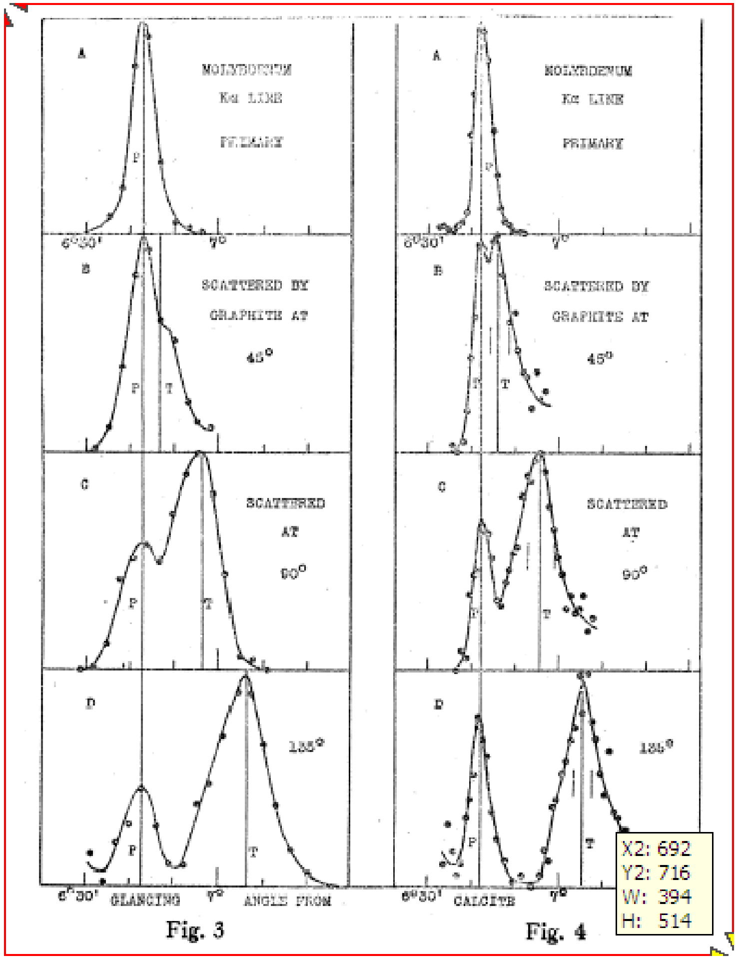


Fig. 3

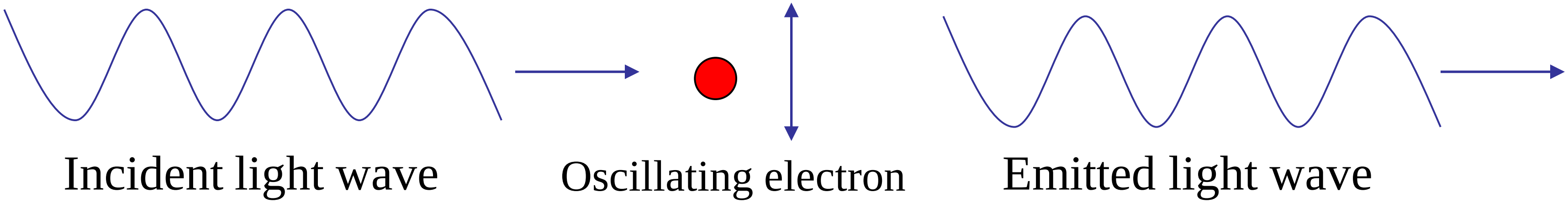
Fig. 4

A.H. Compton, *Phys. Rev.* **22** 409 (1923)

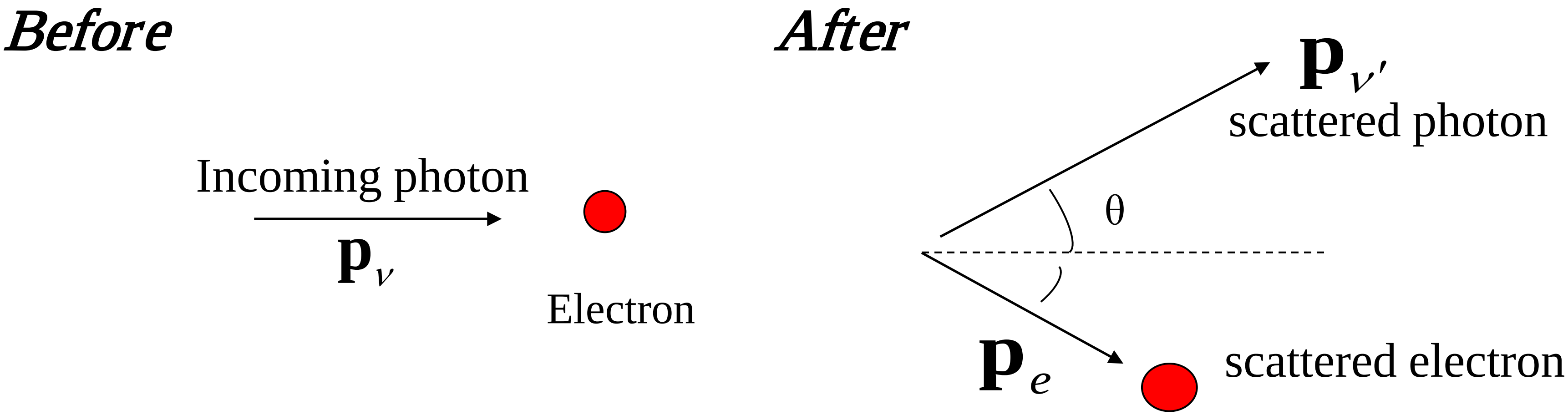
COMPTON SCATTERING (cont)

Classical picture: oscillating electromagnetic field causes oscillations in positions of charged particles, which re-radiate in all directions at *same frequency and wavelength* as incident radiation.

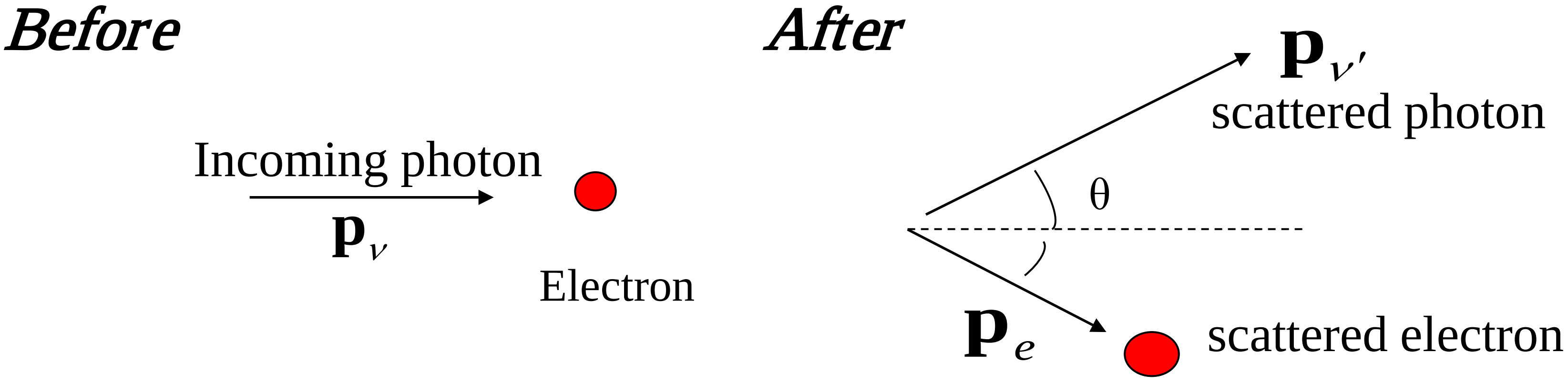
Change in wavelength of scattered light is completely unexpected classically



Compton's explanation: "billiard ball" collisions between particles of light (X-ray photons) and electrons in the material



COMPTON SCATTERING (cont)



Before

Incoming photon

$\mathbf{p}_\nu$

Electron

After

$\mathbf{p}_{\nu'}$

scattered photon

θ

$\mathbf{p}_e$

scattered electron

Conservation of energy

$$h\nu + m_e c^2 = h\nu' + \left(p_e^2 c^2 + m_e^2 c^4\right)^{1/2}$$

Conservation of momentum

$$\mathbf{p}_\nu = \frac{h}{\lambda}\hat{\mathbf{i}} = \mathbf{p}_{\nu'} + \mathbf{p}_e$$

From this Compton derived the change in wavelength

$$\boxed{\begin{aligned}\lambda' - \lambda &= \frac{h}{m_e c}\left(1 - \cos\theta\right)\\ &= \lambda_c\left(1 - \cos\theta\right) \geq 0\end{aligned}}$$

$$\lambda_c = \text{ Compton wavelength } = \frac{h}{m_e c} = 2.4\times 10^{-12}\,\mathrm{m}$$

SUMMARY OF PHOTON PROPERTIES

Relation between particle and wave properties of light

Energy and frequency $E = h\nu$

Also have relation between momentum and wavelength

Relativistic formula relating energy and momentum $\boxed{E^2 = p^2c^2 + m^2c^4}$

For light $E = pc$ and $c = \lambda\nu$

$$\boxed{p = \frac{h}{\lambda} = \frac{h\nu}{c}}$$

Also commonly write these as

wavevector

$$E = \hbar\omega \qquad p = \hbar k \qquad \omega = 2\pi\nu \qquad k = \frac{2\pi}{\lambda} \qquad \hbar = \frac{h}{2\pi}$$

angular frequency

hbar

Let us Estimate some de Broglie wavelengths

- Wavelength of electron with 50eV kinetic energy

$$\boxed{K = \frac{p^2}{2m_e} = \frac{h^2}{2m_e\lambda^2} \Rightarrow \lambda = \frac{h}{\sqrt{2m_e K}} = 1.7\times10^{-10}\,\mathrm{m}}$$

- Wavelength of Nitrogen molecule at room temperature

$$K = \frac{3kT}{2}, \quad \mathrm{Mass} = 28\mathrm{m_u}$$

$$\lambda = \frac{h}{\sqrt{3MkT}} = 2.8\times10^{-11}\,\mathrm{m}$$

- Wavelength of Rubidium(87) atom at 50nK

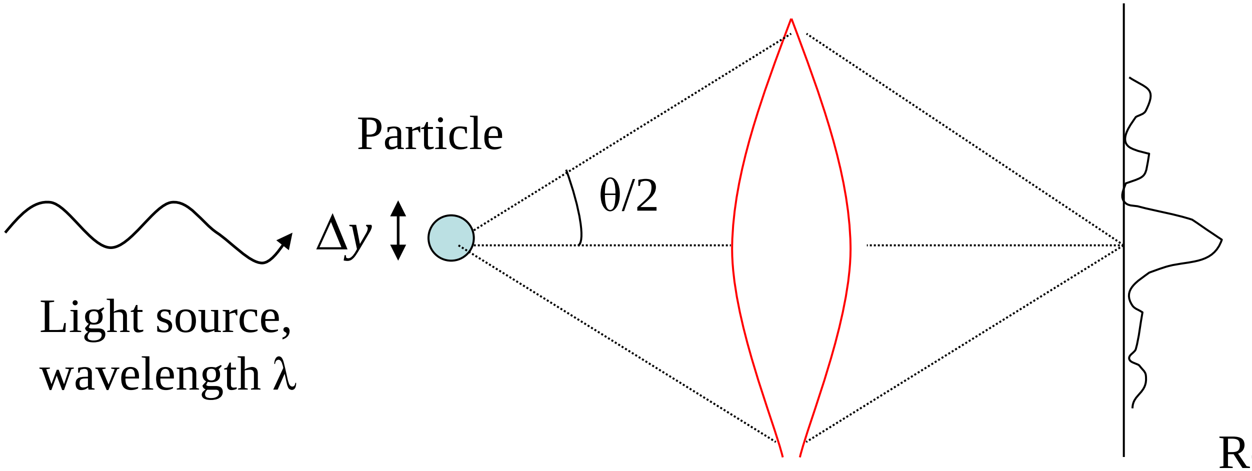
$$\boxed{\lambda = \frac{h}{\sqrt{3MkT}} = 1.2\times10^{-6}\,\mathrm{m}}$$

HEISENBERG MICROSCOPE AND THE UNCERTAINTY PRINCIPLE

(also called the Bohr microscope, but the thought experiment is mainly due to Heisenberg).

The microscope is an imaginary device to measure the position (y) and momentum (p) of a particle.

Heisenberg



Light source, wavelength λ

Lens, with angular diameter θ

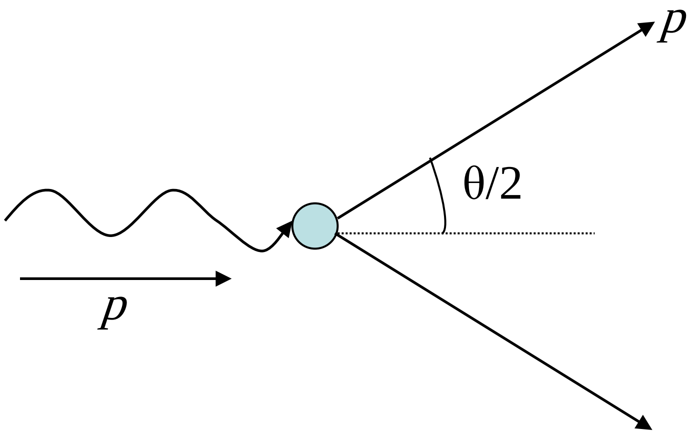
Resolving power of lens:

$$\Delta y \geq \frac{\lambda}{\theta}$$

HEISENBERG MICROSCOPE (cont)

Photons transfer momentum to the particle when they scatter.

Magnitude of p is the same before and after the collision. Why?



Uncertainty in *photon* y-momentum
= Uncertainty in *particle* y-momentum

$$\boxed{-p\sin(\theta/2) \le p_y \le p\sin(\theta/2)}$$

Small angle approximation

$$\Delta p_y = 2p\sin(\theta/2) \approx p\theta$$

de Broglie relation gives $p = h/\lambda$ and so $\Delta p_y \approx \dfrac{h\theta}{\lambda}$

From before $\Delta y \ge \dfrac{\lambda}{\theta}$ hence $\boxed{\Delta p_y \Delta y \approx h}$

HEISENBERG UNCERTAINTY PRINCIPLE.

HEISENBERG UNCERTAINTY PRINCIPLE

It follows that;

$$\boxed{\begin{gathered}\Delta x \Delta p_x \geq \hbar / 2 \\ \Delta y \Delta p_y \geq \hbar / 2 \\ \Delta z \Delta p_z \geq \hbar / 2\end{gathered}}$$

HEISENBERG UNCERTAINTY PRINCIPLE.

We cannot have simultaneous knowledge of 'conjugate' variables such as position and momenta.

Note, however, $\boxed{\Delta x \Delta p_y \geq 0}$ etc

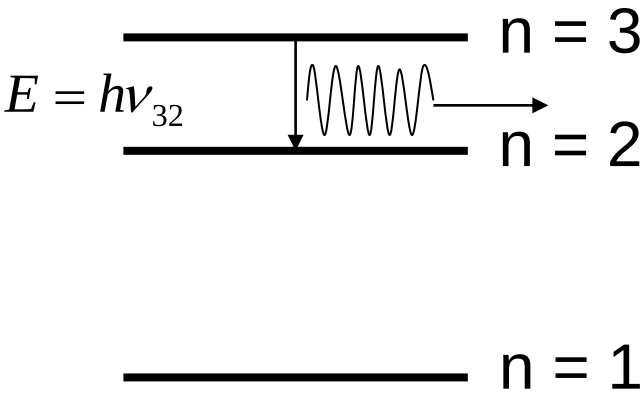
Arbitary precision is possible in principle for position in one direction and momentum in another

HEISENBERG UNCERTAINTY PRINCIPLE

There is also an energy-time uncertainty relation

$$\boxed{\Delta E \Delta t \geq \hbar / 2}$$

Transitions between energy levels of atoms are not perfectly sharp in frequency.



n = 3

$E = h\nu_{32}$

n = 2

n = 1

An electron in $n = 3$ will spontaneously decay to a lower level after a lifetime of order $t \sim 10^{-8}\,\mathrm{s}$

CONCLUSIONS

Light and matter exhibit wave-particle duality

Relation between wave and particle properties given by the de Broglie relations

$$\boxed{E = h\nu \qquad p = \frac{h}{\lambda}}$$

Evidence for particle properties of light
Photoelectric effect, Compton scattering

Evidence for wave properties of matter
Electron diffraction, interference of matter waves (electrons, neutrons, He atoms, C60 molecules)

Heisenberg uncertainty principle limits simultaneous knowledge of conjugate variables

$$\boxed{\begin{aligned} \Delta x \Delta p_x &\geq \hbar / 2 \\ \Delta y \Delta p_y &\geq \hbar / 2 \\ \Delta z \Delta p_z &\geq \hbar / 2 \end{aligned}}$$

PHOTOELECTRICITY

When light falls on metal surfaces, electrons are emitted. This is the photo-electric effect. The emitted electrons are known as photo-electrons i.e. when light (e.g ultraviolent rays) fall on zinc plate, electrons are liberated from zinc plates. This phenomenon is called photoelectric emission.

In general, the emission of electrons as a result of electromagnetic wave falling on the matter is referred to as photoelectric effect.

Photo-electric emission occurs when electrons are emitted from surface of metal plates when it is illuminated by light of sufficient high frequency.

The following important observations were made in the study of the photoelectric effect. Electrons are emitted at the instant the surface is illuminated even with light of very weak intensity:

- For each metal there is a well defined frequency called the Threshold Frequency which must be exceeded for electrons emission to occur, no matter how strong the intensity of light may be.
- The maximum kinetic energy of the emitted electrons increases with the frequency of the incident light but is independent of the intensity of light.
- This follows that, emission of electrons depends on the threshold frequency, but rate of emission of electrons depends on the intensity of the light.
- **Threshold Frequency:** is the minimum frequency of the illuminating light which will just be sufficient to cause photoelectric emission. The threshold frequency is not the same for all metals, the energy of the emitted electrons varies from zero to a maximum.

PHOTOELECTRIC CELL AND ITS MODE OF OPERATION

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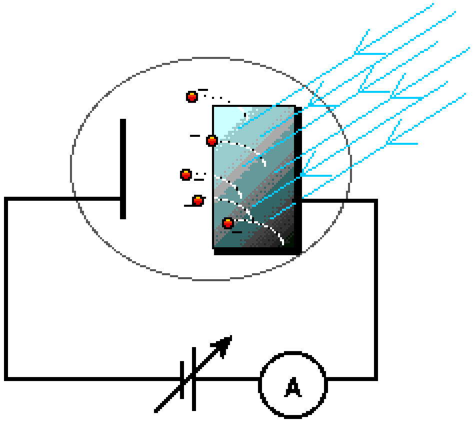

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- When light photons incident or fall on the cathode (i.e. emission metal plate) electrons are emitted which goes to the anode or collector to generate current flow.
- When intensity of light varies, the rate of emission of electrons varies, thus, the flow of current varies.
- Explanation of what happens to energy of light before emission of electrons begins.
- The energy of illuminating light as absorbed by photo-cell and are used to overcome the force that bind the electron together, but this may not be sufficient to remove the electron until light with sufficient threshold frequency is attained. One factor that may affect the number of emitted electron is the intensity of the light.

Work Function

The minimum energy tom liberate an electron from the surface of a metal is called work function of that metal or Binding Energy.

Work function = hf_o, where f_o is the threshold frequency and h = Planck's constant.

Energy of the illuminating light = hf; where f = frequency of the light.

- Part of this energy is also to overcome the work function of the metal (i.e. to get the electron free from the atom and away from the metal surface). The reminder of the energy is used to give the liberated electron a kinetic energy, ($E_k = \frac{1}{2}mv^2$) where v is the velocity of the photoelectron of mass M. the work function, $w = hf_o$
- Energy of the illuminating light = Work Function + Kinetic Energy of Electrons
- Maximum Kinetic Energy a photoelectron can posses = Energy of the illuminating light – Work Function
- $E_k = [hf - hf_o]$; ---(i)
- where$E_k = \frac{1}{2}mv^2$; This is Einstein's Photoelectric Equation.
- Note that, the energy of the ejected electron may be found by determining what potential different (v) must be applied to stop its motion.
- Then, $E_k = \frac{1}{2}mv^2 = eVs$---(ii)
- The product eV is the electron-volt and Vs is the stopping potential.

Stopping Potential (Vs) is point attain for which no electrons reach the collector (Anode).

- $E_k = eV = hf - hf_o$---(iii)

Note also that, Number of electrons hitting the anode per second = current divided by electron charge.

- i.e. No. of Electrons striking the target per second $= \frac{current}{electron\ charge} = \frac{I}{e}$
- also, the Electric Power Input, P = Current x Voltage = IV

Examples:

Calculate the frequency of the photon whose energy is required to eject a surface electron with K.E of $1.97\text{x}10^{-16}$eV, if the work function of the metal is $1.33\text{x}10^{-16}$eV.

(1eV = $1.6\text{x}10^{-19}$J; h = $6.62\text{x}10^{-34}$Js

Solution

$W = hf_0 = 1.33\text{x}10^{-16}$eV

$E_k = 1.97\text{x}10^{-16}$eV,

Using $E_k = [hf - hf_o]$ (making f the the subject of the formula)

$$f = \frac{E_k + hf_0}{h}$$

$$= \frac{1.97\times10^{-16} + 1.33\times10^{-16}}{6.6\times10^{-34}}$$

$$= \frac{3.3\times10^{-16}}{6.6\times10^{-34}} = 5.0\text{x}10^{17}\text{eV}$$

Application of Photoelectric Emission

- Production of Television Camera
- Burglary Alarm
- Automatic Switches for putting on light at dusk
- Industrial controls and counting operations

- Calculate the wavelength associated with the following objects
- Electron moving with velocity of m/s
- Bullet of mass 0.01kg with velocity 400ms^{-1}
- Sprinter of mass 60 kg with velocity 10m/s

- Electrons are accelerated by a P.D
- 100v
- 400v
- Calculate the wavelength associated with the electrons on each case.

- An x- ray photon has a wavelength of 3.3×m. Calculate the momenturn, mass and energy of the particle associated with the photon, which moves with a velocity c.
- Electrons are accelerated from rest through a potential difference of 10,000v in an X-ray tube. Calc.
  - » The resultant energy of the electrons in eV
  - » The wavelength of the associated electron waves
  - » The maximum energy and the minimum wavelength of the x- ray generated.(charge of the electron = 1.6 ×c , mass of the electron = 9.11 ×kg, h= 6.62 ×JS)

- Calculate de- Broglie wavelength associated with a proton moving with a velocity equal to 1/20 th of the velocity of light. Ans = 2.64×10^{-14}m

- Find the energy of the neutron in units of electron volt whose de- Broglie wavelength 1A°. Given mass of neutron=1.67 × 10 -27 kg ,h = 6.6×10^{-34} JS, 1A° = 10^{-10}m ANS= E= 8.13×10^{-2} eV

- Compute the de-Broglie wavelength of 10KeV neutron. Mass of neutron may be taken as 1.675×10^{-27}kg. ANS = 2.86×10^{-13} m

- What is de- Broglie wavelength of an electron which has been accelerated from rest through a potential difference of 100V? ANS=λ=1.225Å= 1.225×10^{-10}m.

- Compute the de-Broglie wavelength of a proton whose kinetic energy is equal to the rest energy of an electron. Mass of a photon is 1836 times that of the electron. ANS= 0.0004Å=4×10^{-4}Å= 4×10^{-14}m.

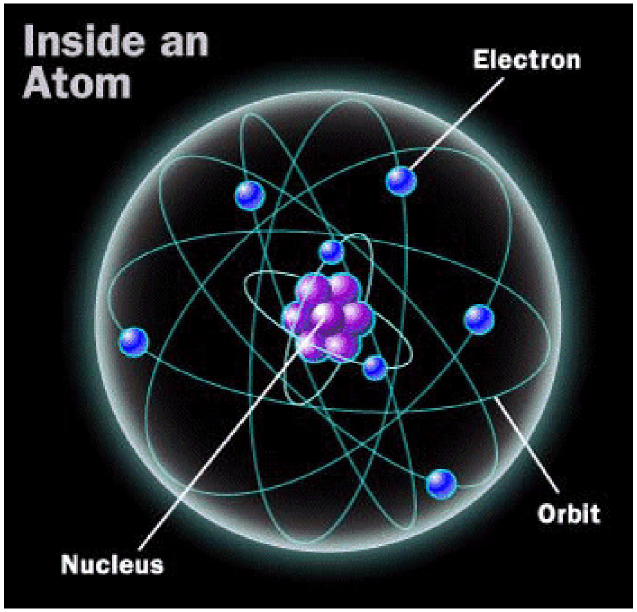
- Energy of a particle at absolute temperature T is the order KT. Calculate the wavelength of thermal neutrons at 27°c, gives mass of the neutron= 1.67×10^{-27} kg , h= 6.6×10^{-34} Js , Bolts- Mann's constant k = 8.6×10^{-5} eVdeg^{-1} = $8.6 \times 10^{-5} \times 1.6 \times 10^{-19}$ = 1.376×10^{-23} Jdeg^{-1} , T= 27°c=300°k.

Atomic & Nuclear Physics

AP Physics B

Life and Atoms

Every time you breathe you are taking in atoms. Oxygen atoms to be exact. These atoms react with the blood and are carried to every cell in your body for various reactions you need to survive. Likewise, every time you breathe out carbon dioxide atoms are released.



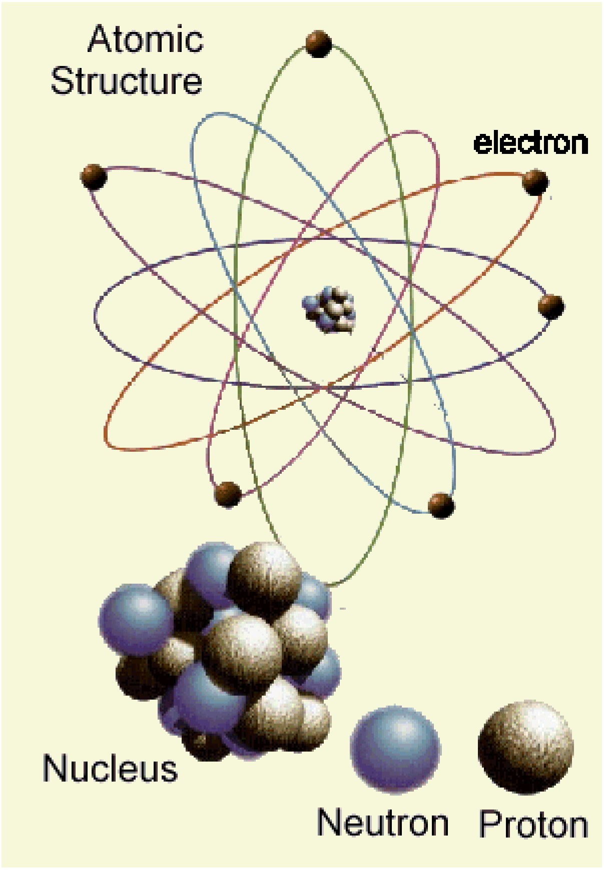
The cycle here is interesting.

TAKING SOMETHING IN. ALLOWING SOMETHING OUT!

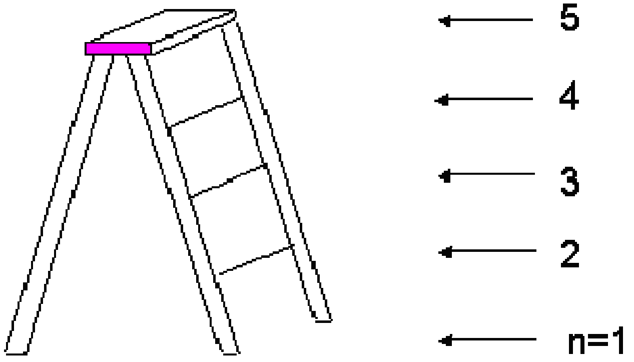
The Atom

As you probably already know an atom is the building block of all matter. It has a nucleus with protons and neutrons and an electron cloud outside of the nucleus where electrons are orbiting and MOVING.

Depending on the ELEMENT, the amount of electrons differs as well as the amounts of orbits surrounding the atom.



When the atom gets excited or NOT



Rungs correspond to energy levels.

n=1 is the lowest energy level.

To help visualize the atom think of it like a ladder. The bottom of the ladder is called **GROUND STATE** where all electrons would like to exist. If energy is **ABSORBED** it moves to a new rung on the ladder or **ENERGY LEVEL** called an **EXCITED STATE**. This state is AWAY from the nucleus.

As energy is **RELEASED** the electron can relax by moving to a new energy level or rung down the ladder.

Energy Levels

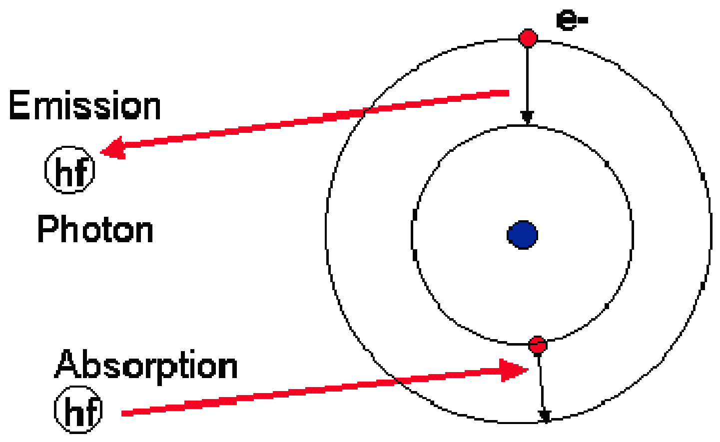
Yet something interesting happens as the electron travels from energy level to energy level.

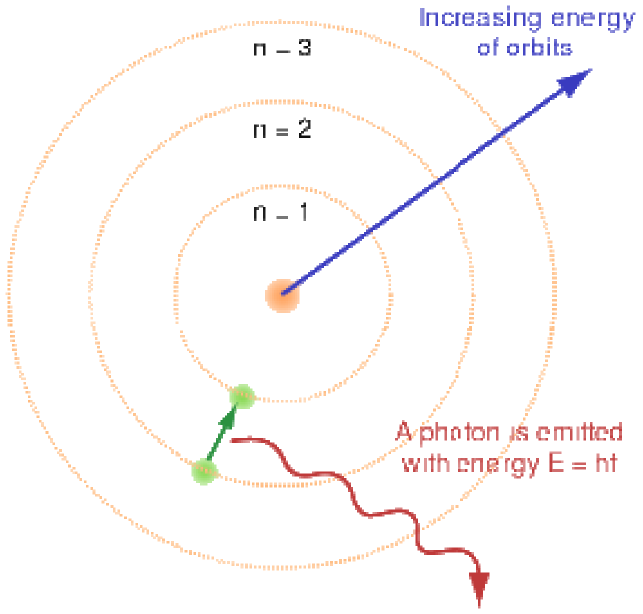
If an electron is **EXCITED**, that means energy is **ABSORBED** and therefore a PHOTON is absorbed.

If an electron is **DE-EXCITED**, that means energy is **RELEASED** and therefore a photon is released.

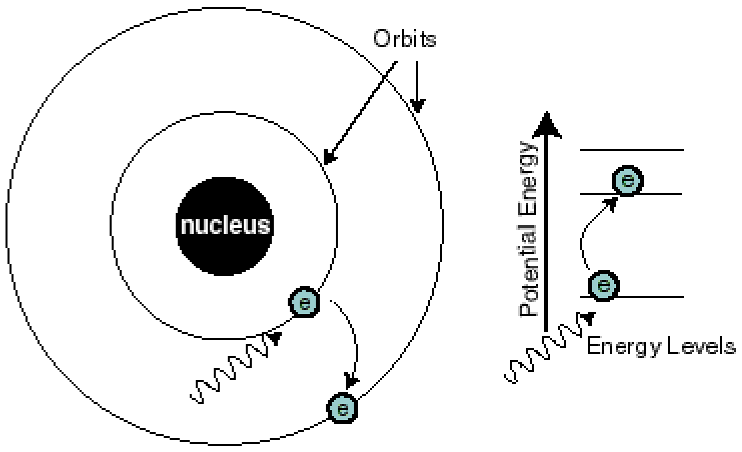
We call these leaps from energy level to energy level QUANTUM LEAPS.

Since a PHOTON is emitted that means that it MUST have a certain wavelength.

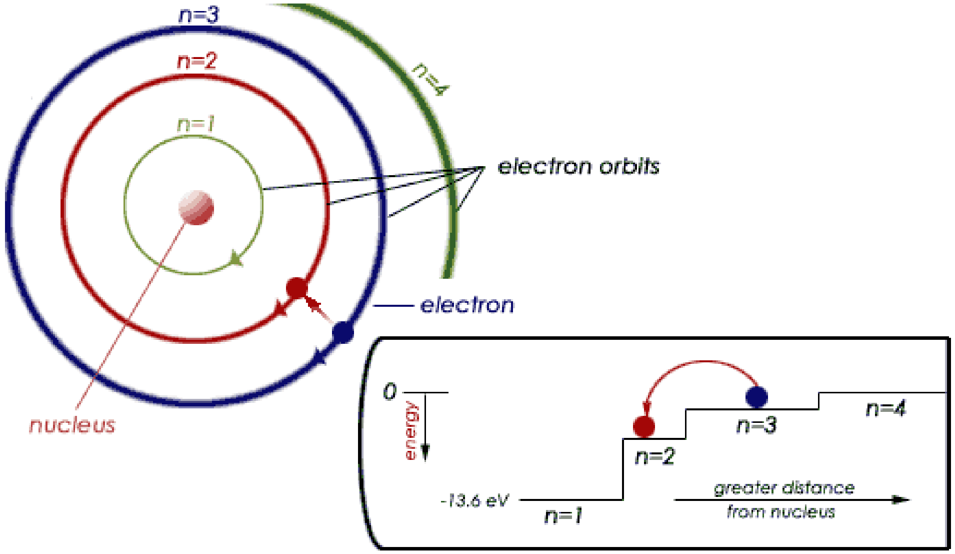




Energy of the Photon



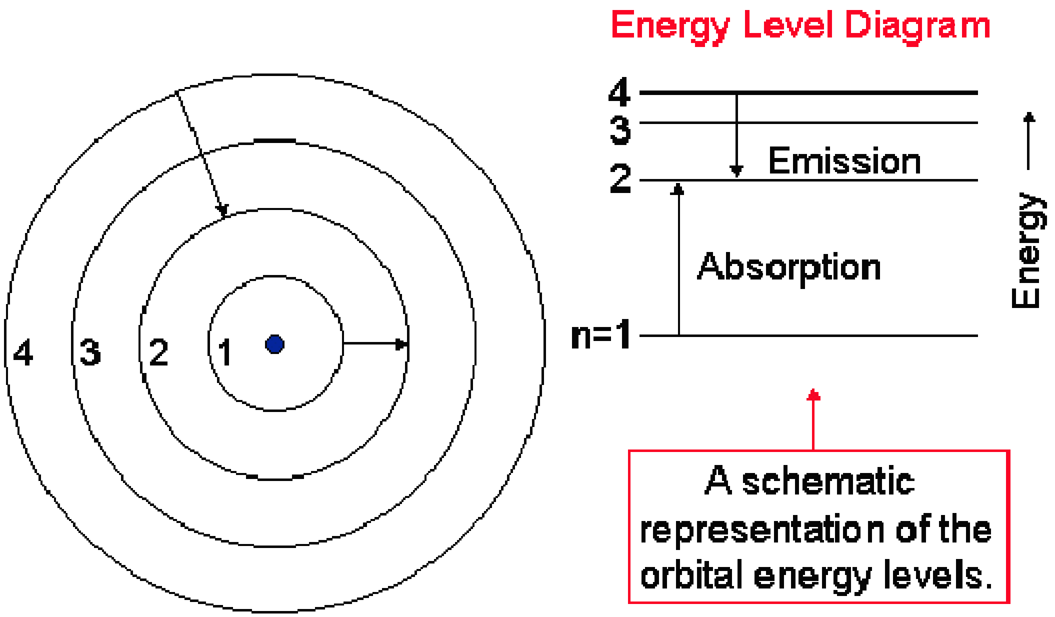
We can calculate the **ENERGY** of the released or absorbed photon provided we know the initial and final state of the electron that jumps energy levels.



$$\Delta E = hf = \frac{hc}{\lambda}$$

Energy Level Diagrams

To represent these transitions we can construct an **ENERGY LEVEL DIAGRAM**



A schematic representation of the orbital energy levels.

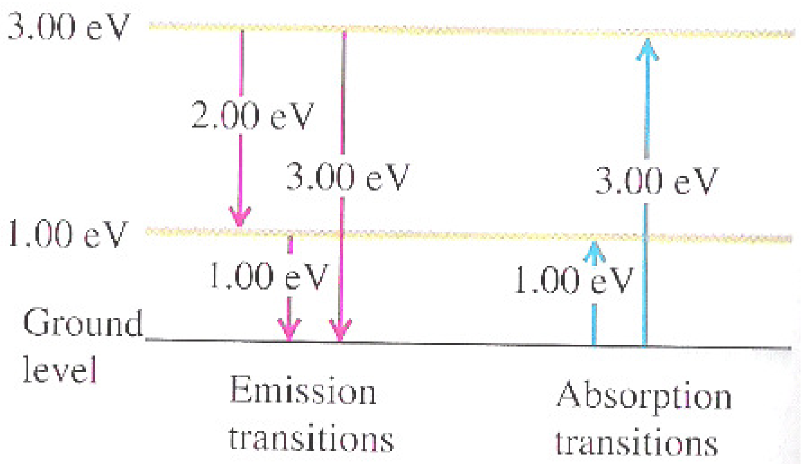
Note: It is very important to understanding that these transitions DO NOT have to occur as a single jump! It might make TWO JUMPS to get back to ground state. If that is the case, TWO photons will be emitted, each with a different wavelength and energy.

Example

An electron releases energy as it moves back to its ground state position. As a result, photons are emitted. Calculate the POSSIBLE wavelengths of the emitted photons.

$$\Delta E = hf = \frac{hc}{\lambda}$$

Notice that they give us the energy of each energy level. This will allow us to calculate the CHANGE in ENERGY that goes to the emitted photon.



$$\lambda = \frac{hc}{\Delta E} = \frac{1240eV \bullet nm}{3eV} = 413nm$$

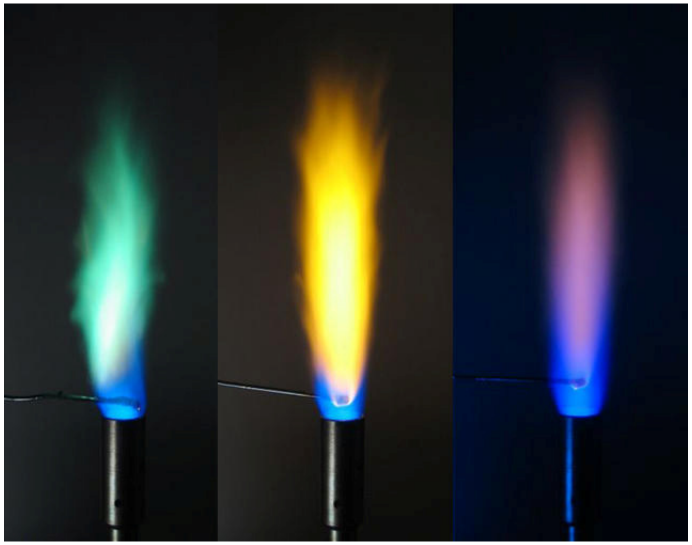
$$\lambda = \frac{hc}{\Delta E} = \frac{1240eV \bullet nm}{2eV} = 620nm$$

$$\lambda = \frac{hc}{\Delta E} = \frac{1240eV \bullet nm}{1eV} = 1240nm$$

This particular sample will release three different wavelengths, with TWO being the visible range (RED, VIOLET) and ONE being OUTSIDE the visible range (INFRARED)

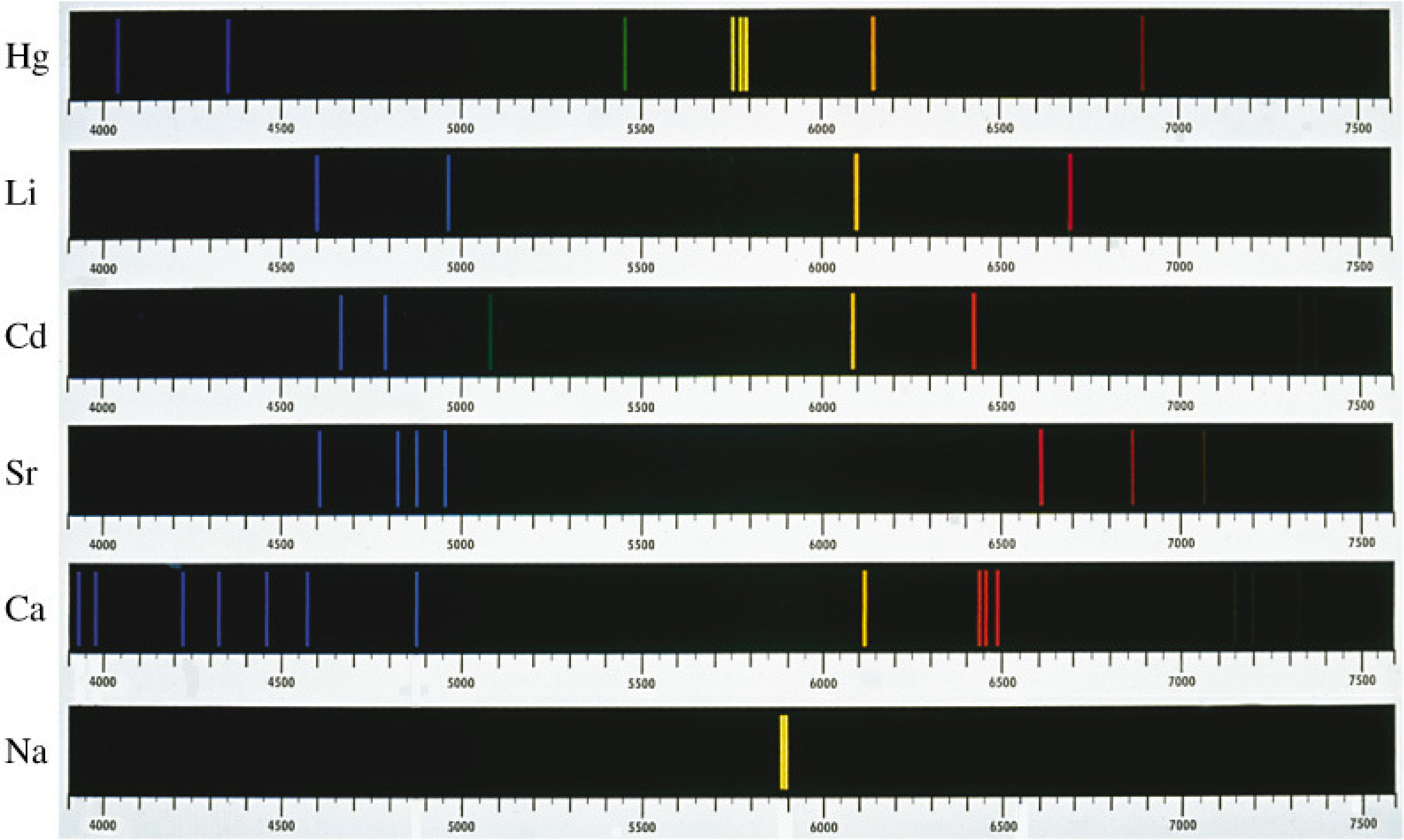
Energy levels Application: Spectroscopy

Spectroscopy is an optical technique by which we can IDENTIFY a material based on its emission spectrum. It is heavily used in Astronomy and Remote Sensing. There are too many subcategories to mention here but the one you are probably the most familiar with are flame tests.



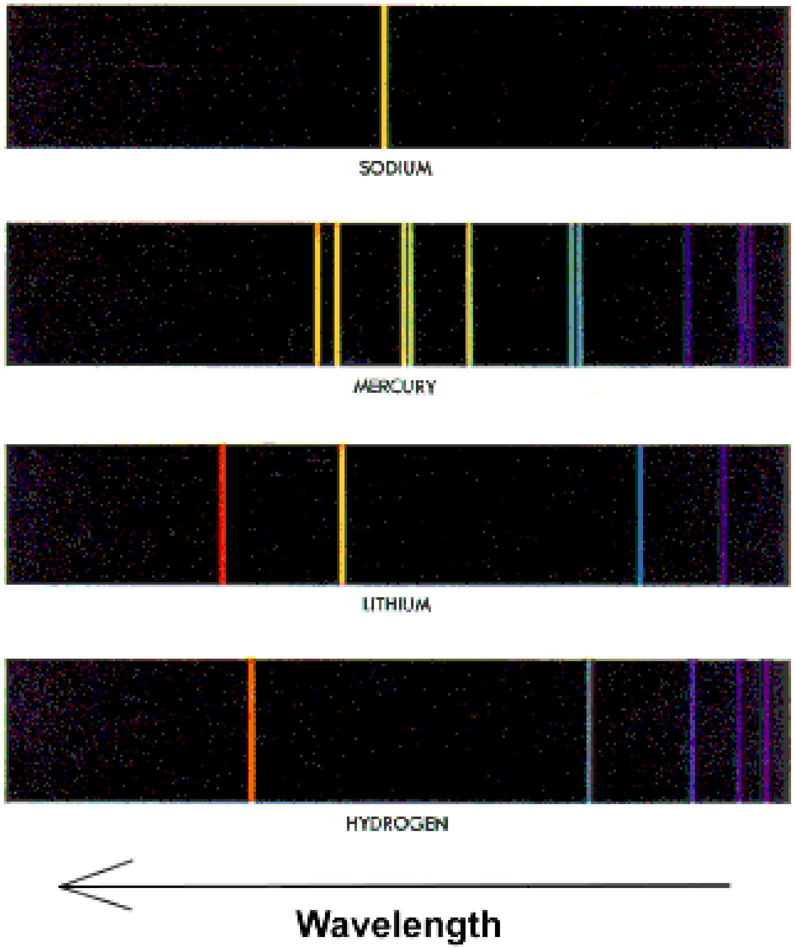
When an electron gets excited inside a SPECIFIC ELEMENT, the electron releases a photon. This photon’s wavelength corresponds to the energy level jump and can be used to indentify the element.

Different Elements = Different Emission Lines



Emission Line Spectra

So basically you could look at light from any element of which the electrons emit photons. If you look at the light with a diffraction grating the lines will appear as sharp spectral lines occurring at specific energies and specific wavelengths. This phenomenon allows us to analyze the atmosphere of planets or galaxies simply by looking at the light being emitted from them.



Nuclear Physics - Radioactivity

Before we begin to discuss the specifics of radioactive decay we need to be certain you understand the proper **NOTATION** that is used.

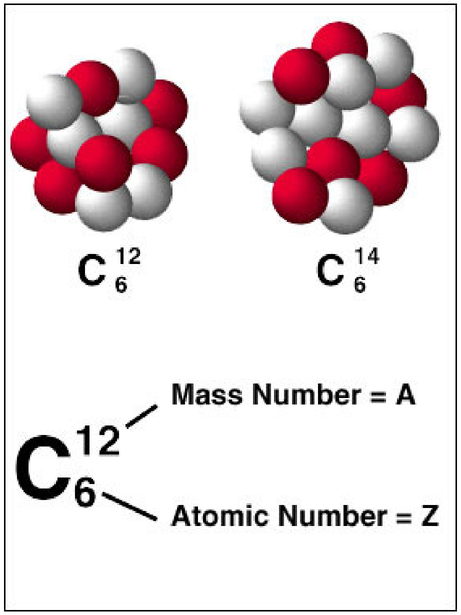
$${}^{A}_{Z}U \rightarrow {}^{238}_{92}U$$

To the left is your typical radioactive isotope.

Top number = mass number = #protons + neutrons. It is represented by the letter "A“

Bottom number = atomic number = # of protons in the nucleus. It is represented by the letter "Z"

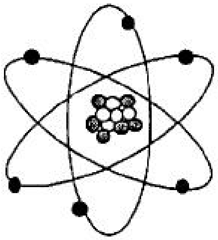
Nuclear Physics – Notation & Isotopes



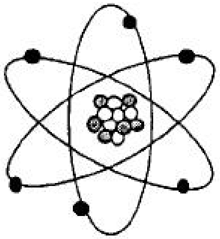
An isotope is when you have the **SAME ELEMENT**, yet it has a **different MASS**. This is a result of have extra neutrons. Since Carbon is always going to be element #6, we can write Carbon in terms of its mass instead.

Carbon - 12

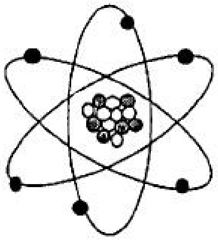
Carbon - 14



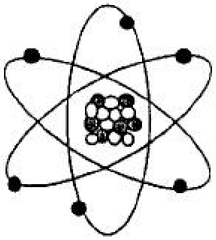
Carbon-11
6 protons
5 neutrons
unstable



Carbon-12
6 protons
6 neutrons
stable

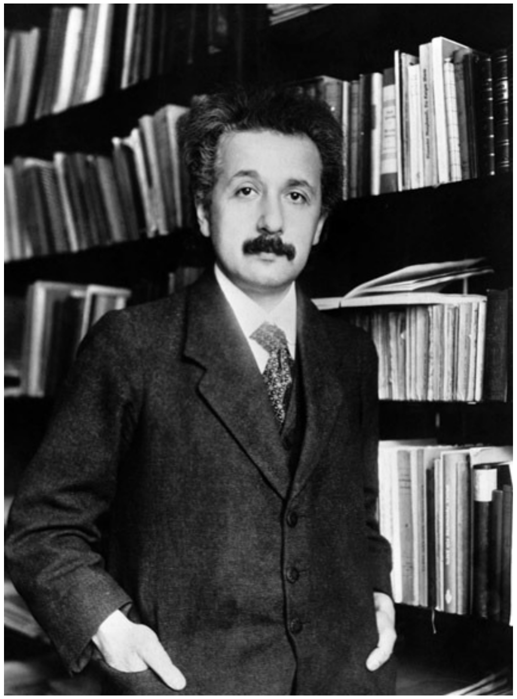


Carbon-13
6 protons
7 neutrons
stable

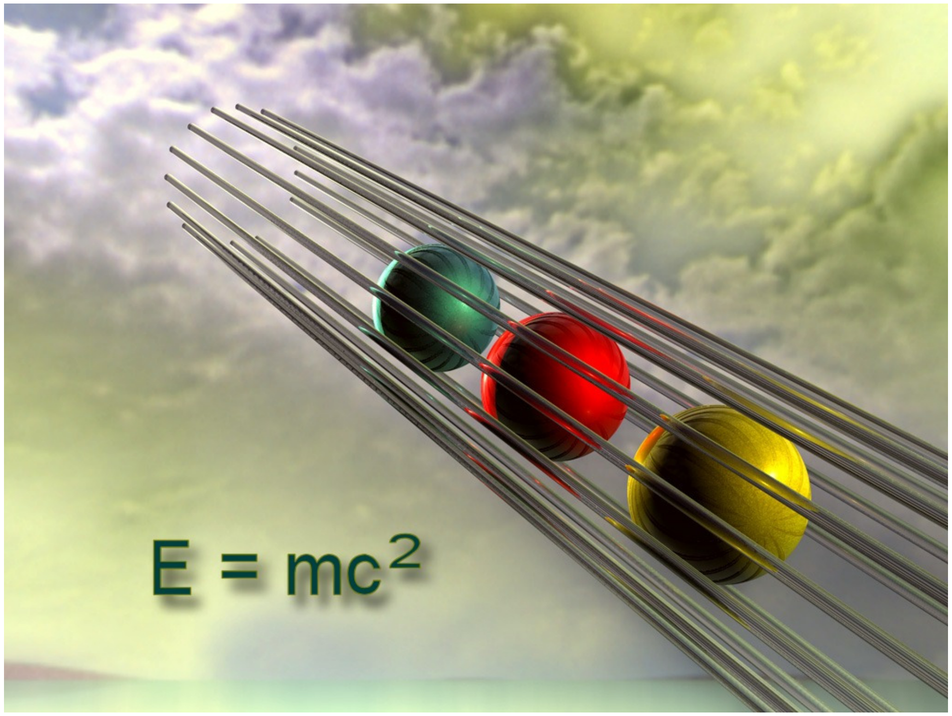


Carbon-14
6 protons
8 neutrons
unstable

Einstein – Energy/Mass Equivalence



In 1905, Albert Einstein publishes a 2nd major theory called the **Energy-Mass Equivalence** in a paper called, “Does the inertia of a body depend on its energy content?”



Einstein – Energy/Mass Equivalence

Looking closely at Einstein's equation we see that he postulated that mass held an enormous amount of energy within itself. We call this energy BINDING ENERGY or Rest mass energy as it is the energy that holds the atom together when it is at rest. The large amount of energy comes from the fact that the speed of light is squared.

Energy Unit Check

$$E_B = \Delta mc^2 \rightarrow Joule = kg \times \frac{m^2}{s^2}$$

$$W = Fx \rightarrow Joule = Nm$$

$$F_{net} = ma \rightarrow N = kg \times \frac{m}{s^2}$$

$$E = W = kg \times \frac{m}{s^2} \times m = kg \times \frac{m^2}{s^2} \quad \checkmark$$

Mass Defect

$$E_B = \Delta mc^2$$

$$E_B = \text{Binding energy}$$

$$\Delta m = \text{mass defect}$$

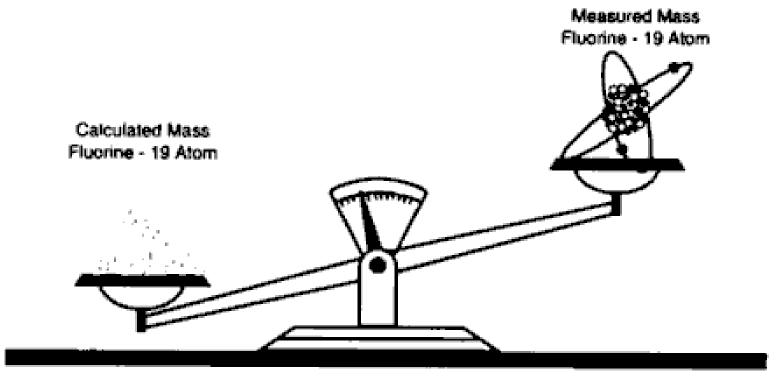


Figure 2-V. Illustration of a Mass Defect

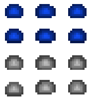
The nucleus of the atom is held together by a **STRONG NUCLEAR FORCE.**

The more stable the nucleus, the more energy needed to break it apart.
Energy need to break to break the nucleus into protons and neutrons is called the **Binding Energy**
Einstein discovered that the mass of the separated particles is greater than the mass of the intact stable nucleus to begin with.
This difference in mass **(Δm) is called the mass defect.**

Mass Defect - Explained

- mass number ≠ isotope mass ≠ mass of separate nucleons!
- example: carbon-12

$$u = 1.660559x10^{-27} kg$$



mass number
12

6 p^{+} @ 1.007276 amu each

6 n @ 1.008665 amu each

mass of separate nucleons
12.095646 amu

isotope mass
11.996709 amu

mass defect: 0.098937 amu

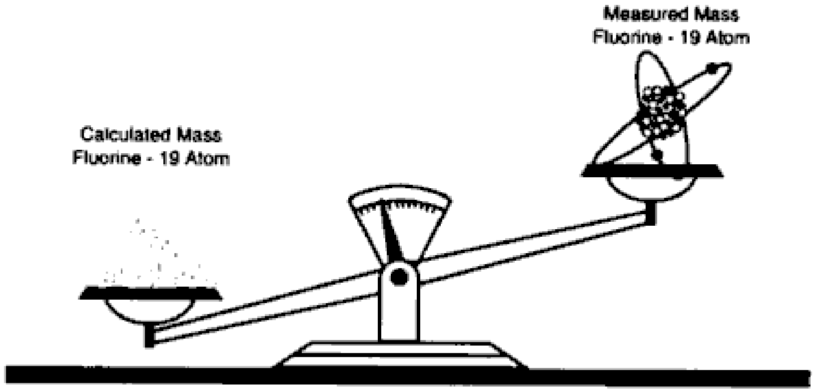


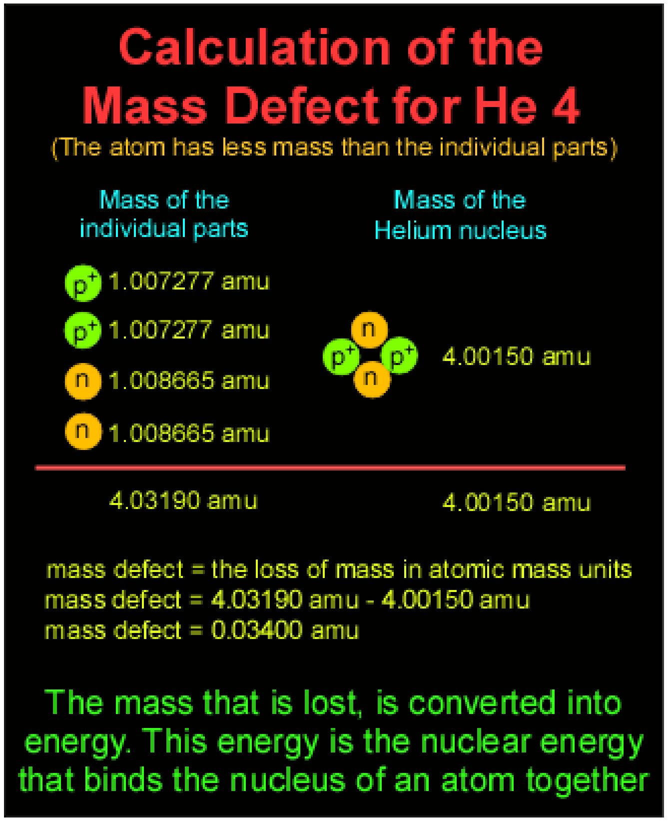
Figure 2-V. Illustration of a Mass Defect

The extra mass turns into energy holding the atom together.

Mass Defect – Example

$$1\,u = 1.660559x10^{-27}\,kg$$

Particle	Mass(kg)	u
Proton	$1.6726x10^{-27}$	1.007276
Neutron	$1.6750x10^{-27}$	1.008665
Electron	$9.109x10^{-31}$	$5.486x10^{-4}$



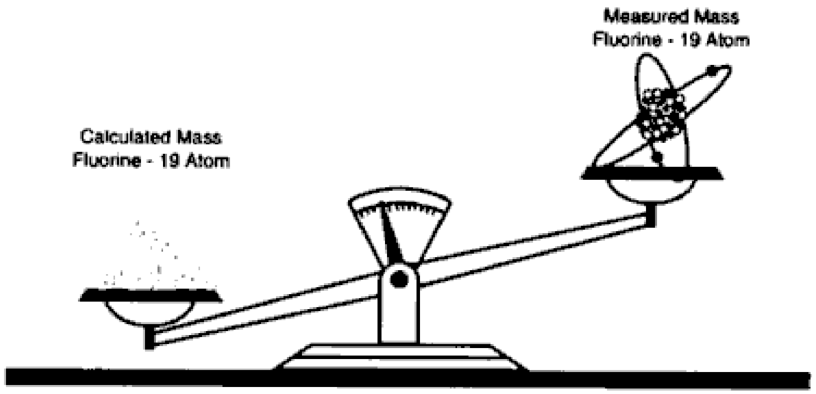
Calculation of the Mass Defect for He 4

(The atom has less mass than the individual parts)

Mass of the individual parts	Mass of the Helium nucleus
p^+ 1.007277 amu p^+ 1.007277 amu n 1.008665 amu n 1.008665 amu	4.00150 amu
4.03190 amu	4.00150 amu

mass defect = the loss of mass in atomic mass units
mass defect = 4.03190 amu - 4.00150 amu
mass defect = 0.03400 amu

The mass that is lost, is converted into energy. This energy is the nuclear energy that binds the nucleus of an atom together



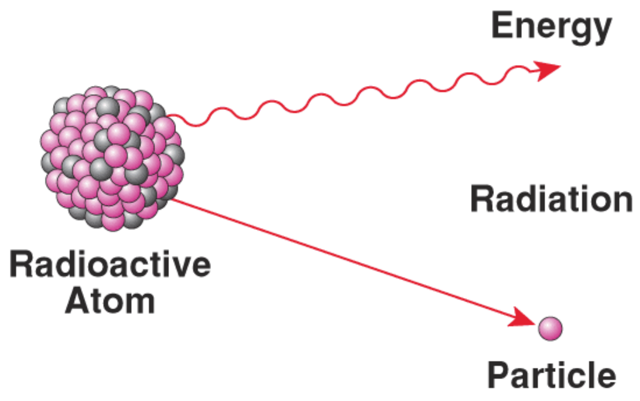
$$E_B = \Delta mc^2$$

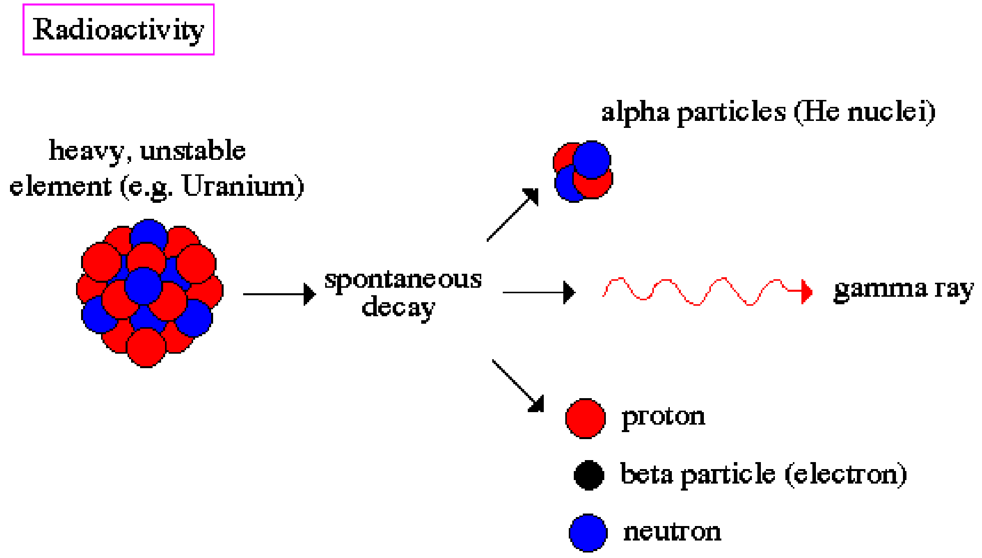
$$E_B = \text{Binding energy}$$

$$\Delta m = \text{mass defect}$$

Radioactivity

When an unstable nucleus releases energy and/or particles.





Radioactive Decay

There are 4 basic types of radioactive decay

- Alpha – Ejected Helium
- Beta – Ejected Electron
- Positron – Ejected Anti-Beta particle
- Gamma – Ejected Energy

You may encounter protons and neutrons being emitted as well

$${}^{4}_{2}He$$

$${}^{0}_{-1}e$$

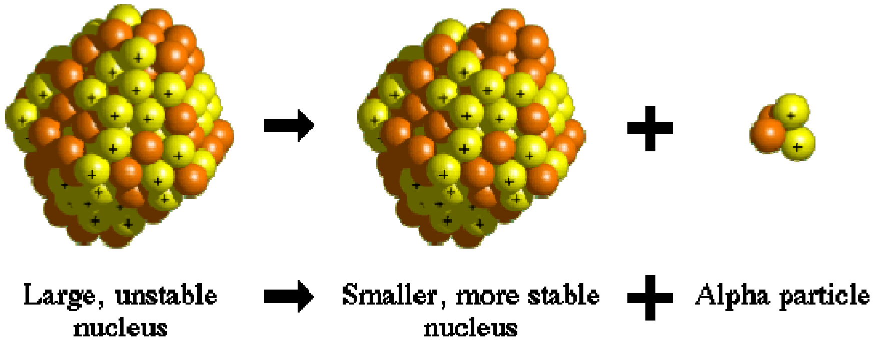
$${}^{0}_{1}e$$

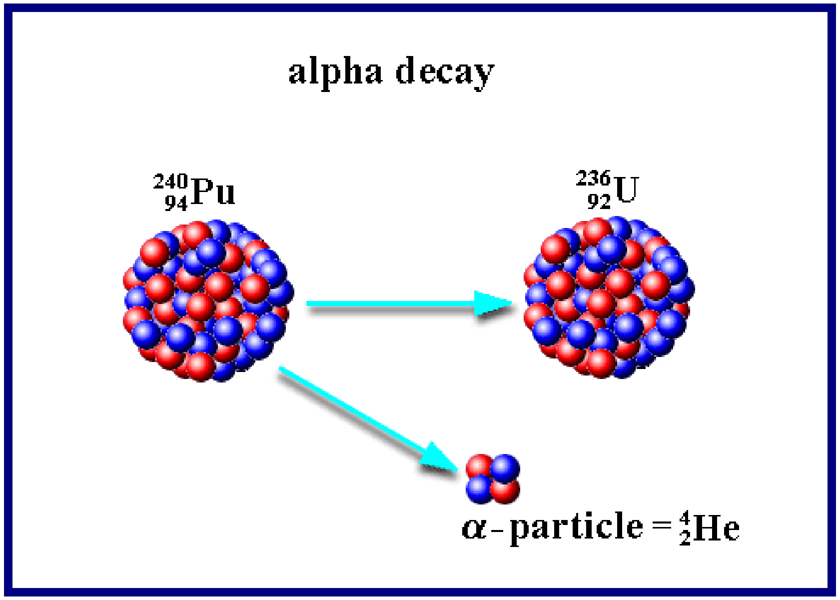
$${}^{0}_{0}\gamma$$

$${}^{1}_{1}p$$

$${}^{1}_{0}n$$

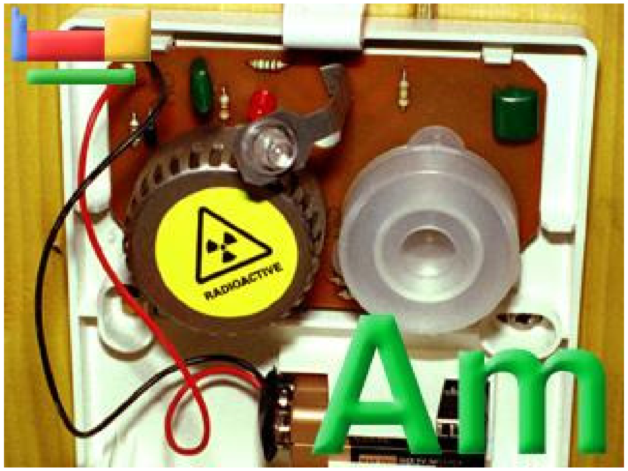
Alpha Decay





$$^{240}_{94}Pu \rightarrow {}^{236}_{92}U + {}^{4}_{2}He$$

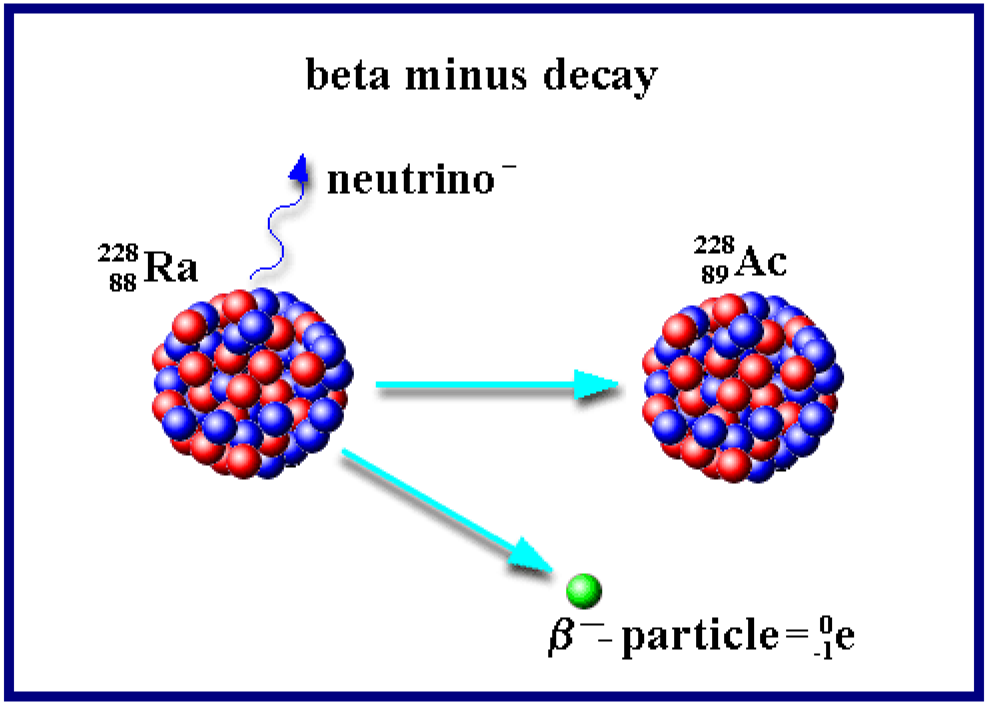
Alpha Decay Applications



$$^{241}_{95}Am \rightarrow ^{4}_{2}He + ^{A}_{Z}?$$

Americium-241, an alpha-emitter, is used in smoke detectors. The alpha particles ionize air between a small gap. A small current is passed through that ionized air. Smoke particles from fire that enter the air gap reduce the current flow, sounding the alarm.

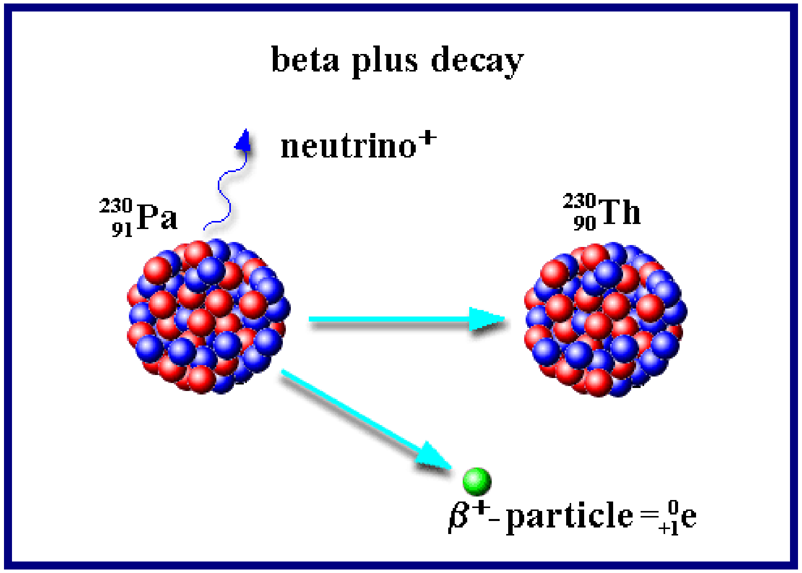
Beta Decay



There aren't really any applications of beta decay other than Betavoltaics which makes batteries from beta emitters. Beta decay, did however, lead us to discover the neutrino.

$$^{228}_{88}Ra \rightarrow {}^{0}_{-1}e + {}^{228}_{89}Ac$$

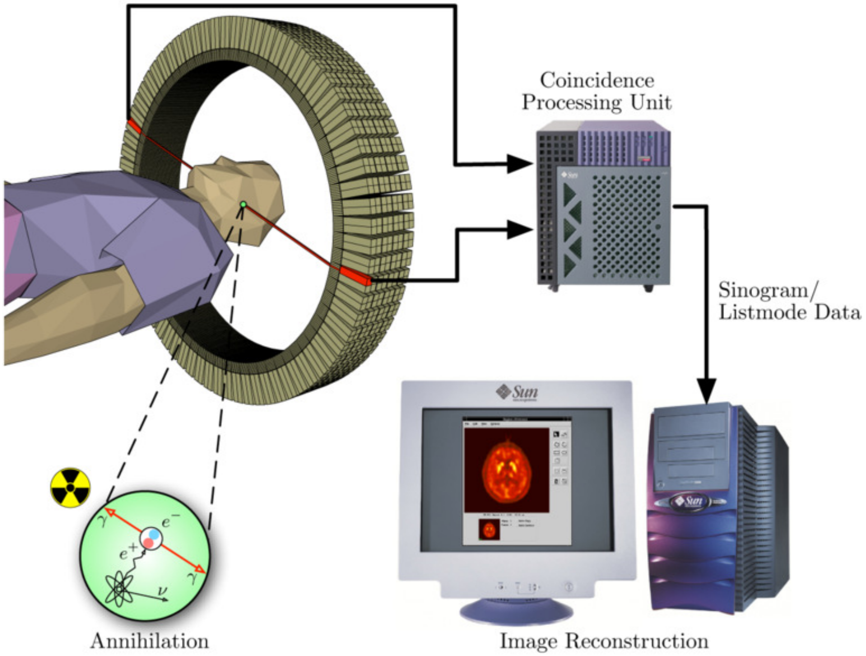
Beta Plus Decay - Positron



Isotopes which undergo this decay and thereby emit positrons include carbon-11, potassium-40, nitrogen-13, oxygen-15, fluorine-18, and iodine-121.

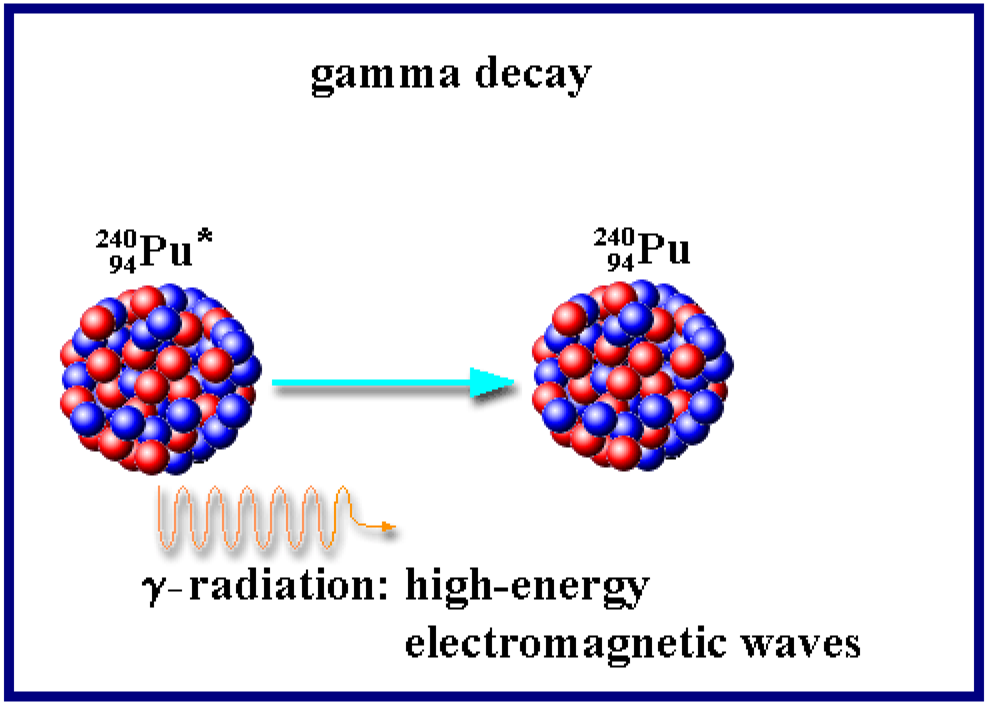
$$^{230}_{91}Pa \rightarrow ^{0}_{1}e + ^{230}_{90}Th$$

Beta Plus Decay Application - **Positron emission tomography (PET)**



Positron emission tomography (**PET**) is a nuclear medicine imaging technique which produces a three-dimensional image or picture of functional processes in the body. The system detects pairs of gamma rays emitted indirectly by a positron-emitting radionuclide (tracer), which is introduced into the body on a biologically active molecule. Images of tracer concentration in 3-dimensional space within the body are then reconstructed by computer analysis.

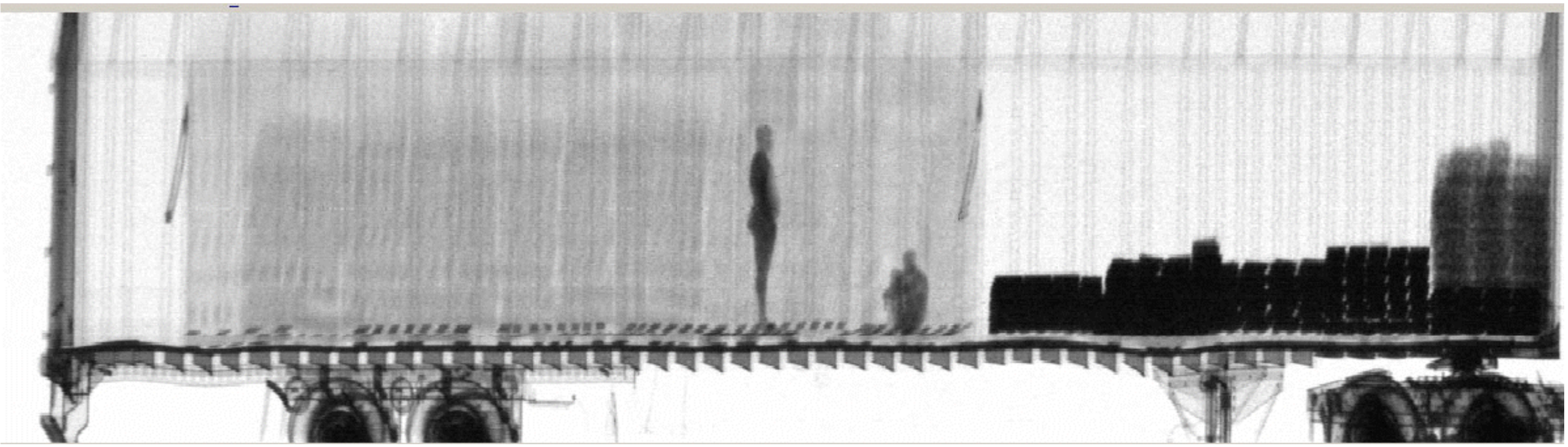
Gamma Decay



$$^{240}_{94}Pu \rightarrow ^{240}_{94}Pu + ^{0}_{0}\gamma$$

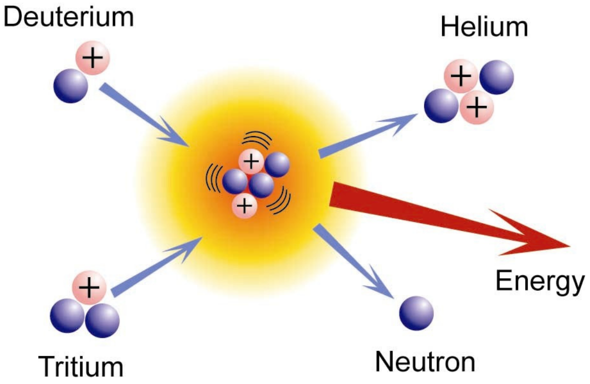
Gamma Decay Applications

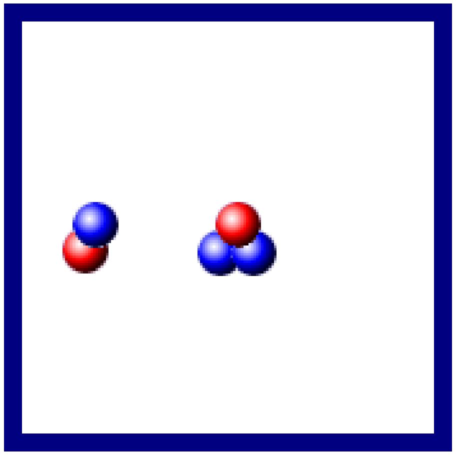
Gamma rays are the most dangerous type of radiation as they are very penetrating. They can be used to kill living organisms and sterilize medical equipment before use. They can be used in CT Scans and radiation therapy.



Gamma Rays are used to view stowaways inside of a truck. This technology is used by the Department of Homeland Security at many ports of entry to the US.

Significant Nuclear Reactions - Fusion



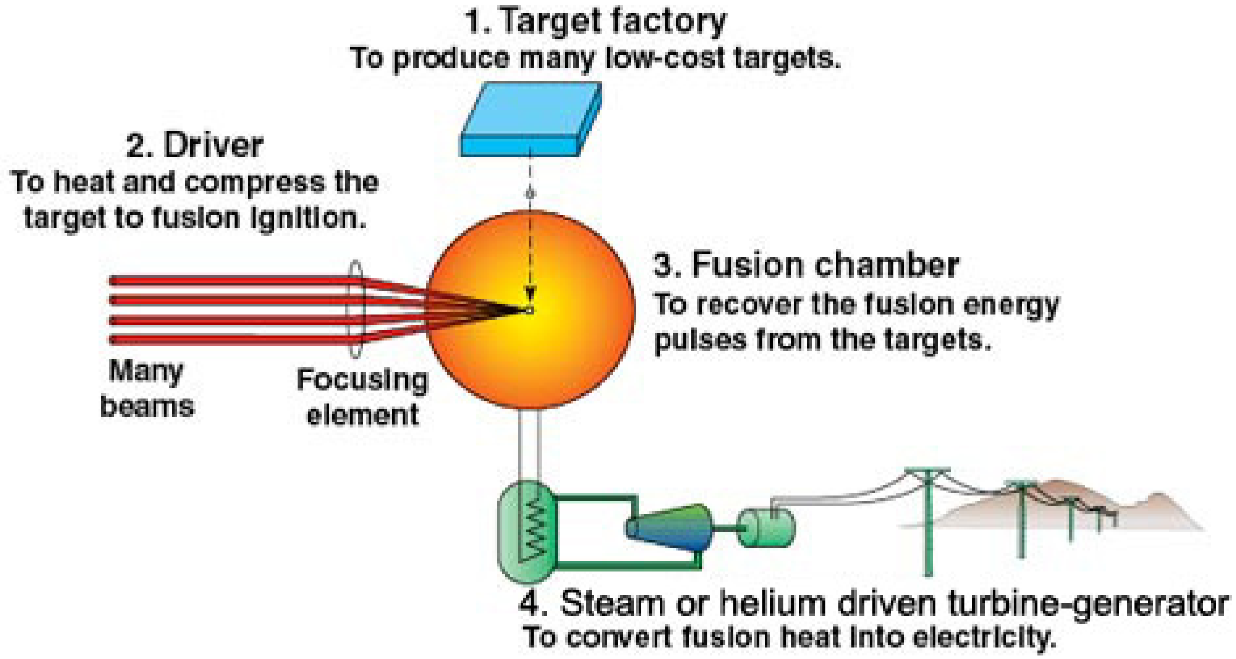


$$ {}_{1}^{2}H + {}_{1}^{3}H \rightarrow {}_{2}^{4}He + {}_{0}^{1}n $$

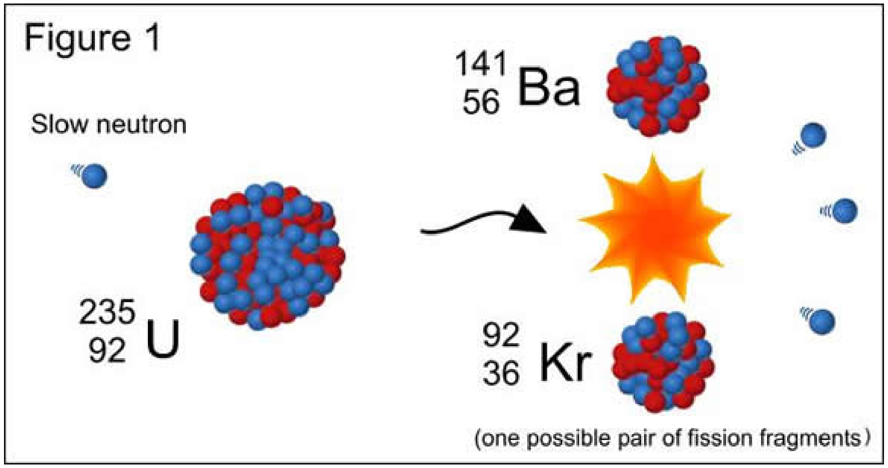
nuclear fusion is the process by which multiple like-charged atomic nuclei join together to form a heavier nucleus. It is accompanied by the release or absorption of energy.

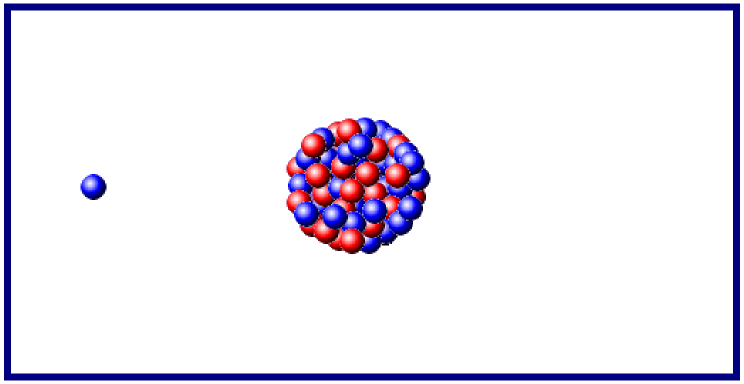
Fusion Applications - IFE

In an IFE (Inertial Fusion Energy) power plant, many (typically 5-10) pulses of fusion energy per second would heat a low-activation coolant, such as lithium-bearing liquid metals or molten salts, surrounding the fusion targets. The coolant in turn would transfer the fusion heat to a power conversion system to produce electricity.



Significant Nuclear Reactions - Fission



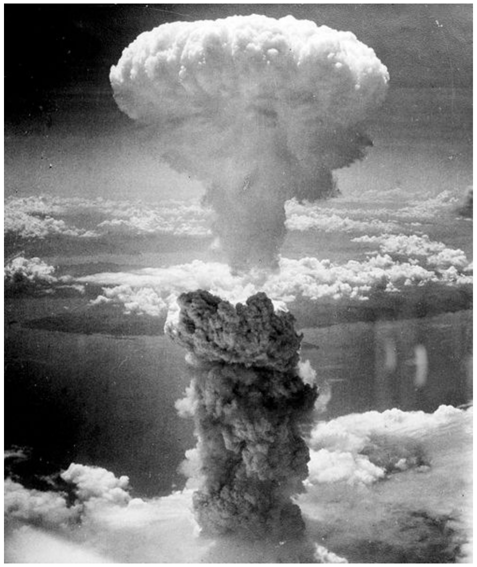


$$ {}^{1}_{0}n + {}^{235}_{92}U \rightarrow {}^{141}_{56}Ba + {}^{92}_{36}Kr + 3\,{}^{1}_{0}n + energy $$

Nuclear fission differs from other forms of radioactive decay in that it can be harnessed and controlled via a chain reaction: free neutrons released by each fission event can trigger yet more events, which in turn release more neutrons and cause more fissions. The most common nuclear fuels are 235U (the isotope of uranium with an atomic mass of 235 and of use in nuclear reactors) and 239Pu (the isotope of plutonium with an atomic mass of 239). These fuels break apart into a bimodal range of chemical elements with atomic masses centering near 95 and 135 **u** (fission products).

Fission Bomb

One class of nuclear weapon, a *fission bomb* (not to be confused with the *fusion bomb*), otherwise known as an *atomic bomb* or *atom bomb*, is a fission reactor designed to liberate as much energy as possible as rapidly as possible, before the released energy causes the reactor to explode (and the chain reaction to stop).



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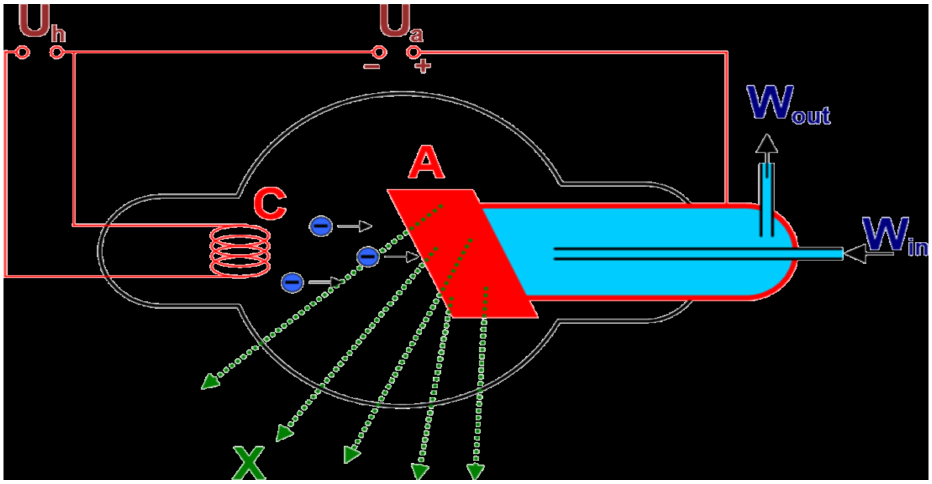
PHY 142 Lecture Note 2014/2015

X -RAYS

Discovery of X-rays

Discovered in late 1895 by a German physicist, W. C. Roentgen was working with a cathode ray tube in his laboratory. **Production of X-rays**

An X-ray tube is a vacuum tube designed to produce X-ray photons. The Crookes tube is also called a discharge tube or cold cathode tube. A schematic x-ray tube is shown below.



The glass tube is evacuated to a pressure of air, of about 100 pascals, recall that atmospheric pressure is 106 pascals. The anode is a thick metallic target; it is so made in order to quickly dissipate thermal energy that results from bombardment with the cathode rays. A high voltage, between 30 to 150 kV, is applied between the electrodes; this induces an ionization of the residual air, and thus a beam of electrons from the cathode to the anode ensues. When these electrons hit the target, they are slowed down, producing the X-rays. The X-ray photon-generating effect is generally called the Bremsstrahlung effect, a contraction of the German “brems” for braking, and “strahlung” for radiation. The radiation energy from an X-ray tube consists of discrete energies constituting a line spectrum and a continuous spectrum providing the background to the line spectrum.

Properties of X-rays

i. X-rays travel in straight lines.
ii. X-rays cannot be deflected by electric field or magnetic field.
iii. X-rays have a high penetrating power.
iv. Photographic film is blackened by X-rays.
v. Fluorescent materials glow when X-rays are directed at them.

vi. Photoelectric emission can be produced by X-rays.

vii. Ionization of a gas results when an X-ray beam is passed through it.

Continuous Spectrum

When the accelerated electrons (cathode rays) strike the metal target, they collide with electrons in the target. In such a collision part of the momentum of the incident electron is transferred to the atom of the target material, thereby losing some of its kinetic energy, ΔK. This interaction gives rise to heating of the target. The projectile electron may avoid the orbital electrons of the target element but may come sufficiently close to the nucleus of the atom and come under its influence. The loss in kinetic energy reappears as an x-ray photon. During deceleration, the electron radiates an X-ray photon of energy. $hv = \Delta K = K_f - K_i$, The resulting spectrum is continuous but with a sharp cut-off wavelength. The minimum wavelength corresponds to an incident electron losing all of its energy in a single collision and radiating it away as a single photon. If K is the kinetic energy of the incident electron, then

$$K = hv = \frac{hc}{\lambda_{min}}$$

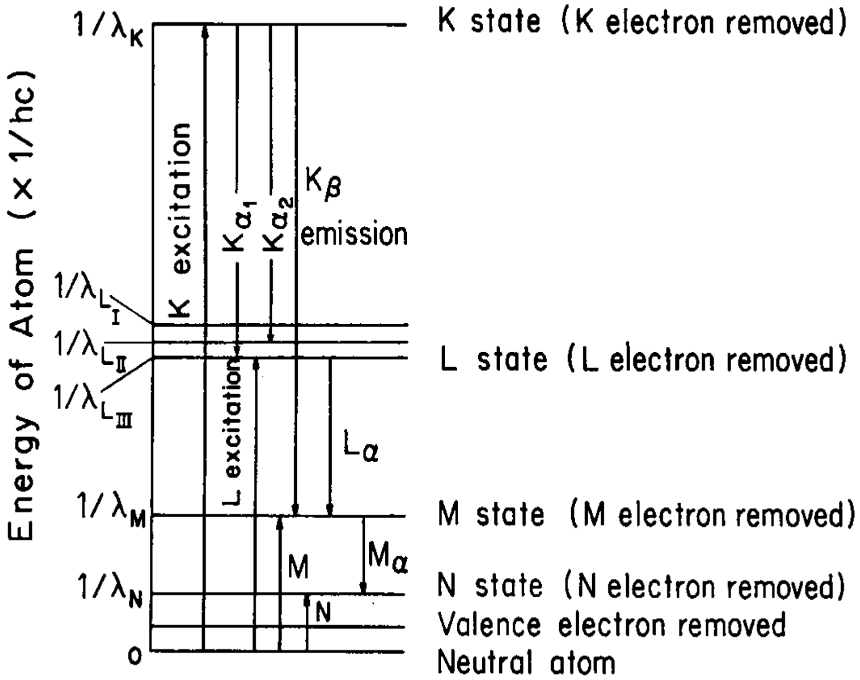
Because of the large accelerating voltage, the incident electrons can

(i) Excite electrons in the atoms of the target.

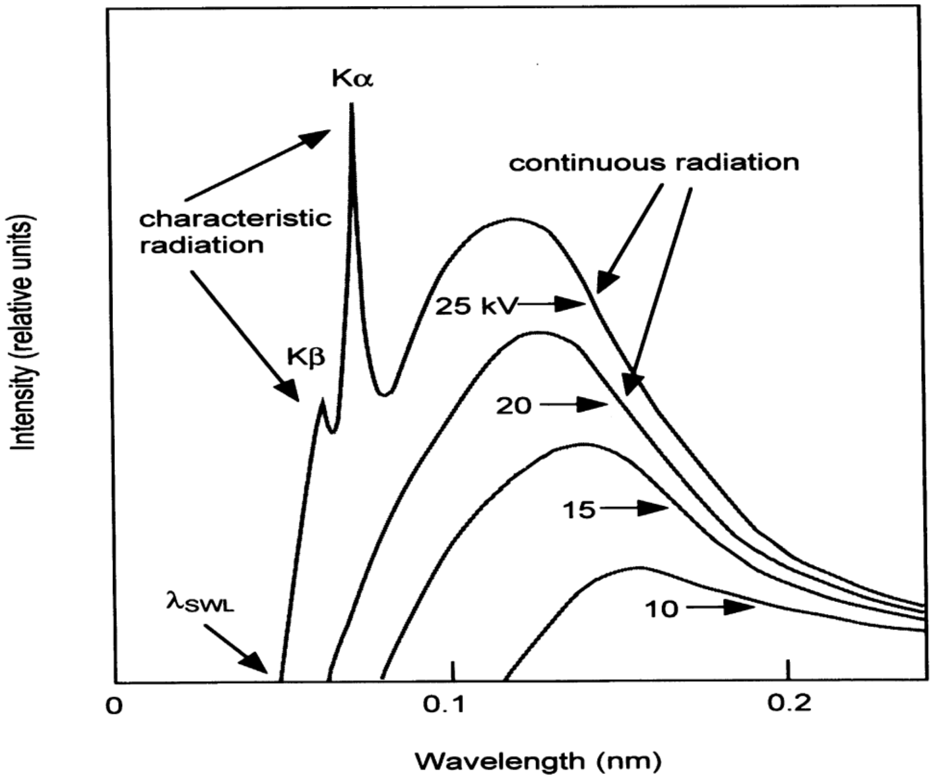
(ii) Eject tightly bound electrons from the cores of the atoms.

Characteristic X-Ray Spectrum

Excitation of electrons will give rise to emission of photons in the optical region of the electromagnetic spectrum. However when core electrons are ejected, the subsequent filling of vacant states gives rise to emitted radiation in the x-ray region of the electromagnetic spectrum. The core electrons could be from the K-, L- or M- shell. If K-shell (n=1) electrons are removed, electrons from higher energy states falling into the vacant K-shell states, produce a series of lines denoted as Kα, Kβ ,... as shown in the Figure below. Transitions to the L shell result in the L series and those to the M shell give rise to the M series, and so on. Since orbital electrons have definite energy levels, the emitted X-ray photons also have well defined energies. The emission spectrum therefore has sharp lines characteristic of the target element.



X–Ray Transitions

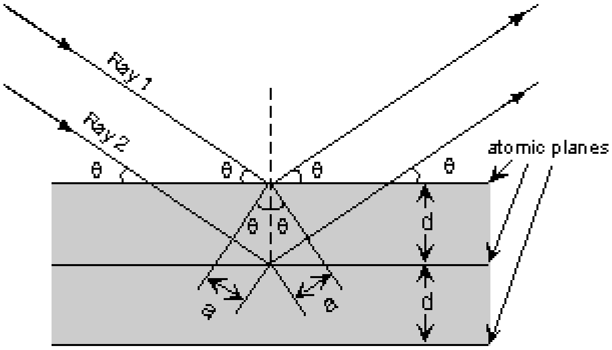


The graph shows the following features:

A continuous background of X-radiation in which the intensity varies smoothly with wavelength. The background intensity reaches a maximum value as the wavelength increases, and then the intensity falls at greater wavelengths. The minimum wavelength depends on the tube voltage. The higher the voltage the smaller the value of the minimum wavelength. The sharp peaks of the intensity distribution occur at wavelengths that is independent of the change in the tube voltage.

X-Ray Diffraction

A plane of atoms in a crystal, also called a Bragg plane, reflects X-ray radiation in exactly the same manner that light is reflected from a plane mirror. **Reflection from successive planes can interfere constructively if the path difference between two rays is equal to an integral number of wavelengths.** This statement is called Bragg’s law.



Thus, the condition for constructive interference to occur is

$n\lambda = 2a$

but, from trigonometry, we can figure out what the distance 2a is in terms of the spacing, d, between the atomic planes.

$a = d \sin \theta$

or $2a = 2 d \sin \theta$

thus, $\mathbf{n\lambda = 2d \sin \theta}$

This is known as **Bragg's Law** for X-ray diffraction.

What it says is that if we know the wavelength ,λ , of the X-rays going in to the crystal, and we can measure the angle θ of the diffracted X-rays coming out of the crystal, then we know the spacing (referred to as ***d-spacing***) between the atomic planes.

$d = n\lambda / 2 \sin \theta$

Again it is important to point out that this diffraction will only occur if the rays are in phase when they emerge, and this will only occur at the appropriate value of n (1, 2, 3, etc.) and θ.

In theory, then we could re-orient the crystal so that another atomic plane is exposed and measure the d-spacing between all atomic planes in the crystal, eventually leading us to determine the crystal structure and the size of the unit cell.

Moseley’s Experiment

The high intensity penetrating radiation emitted by X-ray tubes, characteristic of the metal from which the target anode is made, was first discovered by Barkla. Changing the metal or element from which the target anode in the X-ray tube is made alters the wavelengths at which the high intensity peaks occur. The most penetrating series in an element’s characteristic X-ray spectrum is called the K series; the second is called the L series; the third the M series and so on. Moseley carried out a systematic examination of the characteristic radiation of as many elements as possible. Moseley discovered a simple empirical relationship between the frequencies, (ν) of the lines in each series and the ordinal number, Z, of the element’s position in the periodic table (starting from hydrogen):

$$\sqrt{\nu} = b(Z-a)^2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

ν = Frequency of characteristic radiation

b = Constant which is different for different series

a = Constant known as screening constant and is different for different series

$$b = \frac{m\,e^4}{8\epsilon_0^2 h^3}\left(\frac{1}{n_2^2} - \frac{1}{n_1^2}\right),$$ n_1 and n_2 are principal quantum numbers

For K_x line, b was found to be equal to (¾)R, where R is Rydberg constant and ‘a’ was found to be practically a = 1, hence for K_α line

$$\nu_{K_\alpha} = \frac{3}{4}R(Z-1)^2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Equation (1) is known as Moseley law or Moseley equation.

The exact form of Moseley law is

$$\frac{1}{\lambda} = R(Z-\sigma)^2\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

where σ is a correction factor and n_1 and n_2 are the principal quantum numbers of the energy levels between which the transition occur.

The square root $\sqrt{\nu}$ of the frequency of an element's K line as a function of the ordinal number, N, of its position in the periodic table.

Moseley formed the opinion that some physical attribute of the atom must increase by (a) regular fixed amount, from one element to the next, rising through the periodic table. He postulated that this could only be the atom's nuclear charge.
According to this hypothesis, the number N, that is the element's ordinal position in the periodic table, is equal to the number of natural units of positive electricity carried by the nuclei of the element, i.e., N=Z . The number Z is now called the *atomic number* of the element; it is equal to the number of protons in the element's nuclei. Prior to Moseley's investigation, the elements were arranged in the periodic table in the ascending order of their atomic weights and on the basis of their chemical properties. As a result of Moseley's researches, which provided the first direct means of determining an element's atomic number, inaccuracies in the periodic table were discovered and corrected.

Example 1
Find the minimum wavelength of X-rays produced by an X-ray tube operated at 1000 kV. If $h = 6.63 \times 10^{-34}\ joules - sec,\ \ e = 1.6 \times 10^{-19}\ C\ and\ c = 3 \times 10^{8}\ m/sec$

$$\lambda_{min} = \frac{hc}{eV} = \frac{(6.63 \times 10^{-34})(3 \times 10^{8})}{(1.6 \times 10^{-19})(1000 \times 10^{3})}$$

$$= 0.01237 \times 10^{-10}\ m\ = 0.01237\text{Å}$$

Example 2
If the potential difference applied across an X-ray tube is 5kV and the current flowing through it is 2 mA, calculate

i. The number of electrons striking the target per second
ii. The speed at which they strike

Solution

i. $I = ne$, where n is the number of electrons striking the anode per second.

$$n = \frac{I}{e} = \frac{2 \times 10^{-3}}{1.6 \times 10^{-19}} = 1.25 \times 10^{16}\ electrons$$

ii. If v is the velocity of striking electrons

$$\frac{1}{2}mv^2 = eV$$

$$\sqrt{\left\{\frac{2 \times (1.6 \times 10^{-19}) \times (50 \times 10^3)}{9.1 \times 10^{-31}}\right\}} = 4.2 \times 10^7 ms^{-1}$$

Example 3

The spacing between the principal planes of a NaCl crystal is 2.82 Å. It is found that the first order Bragg reflection occur at an angle of 10˚. Calculate the wavelength of X-rays.

Solution:

According to Bragg"s law

$$2d \sin\theta = n\lambda$$

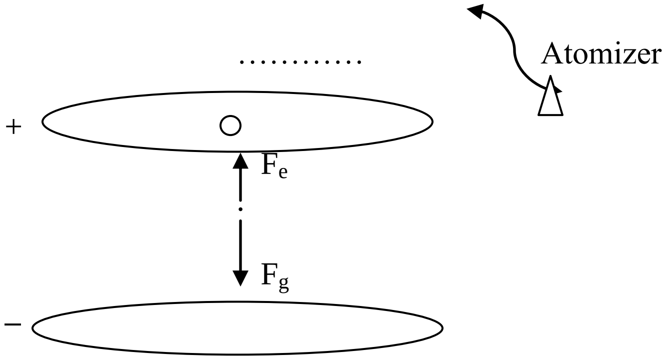
$$\lambda = \frac{2d \sin\theta}{n} = \frac{2 \times (2.82 \times 10^{-10}) \times \sin 10^{\circ}}{1}$$

$$\lambda = 0.98 \times 10^{-10} m = 0.98\text{Å}$$

Millikan's Oil-Drop Experiment

In 1909 Robert A. Millikan came up with an experiment to measure the charge on an electron, called the Oil Drop Experiment.

The apparatus was actually quite simple. There were two parallel plates set at a specific distance apart with a known voltage between them. That way we know the electric field strength. The top plate is positive, and the bottom plate is negative. Millikan drilled a very small hole in the center of the top plate. He then used an atomizer to spray very fine drops of mineral oil over the top plate. An atomizer is like those fancy perfume bottles you see that have a ball you squeeze to make the perfume spray out. Friction between the nozzle of the atomizer and the mineral oil droplets caused some of the drops to gain a small charge (charging by friction).



Illustrating the Milikan"s Oil Drop Experiment

Just by chance, some of the oil drops might fall down the hole in the top plate. If they have a positive charge, we expect them to go accelerating down to the negative plate and crash into it. If they have a negative charge, something different might happen. If the force due to gravity (Fg) pulling the drop down is exactly balanced by the electric force (Fe) pushing it up, the drop should float between the two plates. Since the force due to the electric field and the force due to gravity are balanced, it is possible to derive an equation to calculate the charge on the droplet.

$$F_e = F_g, \qquad qE = mg, \qquad q\frac{V}{d} = mg, \qquad q = \frac{mgd}{V}$$

q is the charge, m is mass of oil droplet, g is acceleration due to gravity, d is distance between plates and V is the voltage.

After thousands of trials, Millikan had enough successful trials to show that all of the charges he calculated were multiples of one number, $1.6 \times 10^{-19} C$.

Example

An oil drop in a Millikan apparatus is determined to have a mass of 3.3e-15 kg. It is observed to float between two parallel plates separated by a distance of 0.95cm with 340V of potential difference between them. Determine how many excess (extra) electrons are on the drop.

$$q = \frac{mgd}{V} = \frac{3.3 \times 10^{-15} \times 9.8 \times 0.0095}{340}$$

$$q = 9.0 \times 10^{-19} C$$

.

$$\text{Number of charges} = \frac{9.0 \times 10^{-19} C}{1.6 \times 10^{-19} electrons} = 5.65337316\ electrons$$

PHY142

Constants: Planck's constant h = 6.6×10^{-34} Js
Speed of light= 3×10^{8} m/s
Electron charge = 1.6×10^{-19} C.
Mass of electron = 9.1×10^{-31} kg
$M_e = 9.109390 \times 10^{-31}$ Kg
$M_p = 1.672623 \times 10^{-27}$Kg
$M_n = 1.674929 \times 10^{-27}$Kg
1eV = 1.60×10^{-19} J
Ryberg Constant R = $1.097 \times 10^{7} m^{-1}$

1 Wave-particle duality theory implies that:
A Light wave can diffract and scatter.
B Light wave can effect Compton effect
C *Light wave can undergo interference and cause photoemission of electrons on a metal.
D Light wave can be seen as a particle and as well effect photoelectric effect.

2 Compton effect obtained when X-rays are scattered by a plane of lattice electrons Implies:
A Radiation absorption.
B *Particle nature of electromagnetic waves.
C X-rays control.
D Crystallographic application of X-rays.

3 An entity exhibits particle nature by possessing:
A Energy and wavelength.
B Momentum and frequency.
C *Energy and momentum.
D Wavelength and frequency.

4 Calculate the mass of a de Broglie's particle traveling at a speed of 30m/s with wavelength 1.49×10^{-26} nm:
A 0.43×10^{-3} kg.
B *0.15 kg.
C 0.35×10^{-3} kg.
D 0.96 kg.

5 Bohr proved electrons as a particle while Schrödinger proved it as a wave. The two ideas can be combined and represented as:
A Angular momentum =h/mv
B *Angular momentum =nh/2π
C Angular momentum = nλ/2π
D Angular momentum = 2 π r/n

6 Calculate the wavelength of the electron-wave for electrons fixed round an orbit whose diameter is 1.2 nm if 24 complete waves are formed round the orbit:
A *1.6×10^{-10} m
B 3.4×10^{-12} m
C 4.3×10^{-10} m
D 9.6×10^{-12} m

7 'HARD' X-rays can be produced by:
A. Increasing the cathode temperature.
B Altering the accelerating voltage
C Evacuating the tube completely.
D *Making the electrons move faster

8 All of these are components in X-ray production tube except:
A. Concave cathode, Lead shield, Lead anode.
B X-ray window, cooling fins, hot cathode.
C Accelerating voltage, Electron beam, Low melting point target metal.
D *A and C.

9 The following are the properties of X- rays except:
A. They are not deflected by electric fields.
B. *'Soft' X-rays can pass through human skull.
C. They can be used to discharge gold-leaf electroscope.
D. They can release photoelectrons.

10 Reflection of X-rays that fell on two electron planes separated by distance 3.1×10^{-10} m were obtained. Calculate Bragg's glancing angle, if the total path difference between the reflected waves from the two planes is 6.2×10^{-10} m.

A 60° B 45° C 73° D*90°

11 Calculate the wavelength of X-rays emitted when electrons accelerated through 30kV strike a target, given that charge electron

A. *4.1 x 10^{-11} m B.17.11 x 10^{-10}m C. 0.5 x 10^{-11}m D. 5.7 x 10^{-10} m.

12 What is the minimum potential difference between the cathode and anode of an X-ray tube if rays of wavelength 0.05nm where produced

A 16 kV B 45 kV C* 25 kV D 99 kV

13 Calculate the thickness of the patient's skin if 40% of the incident X-rays were absorbed by his flesh, let absorption coefficient be 2 units.

A 0.53m B* 0.30m C 27 cm. D 1.2 cm.

14 Diode valve works on principle of :

A. Photoemission B*. Thermionic emission. C. Compton scattering.

D. Electron drifting.

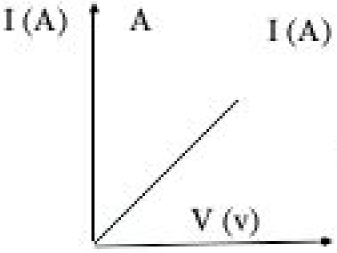
15 If sodium surface in a vacuum is illuminated with 200 nm wavelength beam. Calculate the maximum velocity of the photoelectrons released [Take work function of sodium to be 2.0 x 10^{-19} J.}

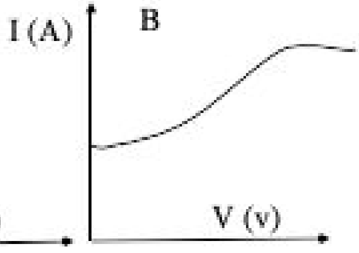
A. 19.2 x 10^{8} m/s , B. 4.7 x 10^{6} m/s , C .*16.0 x 10^{7} m/s, D .1.9 x 10^{6} m/s .

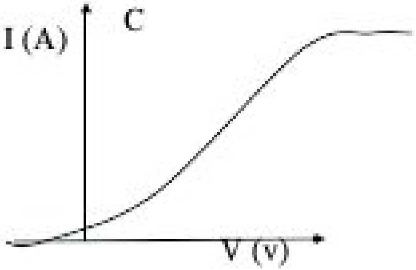
16 . The major use of diode valve is for:

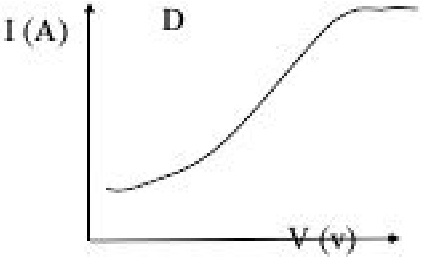
A *Rectification B Amplification C Filtering D Modification.

17. The appropriate characteristics curve for diode valve's I/V curve in the absence of External high tension potential is









18 The major impression of Moseley's law pertaining the line spectra obtained during the production of X-rays holds that:

A The frequency of the line is proportional to the X-ray intensity.

B The frequency of the line is smaller for atom with one atomic number, than for those with higher atomic numbers.

C The frequency of the line is proportional to the wavelength of the X-rays

D The frequency of the line reduces time.

19 All of these are correct about photoelectric emission except:

A No emission if work function and photon energy are equal.

B High work function makes the photoelectrons to move faster.

C A and B.

D Excess energy of photon serves as kinetic energy for the photoelectrons to move.

20 Calculate threshold frequency in a photoelectric emission process if a photon of 1.6 x 10^{-19} J released an electron to move with velocity of 2.4 x 10^{5} m/s

A. 1.4 x 10^{15} Hz B 9.1 x 10^{-18} Hz C 4.1 x 10^{-17} Hz D 2.0 x 10^{14} Hz

21 If ΔE, Δx and Δp are the smallest uncertainty measurements within the smallest uncertainty time Δt, in energy, position and momentum the uncertainty principle can be stated as:

A. $\Delta E. \Delta x = h/2\pi$
B. $\Delta p. \Delta E = h/2\pi$
C. $\Delta p. \Delta x = h/2\pi$
D. $\Delta t. \Delta x = h/2\pi$

22 All of these are instances when an entity behaves like a particle:

A Compton effect and diffraction.
B Photoelectric effect and refraction.
C X-Ray production and interference.
D Photoemission and Compton effect.

23 A Photon of 1.6×10^{-19} J did a work of 0.3×10^{-19} J to free an electron whose mass is 9.1×10^{-31} Kg. Calculate the velocity of the electron after been released.

A 5.3×10^{5} m/s B 60.1×10^{5} m/s C 9.2×10^{5} m/s D 1.12×10^{5} m/s

24 One of the following is not a proper use of X-rays:

A Crystallographic study
B Identification of alteration made on artistic works
C Mapping the internal organ such as bone marrow in human body
D to analyze the internal organ of metal machines

25 Current dies down in a working diode value, without an accelerating potential, because:

A Anode is shielded.
B Of the presence of space charge
C Temperature of the cathode reduces.
D Diode values usually have short life span.

26 Which of the following is not true of J.J Thomson model of atom?

a. There is a central nucleus in which protons are bound

b. Positive charges are spread throughout the atom forming a kind of paste in which electrons are suspended

c. Electrons move around the nucleus randomly.

d. Electron occupy only discrete shells

27 In Ernest Rutherford experiment

a. Alpha particles were bombarded by gold particles

b. No alpha particles were deflected

c. All alpha particles were deflected

d. Atoms of gold were bombarded with alpha particles

28 According to Ernest Rutherford

a. Electrons are concentrated at the centre of the atom

b. Electrons are occupying different orbits or energy levels

c. Electrons revolve randomly around the nucleus

d. Electrons maintain their fixed position around the nucleus

29 The shortest wavelength of the Balmer's series is obtained when n is

a. 0

b. 1

c. 2

d. 3

30 Which of the following represents the wavelength of the Paschen series

a. $1/\ \ = R(1/3^2 - 1/n^2)$

b. $1/\ \ = R(1/2^2 - 1/n^2)$

c. $1/\ \ = R(1/1^2 - 1/n^2)$

d. $1/\ \ = R(1/0^2 - 1/n^2)$

31 An atom is assumed to have zero energy in the ground state and its energy in the first, second and third excited states are 1.635×10^{18}J, 1.93×10^{18}J and 2.024×10^{18}J respectively. What is the wavelength of the photon which would excite the atom from the first excited state to the second excited state?

a. 6.61×10^{7}m

b. 4.24×10^{7}m

c. 3.24×10^{7}m

d. 3.0×10^{7}m

32 A blue line of wavelength 5.17×10^{7}m is observed in the spectrum of the atom in question 6 above. The transition between which energy levels will give rise to the spectral line?

a. E2 to E3

b. E3 to E4

c. E3 to E4

d. E4 to E2

33 The longest and the shortest wavelength of the Balmer's are

a. 365nm, 656nm

b. 656nm, 365nm

c. 823nm, 109nm

d. 109nm, 823nm

34 Which of the following is true of Bohr's model of hydrogen atom

a. The total energy of the atom is positive

b. The total energy is dependent on the radius of orbit

c. No force is exerted on electrons inside an orbit

d. Total energy is independent of the radius

35 Bohr model does not apply where more than one electron are present in an orbit round the nucleus because

a. The model does not account for the electrostatic forces that electrons exert on each other

b. The energy of such atoms does not follow simple theory

c. The idea of photon and quanta do not apply to such atoms

d. The number of orbit will be more than one

36 What is the energy of the second excited state of hydrogen

a. -13.6eV

b. -3.40eV

c. -15.6eV`

d. +13.6eV

37 The line spectrum emitted by atomic hydrogen when electrons transit from high energy levels to the third excited state is called

a. Paschen series

b. Balmer's series

c. Lyman series

d. Bracket series

38 Determine the wavelength that correspond to the transition from ni = 6 to nf =4

a. 4050nm

b. 2629nm

c. 1050nm

d. 3050nm

39 The difference between spontaneous emission and stimulated emission is that

a. Spontaneous emission is a sum of both stimulated emission term and spontaneous emission

b. Spontaneous emission is self emission which does not need external photon

c. Stimulated emission does not need external photon

d. Stimulated emission occurs when electrons move lower energy to higher energy

40 In the production of cathode rays using photoelectric effect, the most important part in the discharge tube is

a. Cathode space

b. The bright region

c. Faraday dark region

d. The positive column

41 Cathode rays are produced in the discharge tube when voltages between the plates is increased by means of

a. Break down

b. Acceleration

c. Collision

d. Saturation

42 A beam of electrons moving with a velocity of 1.0 x 10^7 m/s enters midway between two horizontal parallel plates P and Q in a direction parallel to the plates. P and Q are 5cm long and 2cm apart and have a potential difference V applied between them. Calculate V, if the beam is deflected so that it just grazes the edge of the low plate Q (assume e/m = 1.8 x 10^{11} C/Kg).

a. 17.8V

b. 44.5V

c. 89.0V

d. 178.0V

43 What is the grazing angle of the beam of electrons moving with a velocity of 1.0 x 10^7 m/s entering midway between two horizontal parallel plates P and Q in a direction parallel to the plates. P and Q are 5cm long and 2cm apart and have a potential difference V applied between them

a. 5.71

b. 11.0

c. 2.89

d. 16.3

44 Proton with a charge - mass ratio of 1.0×10^8 c/kg is rotated in a circular orbit of radius r when they enter a uniform magnetic field of 0.5T. Calculate the number of revolutions.

a. 2×10^6Hz

b. 4×10^6Hz

c. 6×10^6Hz

d. 8×10^6Hz

45 The path of a beam of electrons in an electric field is

a. Circle

b. Spiral

c. Parabola

d. Ellipse

46 The maximum wavelength of light that can produce photoelectrons from sodium is 650nm. What is the work function of sodium?
a. 3.05×10^{-17}J
b. 3.06×10^{-26}J
c. 4.31×10^{-10}J
d. 6.50×10^{-9}J

47 The maximum wavelength of light that can produce photoelectrons from sodium is 650nm. If light of wavelength 436nm is used to illuminate a sodium surface in a vacuum, what is the maximum K.E of the photoelectrons?
a. 4.25×10^{-25}J
b. 1.42×10^{-40}J
c. 1.50×10^{-19}J
d. 3.06×10^{-19}J

48 When a metal is illuminated by monochromatic radiation of wavelength 248nm, the maximum kinetic energy of photoelectrons emitted is found to be 8.6×10^{-20}J. Calculate the work function of the metal.
a. -8.599×10^{-20} J
b. 7.16×10^{-19}J
c. -8.58×10^{-20}J
d. 1.72×10^{-19}J

49 Which of the following is the failure associated with the Rutherford's model of the atom.
a. atoms are not electrically neutral
b. electrons can only move round the proton in elliptical orbits
c. the charges are evenly distributed
d. electron will spiral into the proton which is at the center of the nucleus

50 If the energy levels E_n is related to the principal quantum number "n" by $E_n = -13.6\text{eV}/n^2$, calculate the ionization energy of the hydrogen atom.
a. -13.6eV
b. 13.6eV
c. 0eV
d. -27.2eV

51 X-rays of wavelength 1.5 x10-10m is incident on a crystal and it gives a third order diffraction for a glancing angle of 600. What is the separation of the layers of atoms in the crystal?
a. 2.46×10^{-10}m
b. 1.23×10^{-10}m
c. 7.38×10^{-10}m
d. 4.65×10^7m

52 Which of the following does account for the failure of the Bohr model of atom

- a. it is not intellectually satisfactory
- b. it could not explain the observed fine structure of the atomic spectra
- c. it only explains the single electron atoms
- d. it could not explain the observed atomic spectra

53 The potential difference between the target and cathode of an xs-ray tube is 20KV and the current is 20mA. Only 5% of the total energy supplied is emitted as x-rays. What is the minimum wavelength of the x-ray emitted?.

- a. 6.19×10^{-11}m
- b. 3.87×10^{8}m
- c. 3.22×10^{-10}m
- d. 27.22×10^{1}m

54 Calculate the velocity of electrons accelerated from rest to a target in hot cathode vacuum tube by a potential difference of 25V.

- a. 2.98×10^{6}m/s
- b. 3.98×10^{6}m/s
- c. 2.98×10^{5}m/s
- d. 4.44×10^{5}m/s

55 Electrons moving with a constant velocity enter a uniform magnetic field B in a direction perpendicular to B. The path of the electrons in the field is

- a. a helix
- b. a straight line parallel to B
- c. a straight line perpendicular to B
- d. a circle

56 Calculate the De Broglie wavelength of a 0.01kg material having a velocity 0f 10m/s

- a. 6.63×10^{-23}m
- b. 6.63×10^{-33}m
- c. 6.63×10^{-26}m
- d. 6.63×10^{-10}m

57 The wavelength of the spectral line in the hydrogen spectrum are given empirically by $1/\lambda_{nm} = R(1/n^2 - 1/m^2)$ where $R = 1.097 \times 10^7$/m and n and m are integers. Calculate the wavelength of H_β in the Balmer's series.

- a. 4.00×10^{-7}m
- b. 4.86×10^{-7}m
- c. 1.37×10^{-6}m
- d. 7.30×10^{-7}m

58 Which of the following is a correct statement of Milikan's famous experimental results?

- a. electron is a common constituent of all matter
- b. all charges are integral multiple of a discrete electronic charge
- c. electron can be deflected by both the electric and magnetic field
- d. electronic - mass ratio is constant

59 A radioactive source contains 1.0 x 10-6g of platinum239. It is estimated that this source emits 2300 alpha particles per second. Calculate the T1/2 of platinum.

- a. *7.59×10^{11}s
- b. 7.50×10^{11}s
- c. 8.00×10^{11}s
- d. 8.59×10^{11}s

60 Deuterium is represented by the symbol ${}^2H_1$. What nucleons constitute its nucleus?

- a. *one proton, one neutron
- b. two protons, two neutrons
- c. two protons, one neutron
- d. one proton, two neutrons

61 Calculate the nuclear binding energy of deuterium ${}^2H_1$ given that mass of one atom of deuterium is 2.01410mu, mass of one hydrogen atom is 1.00788mu and rest mass of a neutron is 1.00867mu. ($1mu = 1.66 \times 10^{-27}$kg).

- a. 1.749MeV
- b. *2.747MeV
- c. 3.247Mev
- d. 4.000Mev

62 In an x-ray tube, electrons each of charge q are accelerated through a potential difference V and then strike a metal target. If h is Planck's constant and c is the speed of light, what is the minimum wavelength of the x-ray produced?

a. h/c
b. hf/c
c. *hc/qV
d. hf/V

63 Calculate the minimum wavelength of the x-ray produced of electrons on the screen of a television set where the accelerating potential is 20KV.

a. 1.551×10^{-19}m
b. 1.260×10^{-26}m
c. 0.995×10^{-29}m
d. *0.095×10^{-19}m

64. Calculate the energy and momentum of a photon of light of wavelength 500nm.

(a) . 6.63×10^{-17}J, 1.330×10^{-25}kgm/s
(b) 2.98×10^{-19}J, 0.133×10^{-25}kgm/s
(c) *3.98×10^{-19}J, 0.013×10^{-25}kgm/s
(d) 4.00×10^{-19}J, 1.330×10^{-25}kgm/s

65. If the fission of an atom of ^{235}U yields energy of 200MeV, how much energy would be released by the fission of 1g of ^{235}U?

(a) *8.20×10^{10}J
(b) 8.20×10^{6}J
(c) 8.2×10^{10}J
(d) 8.2×10^{-6}J

66 The most abundant isotope of helium has a $^{4}_{2}$He nucleus whose mass is 6.6447×10^{-27} kg. For this nucleus, find the mass defect Δm.

(a) 0.0620×10^{-27}kg
(b) *0.0503×10^{-27} kg
(c) 0.0412×10^{-27} kg
(d) 0.0205×10^{-27} kg.

67 The most abundant isotope of helium has a $^{4}_{2}$He nucleus whose mass is 6.6447×10^{-27} kg. For this nucleus , find the binding energy of the nucleus

(a) *28.3 MeV
(b) 26.4 MeV
(c) 27.2 MeV
(d) 30.0 MeV

68 Determine the energy released when $^{238}_{92}$U decays into $^{234}_{90}$Th.

$^{238}_{92}$U = 238.0508u

$^{234}_{90}$Th = 234.0436u

$^{4}_{2}$He = 4.0026u

1u = 931.5 MeV.

(a) 7.8 MeV (b) 2.8 MeV (c) 5.6 MeV (d) *4.3 MeV.

69 When Uranium $^{238}_{92}$U is decays to Thorium $^{234}_{90}$Th a gamma ray of 0.0496 MeV is also emitted. What is the wavelength of the emitted gamma ray

(a) 4.3×10^{-11}m
(b) 3.66×10^{-11}m
(c) *2.51×10^{-11}m
(d) 1.21×10^{-11}m

70 Radon $^{222}_{86}$Rn was produced when radium $^{226}_{88}$Ra undergoes α – decay. Suppose 3.0×10^{7} radon atoms are trapped and the half-life of radon is 3.83 days. How many radon atoms remain after 31 days.

(a) 4.2×10^{5} (b)* 1.1×10^{5} (c) 2.3×10^{5} (d) 3.0×10^{5} .

71 Radon $^{222}_{86}Rn$ was produced when radium $^{226}_{88}Ra$ undergoes α – decay. Suppose 3.0×10^7 radon atoms are trapped. The half-life of radon is 3.83 days. Find the activity for element (a*) 63Bq

(b) 50Bq (c) 45Bq (d) 70Bq.

72 A $^{14}_{6}C$ activity of about 0.18 Bq per gram of carbon was measured on a scroll. Determine the age of the scroll, If activity $A_0 = 0.23$Bq and the half life is 730years.

(a) 4.0×10^3yr (b) 3.0×10^3yr (c) *2.0×10^3yr (d) 1.0×10^3yr.

73. A device that can be used to detect α , β and γ rays is

(a) *Geiger counter (b) Newton counter (c) Thompson counter (d) Compton counter.

74. What is the wavelength of the 0.186 MeV γ – ray that is emitted by radium $^{226}_{88}Ra$.

(a) 5.72×10^{-12}m
(b) 4.68×10^{-12}m
(c) * 6.68×10^{-12}m
(d) 7.11×10^{-12}

75. Determine the symbol $^{A}_{Z}X$ for the parent nucleus whose α – decay produces the same daughter as the β^- decay of thallium $^{208}_{81}Tl$.

(a) $^{210}_{76}Po$
(b) $^{210}_{81}Po$
(c) $^{214}_{85}Po$
(d) $^{212}_{84}Po$

76 What is the binding energy (in MeV) for oxygen $^{16}_{8}O$,atomic mass = 15.994915u.

(a) 127.6 MeV (b) 125 MeV (c) 123.6 MeV (d) 120.6 MeV.

77 Nuclei that contain the same number of protons but a different number of Neutrons are known as

(a) Isotopes (b) Allotropes (c) Nucleons (d) Positive Particles

78 The total number of protons and neutron is referred to as

a. Atomic Volume
b. Atomic Counting
c. Atomic Summation
d. Atomic mass number.

79 The spontaneous disintegration of unstable nucleus of an element is called

(a) Instability (b) Breaking effect (c) Radioactivity (d) Solidification.

80 The following particles and/or high energy photons are released when an Unstable nucleus disintegrate

(i) Alpha rays (ii) Beta rays (iii) Neutron ray (iv) Gamma ray.

(a) i , ii and iv (b) i, ii and iii (c) i and iv only (d) iv only.

81. A stable nucleus requires certain energy to separate its proton and neutron. This energy is called

(a) Binding energy (b) Fission energy (c) Potential energy (d) Threshold energy.

82 The process of α-decay for which Uranium $^{238}_{92}U$ parents is converted into the $^{234}_{90}Th$ daughter is known as

(a) Transformation (b) Translation (c) Transmutation (d) Tranfiguration

83. Nuclides having the same number of neutron N but a different atomic number Z and therefore a different mass number A are called

(a) Isotones (b) Isotopes (c) Isobars (d) Entropid

84. Nuclides which have the same total number of nucleons but which differ in atomic number Z and also in neutron number N called.

(a) Isotones (b) Isotopes (c) Isobars (d) Allotropes

85. Calculate the nuclear radius of a nucleus with mass number 4. Given that $R_o = 1.4 \times 10^{-15}$m

(a) 2.22×10^{-15}m (b) 1.62×10^{-15}m (c) 2.78×10^{-15}m (d) 1.04×10^{-15}m

86. The atomic mass unit (amu) used in expressing the masses of nuclei is

a) One tenth of the mass of the ${}^{12}C$ atom
b) One fifth of the mass of the ${}^{12}C$ atom
c) One twelfth of the mass of the ${}^{12}C$ atom
(d) One third of the mass of the ${}^{12}C$ atom

87. If one atomic mass unit (1amu) is 1.66×10^{-27}kg. Calculate the energy equivalence of this mass.

(a) 933.7MeV (b) 683.2 MeV (c) 999.1 MeV (d) 709.3 MeV

88. The binding energy of ${}^{35}_{11}Cl$ is 280 MeV. Find its mass in atomic mass unit (amu). Given that 1 amu = 931 MeV

(a) 0.15 amu (b) 0.30 amu (c) 0.52 amu (d) 0.46 amu

89. The fission of a uranium nucleus by a neutron produces lanthanum and bromine nuclei according to the equation. Given that

$${}^{235}_{92}U = 235.12, \quad {}^{85}_{35}Br = 84.84 \quad {}^{148}_{57}La = 147.96 \quad {}^{1}_{0}n = 1.009$$

$${}^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{148}_{57}La + {}^{85}_{35}Br + 3\,{}^{1}_{0}n + Q$$

Calculate the energy released

(a) 200 MeV (b) 180 MeV (c) 230 MeV (d) 218 MeV

90. Deutron and tritium fused to form a helium nucleus according to the relation

$${}^{2}_{1}H + {}^{3}_{1}H \rightarrow {}^{4}_{2}He + {}^{1}_{0}n + Q$$

Calculate the energy released.

Rest masses in amu are ${}^{1}_{0}n = 1.009 \quad {}^{2}_{1}H = 2.015 \quad {}^{4}_{2}He = 4.004 \quad {}^{3}_{1}H = 3.017$

(a) 15.0 MeV (b) 17.7 Mev (c) 12.7 MeV (d) 20.2 MeV

91. If the half - life of a sample of radioactive material is 60 days, what fraction of the original radioactive nuclei will remain after 120 days.

(a) $\frac{1}{4}$ (b) $\frac{1}{2}$ (c) $\frac{1}{3}$ (d) $\frac{2}{5}$

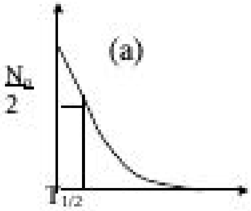
92. A radioactive material has a half-life of 14 hours. How much of 100 of the isotope will be left after 42 hours and what time has elapsed when 6.25g of the 100g are left.

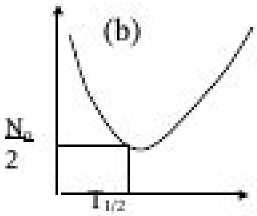
(a) 25g, 60 h (b) 50g, 70h (c) 12.5g, 56h (d) 6.25g, 49h

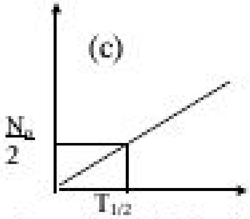
93. A counter positioned close to an α – particle emitter reads 200 per second and this reduced to 50 per second in 720 seconds. Determine the half life of the source.

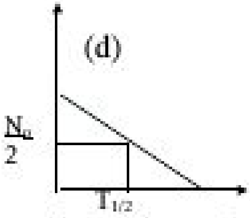
(a) 9 minutes (b) 6 minutes (c) 10 minutes (d) 12 minutes

94. Which of the following is the graphical representation of exponential decay and half life period of a radioactive material.









95. In a Millikan experiment, a charged droplet of mass 1.8×10^{-15}kg just remains stationary when the potential difference between the plates, which are 12mm a apart is 150V. If the droplet suddenly gains an extra electron, calculate the initial acceleration of the droplet.

(a) 2.31 m5^{-2} (b) 3.00 m5^{-2} (c) 2.60 m5^{-2} (d) 1.11 m5^{-2}

96. In a Milikan experiment, a charged droplet of mass 1.8×10^{-15}kg just remains stationary when the potential difference between the plates, which are 12mm apart, is 150V. If the droplet suddenly gains an extra electron, find the voltage needed to bring the droplet to rest again

(a) 120 V (b) 135 V (c) 110 V (d) 250V

97. The primary uses of the Cathode ray oscilloscope (CRO) are to measure the following except

(a) Voltage (b) Frequency (c) Phase (d) Mass

98. Which of the following is not a feature of the Cathode ray Oscilloscope?

(a) Cooling compartment
(b) Heated cathode to produce a beam of electron
(c) Accelerating anode
(d) Fluorescent Screen

99. Which of the following is incorrect

a) α – particle is slightly deflected by magnetic and Electric field and positively charged.

b) α – particle is slightly deflected and β – particle is greatly deflected but both are negatively charged

c) β – particle is greatly deflected by magnetic and Electric field and negatively charged

d) γ-ray is unaffected by magnetic and Electric field and uncharged.

100. Natural Radioactive decay rate depends on

(a) Number of nuclei available to disintegrate

(b) Temperature of the nuclei

c) Time of the day

(d) Location of the nuclei on the planet.

101. The following are the advantages of Fusion over Fission except

(a) Easily achieved with light test elements

(b) By - product are non-radioactive

(c) Raw materials are cheaply available

(d) Very high temperature is required

102. Radiation from radio Isotopes is useful in

(a) Radiotherapy

(b) Earth digging

(c) Archaeological dating

(d) Thickness gauging

103. Calculate the count rate produced by 0.1μg of caesium 137, if the half life of Cs137 is 8.83 x 10^8s.

(a) 3.45 x 105βq (b) 2.20 x 105βq (c) 1.66 x 105β (d) 4.12 x 105βq

104. In an archaeological site a piece of bone is found to give a count rate of 15 counts per minute. A similar sample of fresh bone gives a count rate of 19 counts per minute. Calculate the age of the specimen.

(a) 1789 yrs (b) 1566 yrs (c) 1897 yrs (d) 2011 yrs

105. The three types of radiation from radioactive decay process are
(i) α, β and λ radiation (ii) α, β and γ radiation (iii) α, β and ν radiation

(a) i only (b) i or iii (c) ii only (d) None of the above

106 Determine the velocity of a de Broglie's particle whose mass and wavelength are 0.15 kg and 1.49x10^{-20} nm: {Planck's constant = 6.7 x 10^{-34} Js}
(a) 43 m/s.
(b) 15 m/s.
(c) 35 m/s.
(d) 30 m/s.

107. One of following is an advantage of semiconductor diode over diode value? It is:

(a) Smaller in size (b) Easier to produce (c) Cheaper to purchase (d) All are its advantages

108. A photon with frequency 1.76 x 10^{23}Hz released 9.1 x 10^{-31} kg mass electron at 4.4 x 10^5 Hz threshold frequency. Calculate its speed. (Planck's constant h = 6.63 x 10^{-34}Js)

(a) 3.34 x 10^{23} m/s (b) 1.6 x 10^{10}m/s
(c) 10.4 x 10^{23} m/s (d) 1.76 x 10^{23} m/s

109. During photoelectric emission, if work function is the same with an incoming photon in quantity, one of the following is correct:

(a) Photoelectrons may not be obtained
(b) Photoelectrons may move slower
(c) Photoelectrons may possess little kinetic energy
(d) All above are wrong.

110. One of the following is the effect of the reverse bias connection of a diode value at a very low voltage:

(a) Damage the valve (b) Evacuate its tube
(c) The diode stops conducting (d) Stratifies the tube

111 The process of ejecting electrons from the surface of acold metal by an electromagnetic radiation is an evidence of:
(a) X-radiation (b) particle nature of wave (c) Thermionic emission
(d) Compton effect

112 The household tube television works on the principle of:
(a) Thermionic emission (b) Dispersion of white light (c) Photoemission
(d) Polarisation

113 A beam of x-rays with the atomic spacing 0.72nm is incident on a crystal and gives a first order maximum when the glancing angle is 8^0; find the wavelength of the beam. (a) 0.2 nm (b) 10.72nm (c) 0.55nm (d) 0.09nm

114. An electron of mass 9.1×10^{-31} kg and charge 1.6×10^{-19} c is accelerated to a target by applying a potential difference of 25 kV, calculate its velocity at an instance.
(a) 3.30×10^{7} m/s (b) 5.86×10^{7} m/s (c) 9.38×10^{7} m/s (d) 4.79×10^{7} m/s

115. One of these laws is aimed at seeing how Particles could behave like waves
(a) Bohr's law
(b) Rutherford's law()
(c) de Broglie's law;
(d) Ohm's law

116 All of these are wrong about photoelectric emission except:
(a) No emission if work function and photon energy are equal.
(b) Decrease in workfunction makes the photoelectrons to move faster.
(c) Excess energy of photon serves as kinetic energy for the photoelectrons to move.
a) (a) and (b)

117 X-rays can be suitable to study internal structure of a charged object because it is:
(a) Fast (b) Neutral (c) Positively Charged (d) Negatively Charged

118 X-rays have charge characteristics comparable with that of:
a) Gamma rays (b) Beta rays (c) Proton (d) Alpha particles

119 The presence of space charge in a working diode valve without an accelerating potential causes:
(a) Increase in current.
(b) Current to die down
(c) Temperature reduction in the valve.
(d) Diode values to have short life span.

120 Which of these electronic components is most suitable for AC-DC rectification?
(a) Transistor (b) Integrated circuit (c) Capacitor (d) Thermionic diode.

121 Only 5% of photon energy, with frequency 20 Hz, falling on a metal served as workfunction to release an electron. Calculate the velocity of the photoelectron released. (Electron mass = 9.1×10^{-31} kg. Planck constant h = 6.63×10^{-34} Js)
(a) 0.17 m/s (b) 2.55 m/s (c) 8.07 m/s (d) 3.7×10^{10} m/s

122 31. All of these are characteristics of 'HARDER' x-rays except:

(a) High speed (b) Short wavelength
(c) High Kinetic energy (d) ability to penetrate lead materials

123 Thermionic emission is a principle for the production of:

(a) Gamma rays (b) Beta rays
(c) X-rays (d) Cathode rays

124 'Soft' X-rays are most suitable in:
(a) Analysing internal faults in auto maintenance workshops
(b) Identifying alteration made on paper artistic works
(c) Mapping the internal organ such as bone marrow in human body
(d) Analysing the internal organ of metal machines

125 Ability to measure accurately, the position and velocity of a particle at a certain time, according to uncertainty principle, implies that it is:
a) possible to predict its state at any given future time
b) possible to predict its momentum and size
c) possible to predict its size only at a time
d) impossible to make a decision about it at any time

126 The Uranium nucleus $^{238}_{92}U$ undergoes successive decays, emitting respectively an α-particle, a β-particle and a γ-ray. What is the atomic number and the mass number of the resulting nucleus?
(a) 91 , 234 (b) 90 , 236 (c) 88 , 236 (d) 92 , 234

127 The isotope which decays by β-emission to produce $^{111}_{49}In$ is
(a $^{112}_{40}Ag$ (b) $^{111}_{50}Cd$ (c) $^{110}_{50}Ag$ (d) $^{113}_{50}Sn$.

128 A stationary thorium nucleus (A = 220, Z = 90) emits an α- particle of kinetic energy E. What is the kinetic energy of the daughter nucleus.
(a) E (b) E/12 (c) E/36 (d) E/54.

129. An approximate relationship between the radius R of a nucleus and its nucleon number N is $R/m = 1.2 \times 10^{-15} N^{1/3}$. Estimate the number of nucleons per unit volume of the nucleus.
(a) $0.12 \times 10^{44}\ m^{-3}$ (b) $1,4 \times 10^{44}\ m^{-3}$ (c) $5.78 \times 10^{44} m^{-3}$ (d) $1.2 \times 10^{44} m^{-3}$

130 Which of the following gives the relationship between the decay constant λ and the half life T of a radioactive isotope.
(a) $N = N_o e^{-\lambda T}$ (b) T = In 2λ (c) T = In 2/λ (d) T = λN .

131 The isotope $^{234}_{90}Th$ has a half-life of 24 days and decays to $^{234}_{91}Pa$. How long does it take for 90% of a sample of $^{234}_{90}Th$ to decay to $^{234}_{91}Pa$.
(a) 50 days (b) 60 days (c) 70 days (d) 80 days.

132 The decay of a radioactive nuclide is represented by the equation $dN/dt = -\lambda N$ where $\lambda = 2.4 \times 10^{-8}\ s^{-1}$. What is the half life of the nuclide.
(a) $2.9 \times 10^{7}s$ (b) $8.33 \times 10^{7}s$ (c) $1.25 \times 10^{7}s$ (d) $1.25 \times 10^{-7}s$.

133 If the fission of a atom of ^{235}U yields an energy of 200 MeV. How much energy would be released by the fission of 1g of ^{235}U.

(a) $8.20 \times 10^{10}J$ (b) 8.20 J (c) $8.20 \times 10^{-10}J$ (d) $8.20 \times 10^{-6}J$.

134 The mass of a $^{20}_{10}Ne$ nuclide is 19.99244amu. If the rest mass of a proton and a neutron are 1.007825amu and 1.008665amu respectively, calculate the nuclear binding energy and hence the nuclear binding energy per nucleon of $^{20}_{10}Ne$.

(a) $2.9 \times 10^{-9}J$, $1.29 \times 10^{-12}J$

(b) $2.58 \times 10^{-11}J$, $1.29 \times 10^{-12}J$

(c) $-2.97 \times 10^{-9}J$, $1.29 \times 10^{-12}J$.

(d) None the above .

135 The results of the Geiger and Muller experiment proves that

(a) Electrons are present in the atoms

(b) Electrons move randomly in atoms

(c) There is a central nucleus

(d) There are protons and electrons in an atom.

136 The length of an α-particle track in a cloud chamber is 37mm. If the average energy required to produce an ion pair is $5.2 \times 10^{-18}J$ and on the average an α-particle produces 5.0×10^{3} ion pairs per mm of its track, calculate the initial energy of the α-particle.

(a) 6.01 eV (b) 0.611MeV (c) 6.01 MeV (d) 0.006 MeV

137 The splitting of a large nucleus into smaller nuclei is referred to as

(a) Fusion (b) Radioactivity (c) Fission (d) Decay.

138 In a radioactive decay reaction , the number of radioactive atoms

(a) Decreases sinusoidally with times

(b) Increase s exponentially with time

(c) Decreases hypothetically with times

(d) Decreases exponentially with time

139 Which of the following gives the relationship between the nuclear binding energy ΔE and mass defect Δm of a nucleus.

(a) $\Delta E = hv$ (b) $\Delta E = hc$ (c) $\Delta E = \Delta mc$ (d) $\Delta E = \Delta mc^2$.

140 A uranium nucleus $^{238}_{92}U$, emits two alpha particles and two beta particles and finally forms thorium (Th) nucleus. What is the symbol of this nucleus.

(a) $^{230}_{92}Th$ (b) $^{230}_{90}Th$ (c) $^{234}_{90}Th$ (d) $^{233}_{89}{}^{Th}$

141 The half-life of radium is 10 days . After how many days will only one-sixteenth of radium sample remain.

(a) 30 (b) 45 (c) 40 (d) 50

142 How much $^{235}_{92}U$ must undergo fission per day in a nuclear reactor that provides energy to a 100MW electric power plant .Assume perfect efficiency. Given that 1 kg of $^{235}_{92}U$ can generate 9×10^{13} J of energy.

(a) 9.6×10^{-2} kg/day

(b) 7.6×10^{-2} kg/day

(c) 3.4×10^{-2} kg/day

(d) 6.8×10^{-2} kg/day

143 Calculate the binding energy of $^{57}_{26}Fe$ whose mass is 56.935398 a.m. u given that the mass of protons = 1.007825 a. m.u and the mass of neutron = 1.008665 a.m.u . 1 a.m.u = 931 MeV .

(a) 250eV (b) 300 eV (c) 400 eV (d) 500eV

144 A sample of a radioactive isotope is left to decay . After 1 minute, only 1/8 of the isotope remains in the sample. Calculate the decay constant.

(a) 0.0235 (b) 0.0421 (c) 0.0213 (d) 0.0347

145 Which of the following is a common characteristic among α-particle and γ-rays.

(a) They are e-m radiation of short wavelengths

(b) They are deflected by electric fields

(c) They cause some substance to fluoresce

(d) They have strong penetrating power.

146 Electrons are emitted with negligible speed from a plane cathode in an evacuated tube. The electrons are accelerated toward a plane anode which is parallel to the cathode and 2.0cm from it by a p.d of 100V. Find the time taken for an electron to move from the cathode to the anode ($e/m = 1.8 \times 10^{11}$C/kg).
(a) 4.5×10^{-5}s
(b) 1.8×10^{-8}s
(c) 2.11×10^{-9}s
(d) 1.90×10^{-7}s

147 Find the energy difference and the wavelength of the photon which is emitted when a hydrogen atom undergoes a transition from n=5 to n=2.
(a) 2.856eV, 6.96×10^{-26}m
(b) 0.2856eV, 6.343×10^{-7}m
(c) 2.856eV, 4.343×10^{-7}m
(d) 0.2856eV, 4.343×10^{-10}m

148 Proton with a charge-mass ratio of 1.0×10^{8}C/kg are rotated in a circular orbit of radius r when they enter a uniform magnetic field of 0.5nT. Calculate the number of revolution

a. 2×10^6Hz

b. 4×10^6Hz

c. 6×10^6Hz

d. 8×10^6Hz

149 What is the maximum kinetic energy of electrons emitted by light of wavelength 0.8nm from a surface which has a threshold wavelength of 0.96nm?
(a) -3.168×10^{-26}J
(b) 3.168×10^{-26}J
(c) 1.98×10^{-25}J
(d) 2.178×10^{-26}J

150 X-rays of wavelength 1.5×10^{-10}m is incident on a crystal and it gives a third order diffraction for a glancing angle of 600. What is the separation of the layers of atoms in the crystal?
(a) 2.46 x 10-10m
(b) 3.87 x 108m
(c) 7.38 x 10-10m
(d) 4.5 x 10-10m

151 The potential difference between the target and cathode of an x-ray tube is 20KV and the current is 20mA. Only 0.5% of the total energy supplied is emitted as x-rays. What is the minimum wavelength of the x-ray emitted?
(a) 6.19×10^{-11}m
(b) 3.87×10^{8}m
(c) 6.19×10^{-8}m
(d) 4.00×10^{7}m

152 Calculate the velocity of electrons accelerated from rest to a target in hot cathode vacuum tube by a p.d of 25V
(a) 2.96×10^{6}m/s
(b) 3.98×10^{6}m/s
(c) 2.98×10^{5}m/s
(d) 3.98×10^{3}m/s

153 Calculate the energy and momentum of a photon of light of wavelength 500nm.
(a) 3.96 x10-19J, 1.32 x 10-27kgm/s
(b) 3.3 x 10-31J, 1.32 x 10-27kgm/s
(c) 3.3 x 10-40J, 1.32 x 10-27kgm/s
(d) No answer

154 An alpha particle of energy 5.30 MeV moves directly toward a lead nucleus $^{206}_{82}$Pb which is stationary. Calculate the nearest distance of approach of the alpha particle from the least nucleus.
(a) 3.128×10^{-7}m/s
(b) 3.75×10^{-26}m/s
(c) 3.98×10^{-24}m/s
(d) 4.425×10^{-14}m/s

155 In the production of x-rays most modern x-ray tubes use tungsten for the target because
(a) they are good targets
(b) they are not costly
(c) they have the highest efficiency for x-ray production
(d) they serve as the best cooling agent

156 What is the shortest wavelength in the Lyman series of hydrogen?
(a) 1.097×10^{7}m
(b) 9.1×10^{-8}m
(c) 2.7×10^{6}m
(d) 3.65×10^{-7}m

157 The length of an alpha particle track in a cloud chamber is 37mm. if the average energy required to produce an ion pair is 5.2 x 10-18J and on an average an alpha particle produce 5 x 10 3 ion pairs per mm of its track, calculate the initial energy of the particle.
(a) 6.01ev
(b) 0.611Mev
(c) 6.01Mev
(d) 0.006Mev

158 If the wavelength of the incident light in a photoelectric experiment is increased from30007nm to 30010, calculate the corresponding change in the stopping potential.
(a) 1.38×10^{-2}V
(b) 1.38×10^{-8}V
(c) 1.38×10^{-4}V
(d) 1.38×10^{-5}V

159 Calculate the velocity of electrons accelerated from rest to a target in hot cathode vacuum tube by a potential difference of 25V.

(a) 2.98×10^{6}m/s
(b) 3.75×10^{6}m/s
(c) 2.98×10^{5}m/s
(d) 3.98×10^{5}m/s

160 What is the wavelength of the Balmer series for n = 4?
(a) 4.86×10^{-7}m
(b) 9.7×10^{-8}m
(c) 1.88×10^{-6}m
(d) 2.0×10^{-7}m

161. Electrons are knocked off the cathode at low pressures and low p.d in a discharge tube through
(a) Electrical process
(b) Thermionic emission
(c) Photoelectric effect
(d) Explosion process

162 The point in a discharge tube at which the growth of electrons become uncontrollable at high voltage is known as
(a) Uncontrollable point
(b) Avalanche point
(c) Gas breakdown point
(d) Cathode dark point

163 One disadvantage of the method of discharge tube for the production of cathode rays is
(a) cathode ray produced is usually small
(b) production of x-rays as by-product
(c) very low p.d is required
(d) no gas is required

164 In the modern method of cathode ray production, cathode rays are produced by
(a) chemical method
(b) thermionic method
(c) photoelectric effect
(d) small voltage

165 Which of the following is common to both the discharge tube method and the modern method of producing cathode rays
(a) they both require gas
(b) they both require metals
(c) small electrons produced must be accelerated
(d) they produce x-rays as by-product

166 An application of cathode ray is in
(a) x-ray production
(b) gamma ray production
(c) cathode ray oscilloscope
(d) production of alpha particle

167 In Milikan experiment, an atomizer is used to
(a) produce tiny charged droplet of oil
(b) atomize the environment of the oil
(c) produce a high p.d in the oil
(d) keep the oil motionless

168 According to Milikan, the charge on an oil drop is given by
(a) q = E/d
(b) q = I/t
(c) q = mgd/V
(d) q = V/d

169 The ionization energy for hydrogen atom is
(a) -13.6eV
(b) +13.6eVe
(c) -10.2eV
(d) +10.2eV

170 What is the maximum kinetic energy of electrons emitted by light of wavelength 0.8nm from a surface which has a threshold wavelength of 0.96nm?
(a) -3.168×10^{-26}J
(b) 3.168×10^{-26}J
(c) 1.98×10^{-25}J
(d) 2.178×10^{-26}J

171 If ΔE, Δx and Δp are the smallest uncertainty measurements within the smallest uncertainty time Δt, in energy, position and momentum the uncertainty principle can be stated as:

(a) $\Delta E. \Delta x = h/2\pi$ (b) $\Delta p. \Delta E = h/2\pi$ (c) $\Delta p. \Delta x = h/2\pi$ (d) $\Delta t. \Delta x = h/2\pi$

172 All of these are instances when an entity behaves like a particle:

(a) Compton effect and diffraction.
(b) Photoelectric effect and refraction.
(c) X-Ray production and interference.
(d) Photoemission and Compton effect.

173 A Photon of 1.6×10^{-19} J did a work of 0.3×10^{-19} J to free an electron whose mass is 9.1×10^{-31} Kg. Calculate the velocity of the electron after been released.

(a) 5.3×10^{5} m/s (b) 60.1×10^{5} m/s (c) 9.2×10^{5} m/s (d) $1.12. \times 10^{5}$ m/s

174 One of the following is not a proper use of X-rays:

(a) Crystallographic study
(b) Identification of alteration made on artistic works
(c) Mapping the internal organ such as bone marrow in human body
(d) To analyze the internal organ of metal machines

175 Current dies down in a working diode value, without an accelerating potential, because:

(a) Anode is shielded.
(b) Of the presence of space charge
(c) Temperature of the cathode reduces.
(d) Diode values usually have short life span.

176. Which of these statements is not true of x-rays? They:

a) belong to electromagnetic spectrum
b) appear neutral
c) can be made faster or slower at will
d) originate from energy changes in the nuclei of atoms

177. If x-rays are brought near the top cap of a positively charged gold leaf electroscope, the divergence of the leaves will:

b) decrease to zero slowly
c) steadily increase
d) remain constant
e) decrease to zero and then increase to maximum.

178. Bohr confirmed that the motion of electron towards nucleus of Rutherford atomic model is

(a) Helical (b) Zigzag (c) Spiral (d) circular

179. De Broglie's law is aimed at seeing how:

(a) Particles could behave like waves
(b) X-rays can be made 'HARDER'
(c) Waves can exhibit particle nature
(d) X-rays can be made 'SOFTER'

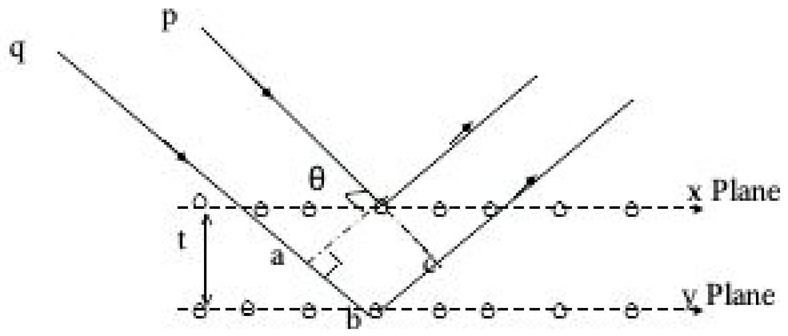
180. Production of x-rays is sourced from the principle of

(a) Photoelectric effect (b) Thermionic emission
(c) Photovotaic emission (d) Comption effect

181. Which of these is wrong about 'HARD' x-rays? They have:

(a) High speed (b) Short wavelength
(c) High Kinetic energy (d) Ability to penetrate plane paper only

182



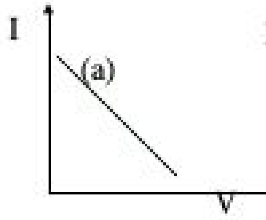
X-rays p and q are reflected from atomic planes x and y in a crystal. For maximum intensity of reflection, in Bragg's view, the path difference must be in the form

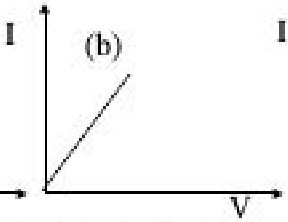
(a) $\frac{2d\sin\theta}{\lambda} = n$ (b) $n\lambda = 2t\sin\theta$ (c) $n\lambda = d\sin\theta$ (d) $t\cos\theta = n\lambda$

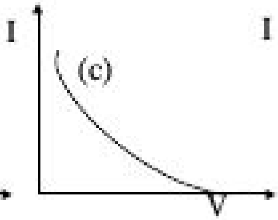
183. A beam of x-rays of wavelength 0.2 nm is incident on a crystal and gives a first order maximum when the glancing angle is 8^0; find the atomic spacing in the crystal.

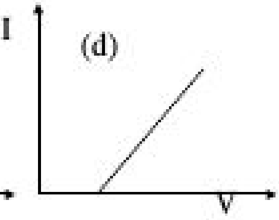
(a) 0.90nm (b) 0.72nm (c) 0.55nm (d) 0.09nm

184. When a diode value is connected in a forward bias mode the appropriate Current I/Voltage V characteristics curve that will be obtained is:

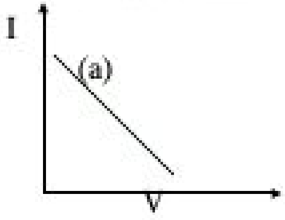


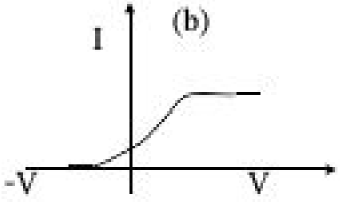


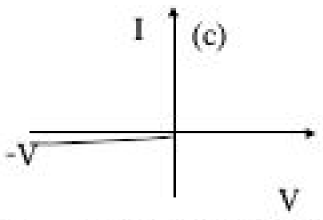


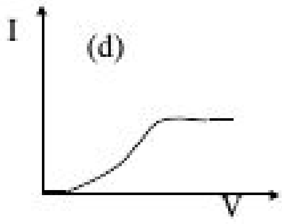


185. A diode value connected in a reverse bias mode will have I/V characteristics curve in the form of.









186. Diode value works on the principle of:

(a) Photo emission (b) Compton effect
(c) Thermionic emission (d) X-Ray emission

187. The reverse bias connection of a diode value at a very high voltage can

(a) Damage the value (b) Lead to the production of a stabilizing device
(c) Evacuate its tube (d) Stratify the tube

188. A 9.1 x 10^{-3} kg mass electron was released by a radiation to move with a speed of 1.6 x 10^{10} m/s. If the threshold frequency is 4.4 x 105 Hz calculate the frequency of the source radiation. (Planck's constant h = 6.63 x 10^{-34}Js)

(a) 3.34×10^{23}Hz (b) 5.11×10^{23}Hz
(c) 10.4×10^{23}Hz (a) 1.76×10^{23}Hz

189. Which of the following is an advantage of diode value over semiconductor diode? It is:

(a) made of glasses (b) usually smaller (c) easier to make (d) cheaper

190. During photoelectric emission, if work function of a metal is extremely high then

(a) Photoelectrons may not be obtained
(b) Photoelectrons may move slower
(c) Photoelectrons may possess little kinetic energy
(d) All above are possible outcome.d

Answer

1 C
2 B
3 C
4 B
5 B
6 A
7 D
8 D
9 B
10 D
11 A
12 C
13 B
14 B
15 C
16 A
17 C
18 B
19 A
20 D
21 C
22 D
23 A
24 C
25 B
26 B
27 D
28. C
29 D
30 A
31 A
32 D
33 B
34 B
35 C
36 B
37 D
38 B
39 A
40 A
41 C
42 C
43 A
44 D
45 C
46 B
47 B
48 A
49 D
50 B
51 C
52 C
53 A
54 C
55 D
56 A
57 B
58 D
59 A
60 A
61 B
62 C
63 D
64 C
65 A
66 A
67 A
68 D
69 C
70 B
71 A
72 C
73 A
74 C
75 B
76 A
77 A
78 D
79 C
80 A
81 A
82 C
83 A
84 C
85 A
86 C
87 A
88 B
89 D
90 B
91 A
92 C
93 B
94 A
95 D
96 B
97 D
98 A
99 B
100 A
101 D
102 B
103 A
104 C
105 C
106 D
107 D
108 B
109 D
110 C
111 B
112 A
113 A
114 C
115 C
116 C
117 B
118 A
119 B
120 D
121 A
122 D
123 C
124 B
125 A
126 A
127 B
128 D
129 C
130 C
131 D
132 A
133 A
134 B
135 C
136 C
137 C
138 D
139 D
140 B
141 C
142 A
143 D
144 D
145 C
146 C
147 A
148 C
149 D
150 C
151 A
152 A
153 A
154 D
155 C
156 D
157 C
158 B
159 C
160 A
161 C
162 C
163 B
164 C
165 C
166 C
167 A
168 C

169	B
170	D
171	C
172	D
173	A
174	C
175	B
176	D
177	C
178	C
179	A
180	B
181	D
182	B
183	B
184	B
185	C
186	C
187	B
188	D
189	C
190	D

PHY 142 PRACTICE QUESTIONS

1). The nuclear atom model is validated by

Bohr's experiment

Rutherford's experiment

Lorentz's experiment

Dalton's experiment

2). When light is incident on a metal plate, electrons are emitted only when the frequency of the light exceeds a certain value known as

Photoelectric frequency

Photoelectric threshold frequency

Work function

Working potential

3). One major difference between the electromagnetic spectrum emitted by solid and gases is that

a) Gases emit continuous spectrum while solids emits line spectrum

b) **Gases emit line spectrum while solids emits continuous spectrum**

c) Gases emits both line and continuous spectrum while solid emits only continuous spectrum

d) Gases emits line spectrum while solids emits both line and continuous spectrum

4). radiation with a wavelength 281nm shines on a metal surface and ejects electrons that have a maximum velocity of 3.58 × m/s. which one of the following metals is present, the values in parenthesis being the work function: potassium (2.24eV), calcium (2.71eV), uranium (3.63eV), Aluminum (4.08eV), and gold (4.82eV)

Uranium

Aluminum
Calcium
Potassium

5). the total energy of the Bohr atom is given by

Kze2/2r

–kze2/2r
±kze2/2r
P.E

6). Radiation with a given wavelength causes electrons to be emitted from the surface of one metal but not from the surface of another metal. Which of the following could be the reason?

They both have same work function

The metals have different work function
The metals have different frequency
The metals have same frequency

7). Ceasium has a work function of 1.9eV. Find its threshold wavelength

1.57 ×

6.54 ×
3.04 ×
4.56 ×

8). The maximum kinetic energy of the electrons emitted from a metallic surface is 1.6 × when the frequency of the incident radiation is 7.5× Hz. Calculate the minimum frequency of radiation for which electrons will be emitted.

4.8 × Hz

5.1 × Hz
6.63× Hz
3.98 × Hz

9). Determine the De Broglie wavelength for an electron (mass -9.1 × kg) moving at a speed of 6.0 × m/s.

1.98 × m

1.2 × m
1.79× m
2.1 × m

10). The work function for a silver is W_o =4.73eV. Find the maximum frequency that light must have in order to eject electron from the surface. (1eV=1.6 × j).

1.4 × Hz

1.14× Hz
1.78 × Hz
2.1 × Hz

11). Calculate the wave number of the second line in lyman series for an hydrogen atom. (R = 1.097 x $10^7 m^{-1}$)

6.75 × 10^6 m^{-1}
9.75 x 10^6 m^{-1}
7.75 × 10^6 m^{-1}
8.25 × 10^6 m^{-1}

12). If the line with the longest wavelength in Pfund series for double ionized Lithium atom is counted as the first line, what is the wavelength of the fourth line?

5.66 × 10^{-6} m
3.49 x 10^{-7}m
6.66 x 10^{-7}m
2.25x 10^{-7}m

13). The ground state energy of a particular atom is -54.4 eV, calculate the energy of the 3rd excited state of this atom

3.4eV

-3.4 eV

-4.5eV

-13.6eV

14). The ground state energy for double ionized lithium atom L_i^{2+} (Z = 3) is -122.4 eV. Calculate the ionization energy in Joules for this atom

1.45 x 10^{-17}J

1.96 x 10^{-17}J

2.54 x 10^{-17}J

1.96 x 10^{-17}m

15). In a Rutherford scattering experiment, an α-particle (+ 2e) heading directly towards a nucleus of a silver foil (Z = 47) come to an halt 30 x 10^{-16} m from the nucleus. Calculate the kinetic energy of the α-particles. (e = 1.6 x 10^{-19} C, k = 9.0 x 10^{9} Nm^2/c^2)

Ans 7.21 x 10^{-11}J

15). Calculate the wavelength of the third line in Pfund series for double ionized lithium atom. (R = 1.097 x $10^{7}m^{-1}$)

2.25 x 10^{-7}m
4.16 x 10^{-7}m
6.65x 10^{-7}m
3.28 x 10^{-7}m

16). In a certain Bohr's obit, the total energy is -6.80 eV. For this orbit, determine the kinetic energy of the electron.

13.6eV

6.80 eV

5.54eV

1.54eV

17). The velocity of the electron in the first Bohr's orbit (n = 1) for an hydrogen atom V_o = 2.19 x 10^{6} m/s. Calculate the velocity this electron when it moved to fourth orbit (n = 4)

3.58 x 10^{6}m/s

5.48 x 10^{6}m/s

4.45 x 10^{6}m/s

6.78 x 10^{6}m/s

18). The electron in an hydrogen atom undergoes a transition from the ground state level to the third excited state level, calculate the excitation energy required for this transition. E_o = -13.6 eV

13.6eV
12.75 eV
8.06eV
5.54eV

19). If the wavelength of the incident light in a photoelectric experiment is increased from 30007nm to 30010, calculate the corresponding change in the stopping potential.

1.68 x 10^{-8}V

1.38 x 10^{-8}V

2.68 x 10^{-8}V

3.68 x 10^{-8}V

20). The ground state energy for the atoms of a particular substance is -54.5 eV, calculate its energy when it is in second excited state.

-13.6eV

-6.04 eV

-1.54eV

54.5eV

21). Find the energy of the photon that is emitted when the electron in an hydrogen atom undergoes transition from the n = 7 energy level to produce the first line in the Paschen series. (E_o = 13.6 eV)

2.23eV

1.23 eV

13.6eV

5.4eV

22). In a fine-beam tube method for measuring e/m, calculate the circular radius of the deflecting electrons if the magnetic field strength is 6.0 x 10^{-3} T are the accelerating voltage in the electron gun is 320 V.

0.07m

0.02m

0.088m

0.20m

23). In a certain Bohr's orbit, the total energy is – 6.80 eV. For this orbit, determine the value of the electric potential energy of the electron.

13.6eV

-13.6 eV

5.54eV

-2.5eV

24). In an evacuated tube, electrons are accelerated from nest through a potential difference of 3500 V and then travel; in a narrow beam through a field free space before entering a uniform magnetic field the flux lines of which are perpendicular to the beam. If the radius of its path in the field is 13cm. Calculate the magnitude of the magnetic flux density B.

1.66 x 10^{-2}T

1.54 x 10^{-3}T

1.23 x 10^{-3}T

25). Calculate the velocity of electrons accelerated from rest to a target in hot cathode vacuum tube by a potential difference of 25V.

3.88 x 10^{3}m/s

2.98 x 10^{3}m/s

1.29 x 10^{3}m/s

6.67 x 10^{3}m/s

26). If the electron in an hydrogen atom, initial at the first excited state moved to another excited state when its absorbed an additional 2.55 eV. What is the quantum number of the state into which the electron moved? (E_o = -13.6 eV for hydrogen atom)

3
4
5
2

27). In a Rutherford scattering experiment, an α-particle (+ 2e) heading directly towards a nucleus of a silver foil (Z = 47) come to an halt 30 x 10^{-16} m from the nucleus. Calculate the kinetic energy of the α-particles. (e = 1.6 x 10^{-19} C, k = 9.0 x 10^{9} Nm^{2}/c^{2})

6.36 x 10^{-11}J
7.21 x 10^{-11}J
2.36 x 10^{-11}J
3.97 x 10^{-11}J

28). For radium $^{226}Ra_{88}$ (atomic mass = 226.029 402u) obtain the mass defect in atomic mass unit.

0.17107u
0.14107u
0.24197u
0.04107u

29). In a Rutherford scattering experiment, an α-particle (+ 2e) heading directly towards a nuclear of a gold foil (Z = 79) will come to an halt when all the particle's kinetic energy is converted to electric potential energy. Calculate how close the α-particle get to the nucleus if its kinetic energy is 6.5 x 10^{-14} J. (e = 1.6 x 10^{-19} C, k = 9.0 x 10^{9} Nm^{2}/c^{2})

6.6 x 10^{-13}m
5.6 x 10^{-13}m
4.5x 10^{-13}m
2.2x 10^{-13}m

30). An electron with a velocity of 10^{7}m/s enters vertically a region of uniform magnetic field of 0.12 T, calculate the radius of the circular path of the electron in the field. (e/m = 1.8 x 10^{11} c kg^{-1} Mass of electron = 9.11 x 10^{-31}kg e = 1.6 x 10^{-19} C).

5.56 x 10^{-4}m
4.69 x 10^{-4}m
3.37 x 10^{-4}m
4.0 x 10^{-4}m

31). For radium $^{226}Ra_{88}$ (atomic mass = 226.029 402u) obtain the binding energy per nucleon.

a) 0.6876544MeV

b) **0.5814456MeV**

c) 0.3467586MeV

d) 0.6346757MeV

32). Calculate the shortest wavelength in Brackett series for a single ionized Helium atom.

a) 6.89 x 10^{-7}m

b) **3.65 x 10^{-7}m**

c) 4.56 x 10^{-7}m

d) 2.66 x 10^{-7}m

33).Calculate wavelength of the first line in Balmer series for an hydrogen atom (R = 1.097 x 10^{7}m^{-1})

a) 5.35 x 10^{-7}m

b) **6.61 x 10^{-7}m**

c) 4.75 x 10^{-7}m

d) 4.79 x 10^{-7}m

34). Calculate the energy of the photon, in eV, that is absorbed when the electron in a double ionized lithium atom L_i^{2+} (Z = 3) undergoes a transition from n = 1 energy level to n = 3 energy level (E_o = -13.6 eV for hydrogen atom)

a) 54.4eV

b) **108.8 eV**

c) 13.6eV

d) 6.67eV

35). A device used in radiation therapy for cancer contains 0.50g of colbalt $^{60}Co_{27}$. If the half life of cobalt is 5.27years, determine the activity of the radioactive material.

a) 6.32 x 10^{20}/year

b) **6.57 x 10^{20}/year**

c) 7.76 x 10^{20}/year

d) 3.54 x 10^{20}/year

36).If an accelerating potential difference of 3000 V is applied to an electron beam, calculate the kinetic energy of the electron. (Mass of electron = 9.11 x 10^{-31}kg e = 1.6 x 10^{-19} C)

a) 5.5 x 10^{-16}J

b) **4.8 x 10-16J**

c) 3.9 x 10^{-16}J

d) 3.5 x 10^{-16}J

37). If the ground state energy for an hydrogen atom $E_{o(H)}$ = 13.6 eV, calculate the ground state energy for a double ionized lithium atom $E_{o(Li2+)}$

a) 122.4eV

b) **– 122.4eV**

c) 13.6eV

d) -13.6eV

38). If the line with the longest wavelength in Balmer series for atomic hydrogen is counted as the first line, calculate the wavelength of the second line. (R = 1.097 x 10^{7} m^{-1})

a) 5.56 x 10^{-7}m

b) **4.86 x 10^{-7}m**

c) 3.80 x 10^{-7}m

d) 3.56 x 10^{-7}m

39).To make the dial of a watch glow in the dark, 1.00 x 10^{-6}g of radium $^{226}Ra_{88}$ is used. The half-life of this isotope is 1.6 10^{3}years. How many grams of radium disappear while the watch is in use for 50year.

a) 1.1 x 10^{-8}g
b) 2.1 x 10^{-8}g

c) 3.1 x 10^{-8}g

d) 4.1 x 10^{-8}g

40). What is the maximum kinetic energy of electrons emitted by light of wavelength 0.8nm from a surface which has a threshold wavelength of 0.96nm?

a) 3.178 x 10^{-26}J

b) **2.178 x 10^{-26}J**

c) 4.178 x 10^{-26}J

d) 1.178 x 10^{-26}J

41).Calculate the frequency of the photon emitted when an electron makes a quantum jump from n = 4 state to the ground state of the hydrogen atom. (Ground state energy for hydrogen atom E_o = -13.6 eV, h = 6.626 x 10^{-34} Js)

a) 3.06 x $10^{15}$$H_z$

b) **2.06 x $10^{15}$$H_z$**

c) 3.67 x $10^{15}$$H_z$

d) 4.48 x $10^{15}$$H_z$

42).Calculate the wavelength of the photon emitted when an electron makes a quantum jump from n = 4 state to the ground state of the hydrogen atom. (Ground state energy for hydrogen atom E_o = -13.6 eV, h = 6.626 x 10^{-34} Js)

a) 3.67 x 10^{-7}m

b) **1.46 x 10^{-7}m**

c) 4.13 x 10^{-7}m

d) 2.25 x 10^{-7}m

43).Calculate the energy and momentum of a photon of light of wavelength 500nm

a) 4.48 x 10-19J, 1.32 x 10-27kgm/s

b) **3.96 x 10-19J, 1.32 x 10-27kgm/s**

c) 6.67 x 10-19J, 1.32 x 10-27kgm/s

d) 3.96 x 10-19J, 1.23 x 10-27kgm/s

44). A sample of ore containing a radioactive element has an activity of 4.0 x 10^{4}Bq. How many grams of the element are in the sample, assuming the element is radium $^{226}Ra_{88}$ (half life = 1.6 x 10^{3}years)

a) 2.1 x 10^{-6}g

b) **1.1 x 10^{-6}g**

c) 3.2 x 10^{-6}g

d) 4.6 x 10^{-6}g

45).The number of radioactive nuclei present at the start of an experiment is 4.60 x 10^{15}. The number present twenty days after is 8.14 x 10^{14}. what is the half –life (in days) of the nuclei?

a) 44days

b) **53days**

c) 35days

d) 21days

46).The isotope which decays by β- emission to produce $^{111}In_{49}$ is

a) 226 Ra88

b) **112 Ag49**

c) 115 In48

d) 111 Ag50

47).The radius of the first Bohr's orbit (n = 1) in an hydrogen atom r_o = 5.29 x 10^{-11}m. Calculate the radius of the third orbit (n = 3)

a) 3.67 x 10^{-6}g

b) **4.76 x 10^{-6}g**

c) 4.48 x 10^{-6}g

d) 2.26×10^{-6}g

48).The ground state energy for single ionized helium atom H_e^+ (Z = 2) is -54.4 eV. Calculate the ionization energy in Joules for this atom.

a) 7.80×10^{-18}J

b) **8.70×10^{-18}J**

c) 5.23×10^{-18}J

d) 3.89×10^{-18}J

49). In the deflection tube method for measuring the e/m, calculate the magnitude of the field strength required to deflect electron in a circular radius 5cm if the acceleration voltage in the electron gum is 320 V. (Mass of electron = 9.11 x 10^{-31kg} e = 1.6×10^{-19}C)

a) 3.1×10^{-3}T

b) **1.2×10^{-3}T**

c) 2.2×10^{-3}T

d) 3.2×10^{-3}T

50).The ground state energy of a particular atom is -54.4eV, Calculate the ionization energy for this atom.

a) -54.4eV

b) **54.4 eV**

c) 122.4eV

d) -122.eV

51). The half-life for the α- decay of uranium $^{238}U_{92}$ is 4.47 x 10^9years. Determine the age of a rock that contains sixty percent of its original $^{238}U_{90}$ atoms.

a) 1.3467×10^7years

b) **1.2647×10^7years**

c) 1.6743×10^7years

d) 1.1556×10^7years

52).Calculate the longest wavelength in Brackett series for a single ionized Helium atom

a) 3.67×10^{-6}m

b) **1.01×10^{-6}m**

c) 1.56×10^{-6}m

d) 1.89×10^{-6}m