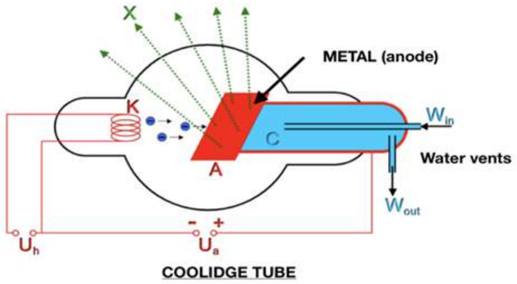
44. X-rays

Short Answer

Answer.1

William Coolidge refurbished the hot cathode ray tube to generate X-rays, which is now known as Coolidge tube. It contains a hot filament which generates electrons by *thermionic emission* and a metal anode where electrons loose the kinetic energy to produce x-rays. There exists an electric field between the filament and the metal to accelerate the electrons to high energies. As the electrons strike the metal, some of their energy is utilized in created in x-rays, and the leftover energy (due to collisions) is absorbed by the metal as heat. This energy along with the hot filament, raises the temperature of the Coolidge tube. So, water .

vents are provided to cool off the metal



Answer.2

A Coolidge tube is a complete circuit, with filament as the cathode, metal plate as the anode and a power supply to drive the circuit (as shown in the figure above). The electrons ejected from the cathode by thermionic emissions are received by the metal where they give off X-rays and knock off electrons from the target atoms till they finally come to rest. These newly generated electrons are then driven by the electric field of the circuit towards the terminals of the power supply. There are no excess electrons in the metal and thus the target does not get more negative.

Answer.3

Photoelectric effect is the ejection of an electron from the target metal when the energy of the incoming radiation (photon) is greater than (or equal to) the work function of the metal. Thus, if the energy of the photon of the X-ray exceeds the work function, it can participate in the photoelectric process.

Answer.4

Electromagnetic waves such as X-rays have an Electric field and Magnetic field components perpendicular to each other which gives it two dimensions. These are transverse waves and thus can be polarized.

Answer.5

The refractive index varies slightly with wavelength which is why we have the phenomena of chromatic aberration. The formula of refractive index is as follows:

$$n = \frac{c}{v}$$

Where, n is the index of refraction, c is the speed of light in vacuum and v is the speed of light in the medium.The refractive index of x-rays is slightly less than 1 and hence less than that of visible light. Thus, the speed of X-rays is more in glass (and in other materials) than in vacuum.

Answer.6

The production process of characteristic x-rays and continuous x-rays are quite different. Characteristic x-rays are created when electrons knock off inner shell electrons of the target atom. The vacancy created by this is later filled by transition of electrons from higher energy levels giving off a photon of energy equal to the energy difference between the two levels. The energy of photon is unique to each element which is why they are used to identify elements. Continuous x-ray on the other hand are created by collisions of electrons with the target. This converts a fraction of the kinetic energy of the electron to photon. The energy of photon can be anywhere between 0 to maximum energy of the incoming electron (eV). So, this cannot be used to detect elements as it depends on the incoming electron and not the target.

Answer.7

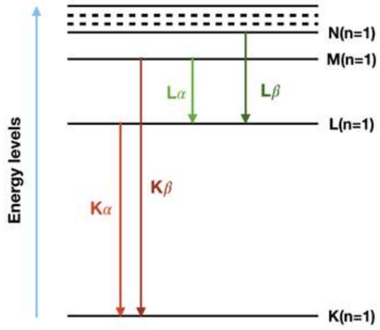
Kα X-rays are created when an electron jumps from L shell to fill the vacancy in K-shell. Lα X-rays are produced when the vacancy in L shell is filled by M shell. This can only happen when L shell gives its electron to K shell initially to create Kα X-rays. So, it's not possible to get characteristic Lα X-rays prior to Kα X-rays.

Answer.8

The energy gap between the L shell and the K shell is very large as compared to the gap between L shell and M shell or any such subsequent shells. The difference in energy between the shells is the emitted X-ray photon energy. Wavelength is inversely proportional to the energy. So, higher the energy, shorter is the wavelength. As the transition energy to K shell from any successive shell will always be higher than the transitions occurring to L shell, Kα X-ray will always have shorter wavelength than Lα X-ray.

Answer.9

Hydrogen atom has very closely spaced energy levels. As the difference between two energy levels is very small, we do not get characteristic x-rays from hydrogen.



Answer.10

X-rays are high energy radiation with high penetration power. They can easily penetrate through human tissue and bones and can damage them. Prolong exposure can mutate cells and cause genetic defects and cancer.

Objective I

Answer.1

X-rays are packets of electromagnetic energy or photons which are uncharged. Thus, they cannot be deflected by either electric or magnetic field.

Answer.2

The continuous energy spectrum of X-rays is a result of electrons striking the target atoms and loosing energy. An electron has a kinetic energy (K) given by K=eV, where "e" is the charge of the electron and "V" is the potential difference applied. Now, electrons can either give all of its energy to the target or only a fraction. So the generated photon can have any energy between "0" to "e" V. This gives us the continuous spectrum of wavelengths: $\lambda = \frac{hc}{E}$ Here, λ is the wavelength of light, h is the Planck's constant ($6.62607004 \times 10^{-34}$ m^2 kg / s), c is the speed of light in vacuum and E is the energy of the photon.

Answer.3

The electron striking the metal can knock off electrons from the shells of the target atoms. These electrons are then filled by the subsequent energy levels. During the transition of electrons from higher energy level to the newly created vacant space, the difference of the energy between the two energy levels is given off as photons forming characteristic x-rays.

Answer.4

The cut-off wavelength is given by:

$\lambda_{min} = \frac{hc}{eV}$where, λ_{min} is the cut-off wavelength, h is the Planck's constant ($6.62607004 \times 10^{-34}$ m^2 kg / s), c is the speed of light in vacuum, e is the charge of the electron and V is the potential difference applied at the ends of the tubeSo, doubling the applied potential will reduce the cut-off wavelength by half.

Answer.5

The cut-off wavelength does not depend on the current and only depends on the potential. So, it will remain unchanged. Increasing the current will increase the number of photons per unit time which is the intensity of x-rays.

Answer.6

In Moseley's law, "a" represents the proportionality constant while "b" represents the screening constant, with independent of the target material.

Answer.7

Moseley's equation is given by:

$\sqrt{v} = a(Z - b)$ $v = a^2(Z - b)^2$ where, "a" represents the proportionality constant while "b" represents the screening constant and Z is the atomic number of the element.Squaring both sides, we getSo the graph should resemble a parabola ($y=x^2$)

Answer.8

The wavelength of X-ray photon is given by:

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

Here, λ is the wavelength of light, h is the Planck's constant (6.62607004 × 10^{-34} m^2 kg / s), and c is the speed of light in vacuum and E" is the energy of the electron which can range from 0"to eV

$\lambda_{min} = \frac{hc}{eV}$And the minimum wavelength that the photon can have iswhere, "eV" is the kinetic energy acquired by the electron. So, in principle, x-rays can have any wavelength greater than the cut-off wavelength.

Answer.9

In a Coolidge tube, all wavelengths above cut-off wavelength are present. Thus, 25pm is the cut-off minimum wavelength and is absent.

Answer.10

The cut-off frequency is given by:

$$\frac{1}{\lambda} = a^2(Z-b)^2$$

$\lambda_{min} = \frac{hc}{eV}$where, λ_{min} is the cut-off wavelength, h is the Planck's constant (6.62607004 × 10^{-34} m^2 kg / s), c is the speed of light in vacuum, e is the charge of the electron and V is the potential difference applied at the ends of the tubeSo, greater the operating voltage, lesser would be the cut-off wavelength. As, λ_{min} is less of A than B, $V_A > V_B$ .From Moseley's law, $\sqrt{v} = a(Z - b)$, therefore in terms of wavelength(λ), we havewhere, "a" represents the proportionality constant while "b" represents the screening constant and Z is the atomic number of the element.Looking at the characteristic peaks, we can see that $\lambda_A > \lambda_B$. So from the inverse relation, $Z_A < Z_B$.

Answer.11

More the applied potential in the Coolidge tube, more will be the energy of the x-rays and thus greater will be their penetrating power. So, more x-rays will be transmitted through the foil.

Answer.12

Increasing the operating potential increases the penetrating power of the x-rays. Thus to allow the same fraction of x-rays to pass for increased potential, we need to thicken the foil (to aid in the attenuation process)

Answer.13

Increasing the operating voltage increases the energy of x-rays, while increasing the current increases the intensity. Thus, if we increase the current, the intensity will increase.

Answer.14

From the theory of diffraction, the radius of diffraction varies directly with the wavelength. So, radius is smaller for smaller wavelengths (X-rays) and larger for larger wavelengths (visible light)

Objective II

Answer.1

Energy and wavelength decide the kind of x-ray (soft or hard) that will be generated. The hard x-rays have shorter wavelength and thus possess greater energy.

Answer.2

The cut-off wavelength is given by:

$\lambda_{min} = \frac{hc}{eV}$where, λ_{min} is the cut-off wavelength, h is the Planck's constant(6.62607004 × 10^{-34} m^2 kg / s), c is the speed of light in vacuum, e is the charge of the electron and V is the potential difference applied at the ends of the tubeThus, it only depends on the potential and not the target or the temperature or the distance between the target and the filament.

Answer.3

An atom with vacancy has higher energy than a neutral atom. So, (A) is incorrect.K X-ray is created when a vacancy (hole) is filled in the K shell by an electron jumping from the successive shell to k-shell. So, the hole or vacancy is created in the shell where the electron jumps from. Hence, option (B) is correct.Characteristic K X-rays are produced when an electron from subsequent L, M, and N… shells drops to fill the vacant K shell. The energy of this transition is greater than the energy of transition form M, N, O… to L shell. Wavelength is inversely promotional to energy. So, KX rays have shorter wavelengths.The wavelengths for K and K are given as:

$\lambda_\alpha = \frac{hc}{E_K - E_L}\lambda_\beta = \frac{hc}{E_K - E_M}$where, λ_α and λ_β are the wavelength, h is the Planck's constant(6.62607004 × 10^{-34} m^2 kg / s), c is the speed of light in vacuum, E_K-E_M and E_K-E_L are the difference in energy levels between the K and M shells and K and L shells.As, E_K-E_M is more than E_K-E_L, λ_α >λ_β. So, (D) is incorrect.

Answer.4

Higher the shell from where the electron is transitioning, higher will be the energy. So energy of K_β transition is more than K_α . Energy is inversely promotional to wavelength. So, λ (K_α) > λ (K_β) > λ (K_γ).M_α is a transition of an electron from N shell to M shell and requires much less energy than K_α transition from L shell to K shell. Thus, in terms of wavelength, λ (M_α) > λ (L_α) > λ (K_α).

Answer.5

From the equation of cut-off wavelength:

$\lambda_{min} = \frac{hc}{eV}$where, λ_{min} is the cut-off wavelength, h is the Planck's constant ($6.62607004 \times 10^{-34}$ m^2 kg / s), c is the speed of light in vacuum, e is the charge of the electron and V is the potential difference applied at the ends of the tubeIncreasing the potential (V) will decrease the minimum wavelength. Hence, option (D) is correct.Intensity depends on the heating current. As this is not changed, Intensity is unchanged. So, (C) is correct.

Answer.6

An electron striking the metal can lose its energy via collisions which generates heat and bremsstrahlung and/or can knock off electrons to produce characteristic x-rays. So, the energy may be converted to heat or to a photon.

Answer.7

A X-ray can issue a force on the material as it's penetrating. Essentially they are made of photons of particular energy which can impart energy, impulse and momentum to the target atom's electron. So, all options are correct.

Answer.8

Here, the photons are of same wavelength. So they carry the same frequency from ν=c/λ.As frequency is same, the energies are same and thus their penetrating power is same. So, option (A), (B) and (C) are incorrect.Continuous x-rays are produced due to collisions of electrons in the target material whereas Characteristic x-rays are produced when the electrons knock off bounded electrons from the shells of the target atom. So the method of creation is different. Hence, option (D) is correct

Exercises

Answer.1

Given:

Wavelength of X-ray (λ)=0.10 nm or

$$\mathrm{E = h\vartheta}$$

$$\vartheta = \frac{c}{\lambda}$$

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

$$E = \frac{(6.626 \times 10^{-34}.3 \times 10^{8})}{0.10 \times 10^{-9}}$$

E = 1.98×10^{-15} Joules/ photon

from above we can calculate, the frequency

$$\vartheta = \frac{c}{\lambda} = \frac{(3 \times 10^{8})}{0.10 \times 10^{-9}} = 3 \times 10^{18}\ hertz$$

to find the momentum, we use

$$p = \frac{h}{\lambda} = \frac{6.626 \times 10^{-34}}{(0.10 \times 10^{-9})} = 6.626 \times 10^{-24} kg.m/s$$

Answer.2

Given: Iron ray energy=6.4 Kev

Calcium ray of energy= 3.69 Kev

We have to calculate the time taken each of those rays to travel a distance of 3 Km

$$t = \frac{Distance}{speed}$$

$$= \frac{3 \times 10^3}{3 \times 10^8}$$

$$t = 10^{-5} s \text{ or } 10\ \mu s$$

Both the Ka photon and X-ray photon will take the same time that is 10μs

Answer.3

Given:

X-ray tube operating at 30Kv

To calculate, cut-off wavelength we use

$$\lambda = \frac{hc}{eV} = \frac{1242eV - nm}{e \times 30 \times 10^3} = 414 \times 10^{-4} nm$$

At this wavelength cut-off occurs

Answer.4

Given:

wavelength of X-ray$(\lambda) = 0.10\ nm\ or\ 0.10 \times 10^{-9} m$

$$\lambda = {}^{hC}/_{eV}\ or\ V = hc/e\lambda$$

$$= \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{1.6 \times 10^{-19} \times 10^{-10}}$$

$$= 12.4 \text{ KV}$$

To Find the Max. energy of photon of wavelength λ

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

$$E = \frac{(6.626 \times 10^{-34}.3 \times 10^8)}{0.10 \times 10^{-9}}$$

Maximum energy of photon of this X-ray in joule $E = 1.98 \times 10^{-15}$ Joules/ photon

Answer.5

Given:

Cutoff wavelength of the Coolidge tube,

λ=80pmEnergy of the electron hitting the target

E is given by

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

Here,

h=Planck's constant$c$ = Speed of light

λ= Wavelength of light

$\therefore E = \frac{1242 \times 10^{-9}}{80 \times 10^{-12}}$

$\Rightarrow E = 15.54 \times 10^{3}\ eV$

≈15.5 keV

Answer.6

Given:

Let

λ be the cut off wavelength and V be the operating potential in the X-ray tube.Then,

$$\lambda = \frac{hc}{V}$$

Here,h = Planck's constant$c$ = Speed of light

If the operating voltage is increased by 1%, then the new operating voltage v' will be given by

V'=V+1/100×V= 1.01

$$V' = \frac{V+1}{100} \times V = 1.01$$

V Cut-off wavelength λ on increasing the operating voltage is given by

$$\lambda = \frac{\text{h}}{1.01}\ V = \frac{\lambda}{1.01}$$

difference in wavelength = $\lambda - \frac{\lambda}{1.01} = \frac{0.01}{\lambda 1.01}$

Percentage change in the wavelength is given by

$\frac{0.01}{\lambda 1.01} \times \lambda \times 100$ =11.01=0.9901 = 1% (approx.)

Answer.7

Given:

Distance between the filament and the target in the X-ray tube d=1.5m

cut-off wavelength= 30pm

Energy(E) is given by

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

thus,

$$E = \frac{6.626 \times 10^{-34} \times 3 \times 10^{8}}{30 \times 10^{-12}} \, Joules$$

$$= \frac{1242 \times 10^{-9}}{30 \times 10^{-12}} \, eV$$

$$= 41.4 \times 10^{3} \, eV$$

Now,

Electric field = V/d= $\frac{41.4 \times 10^{3}}{1.5}$

=27.6 kV/m

Answer.8

Given:

Let λ be the initial wavelength, V be the initial potential

Hence, λ' be the new wavelength and V' be the new operating voltage

When the operating voltage of the X-ray tube is increased to 1.5 times

$$\lambda' = \lambda - 26pm$$

$$V' = 1.5V$$

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

$$eV = \frac{hc}{\lambda}$$

V- operating potential

$$\lambda = \frac{hc}{eV}$$

$$\lambda V = \lambda' V'$$

$$\lambda V = \lambda - 26 \times 1.5V$$

$$0.5\lambda = 26 \times 1.5$$

$\lambda = 78pm$

Therefore the initial wavelength is $78 \times 10^{-12}m$

Now, the operating voltage V is given by

$$V = \frac{hc}{e\lambda}$$

$$V = \frac{6.626 \times 10^{-34} \times 3 \times 10^{8}}{1.6 \times 10^{-19} \times 78 \times 10^{-12}}$$

$$V = 15.9\ kV$$

Answer.9

Given:

potential across the X-ray Tube V= 32kV

Equation relating wavelength and energy (In terms of eV) is given by

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

$$\lambda = \frac{1242 \times 10^{-9}}{32 \times 10^{3}}$$

$$\lambda = 38.8\ pm$$

Answer.10

Given:

potential applied to the X-ray tube V=40kV

Frequency of the X-ray= 9.7$\times 10^{18}hz$

wavelength of X-ray is given by,

$$\lambda = \frac{hc}{eV}$$

$$h = \frac{eV}{v}\ \because v = c/\lambda$$

$$h = \frac{40 \times 10^{3}}{9.7 \times 10^{18}} \times e$$

$$h = 4.12 \times 10^{-15}eVs$$

Answer.11

Given:

Potential of the X-ray tube V= 40kv

energy of the X-ray = $40 \times 10^3 eV$

Energy utilized by the electron is given by

$$E = \frac{70}{100} \times 40 \times 10^3 eV = 28 \times 10^3 eV$$

Wavelength of the X-ray is given by

$$\lambda = \frac{hc}{eV}$$

$$\lambda = \frac{1242 \times 10^{-9}}{28 \times 10^3}$$

$$\lambda = 44.35\ pm$$

for the second wavelength

E=30%

$$E = \frac{70}{100} \times (40 - 28) \times 10^3 eV = 84 \times 10^2 eV$$

Therefore,

$$\lambda = \frac{hc}{eV}$$

$$\lambda = \frac{1242 \times 10^{-9}}{84 \times 10^2}$$

$$\lambda = 148\ pm$$

For the third wavelength,

$$E = \frac{70}{100} \times (12 - 8.4) \times 10^3 eV = 25.2 \times 10^3 eV$$

$$\lambda = \frac{1242 \times 10^{-9}}{25.2 \times 10^2}$$

$$\lambda = 493\ pm$$

Answer.12

Given:

wavelength of X-ray = 21.3 pm

Energy required to knock out an electron from L-shell = 11.3 KeV

and the voltage required= 11.3 kV

The energy gap between K and L shell, is given by

$$E_k - E_L = \frac{1242 \times 10^{-9}}{21.3 \times 10^{-12}}$$

$$Ek - EL = 58.309\ KeV$$

$$EL = 11.3\ KeV$$

$$Ek = 69.609\ KeV$$

Thus the accelerating voltage across the X-ray tube for the production of kα ray is

V_k=69.609 keV

Answer.13

Given:

Wavelength of Kβ X-ray of argon= 0.36 nm

Energy required to ionize an argon atom= 16eV

Energy of Kβ x-ray of argon E is given by,

$$E = \frac{1242 \times 10^{-9}}{0.36 \times\ 10^{-9}}$$

E= 3450 eV

Energy needed to knock out an electron from K shell

Ek=3450+16 eV

Ek=3.47 KeV (approx.)

Answer.14

Given:

Kα X-rays of zinc and aluminum have wavelengths, respectively

$$\lambda 1 = 887\ \text{pm}$$

$$\lambda 2 = 146\ pm$$

By using the formula

$v = c/\lambda$

frequencies of Kα X-rays of zinc and aluminum, respectively are

$v1 = 33.82 \times 10^{20}$

$v2 = 2.055 \times 10^{18}$

Using Moseley's law √v = α (Z – b),

for Aluminum,

$5.815 \times 10^{8} = a(13 - b)$ …… (1)

for Zinc,

$1.4331 \times 10^{9} = a(30 - b)$ …… (2)

Dividing equations 1 by 2,

$$\frac{13 - b}{30 - b} = \frac{5.815 \times 10^{8}}{1.4331 \times 10^{9}}$$

solving. we get

b= 1.3949

Therefore

a = 5×10^{7}

for Fe(Iron), Frequency is given by

$v = 5 \times 10^{7}(26 - 1.39)$

$v = 123.05 \times 10^{7}$

By using the formula

$v = c/\lambda$

wavelength of Kα X-rays given out by Iron atom is given by

$$\lambda = \frac{3 \times 10^{8}}{5.1413 \times 10^{14}} = 198\ pm$$

Answer.15

Given:

Energy of Kα X-rays= 3.69 KeV or 3690 eV

we're asked to identify the element which exhibits this behavior,

Wavelength is given by

$$\lambda = \frac{hc}{eV}$$

$$\lambda = \frac{1242 \times 10^{-9}}{3690} = 0.34 \times 10^{-9} m$$

Using Moseley's law $\sqrt{c/\lambda} = \alpha(Z - b)$,

$$\frac{\sqrt{3 \times 10^8}}{\sqrt{0.34 \times 10^{-9}}} = 5 \times 10^7 (Z - 1.39)$$

$$9.39 \times 10^8 = 5 \times 10^7 (Z - 1.39)$$

$$(9.39 \times 10^8) = 5 \times 10^7 (Z - 1.39)$$

$$\frac{9.39}{5} = (Z - 1.39)$$

Which gives us,

$$Z = \frac{9.39}{5} + 1.39$$

Z=20.17 (atomic number) which can be approximated to Z=20

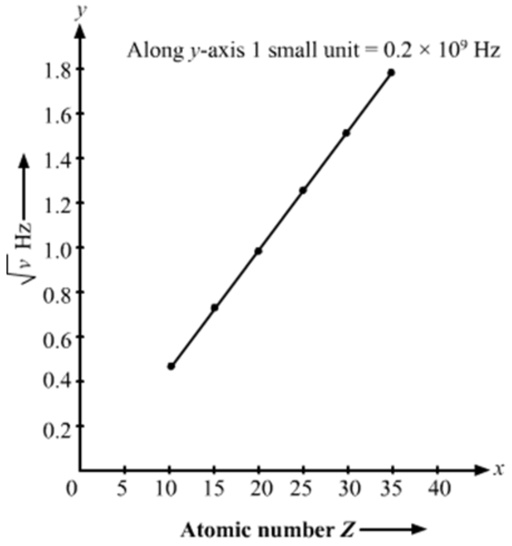
Therefore, the element with z=20 is calcium (Ca)

Answer.16

Given:

Element	Ne	P	Ca	Mn	Zn	Br
Energy (keV)	0.858	2.14	4.02	6.51	9.57	18.3

The required graph is as follows, the atomic number Z is plotted along x axis and $\sqrt{v}$ along y axis



Answer.17

Given:

Using Moseley's law

$$\frac{\sqrt{c}}{\lambda} = \alpha(Z - b), b = 1$$

comparing both conditions,

$$\frac{vLa}{vCu} = \left(\frac{ZLa - 1}{ZCu - 1}\right)^2$$

$$vLa = vCu\left(\frac{ZLa - 1}{ZCu - 1}\right)^2$$

$$vLa = 1.88 \times 10^{18}\left(\frac{ZLa - 1}{ZCu - 1}\right)^2$$

$$Wkt, ZLa = 57\ ZCu = 29$$

$$vLa = 1.88 \times 10^{18}\left(\frac{57 - 1}{29 - 1}\right)^2$$

$$vLa = 7.52 \times 10^{18} hz$$

Answer.18

Given:

$$K\alpha = Ek - EL\ \ldots (1)\ \lambda K\alpha = 0.71\ A^0$$

$K\beta = Ek - EM$ ... (2) $\lambda K\beta = 0.63\ A^0$

$L\alpha = EL - EM$ ... (3) $\lambda L\alpha = ??$

relating and comparing them together,

$K\alpha - K\beta = EM - EL = -L\alpha$

$$L\alpha = K\alpha - K\beta = \frac{3 \times 10^8}{0.63 \times 10^{-10}} - \frac{3 \times 10^8}{0.71 \times 10^{-10}}$$

simplifying

$L\alpha = 0.536 \times 10^{18} hz$

Therefore wavelength= $\lambda = {}^{c}/_{\vartheta} = \frac{3\times10^8}{0.536\times10^{18}}$

$= 5.6\ A^0$

Answer.19

Given:

wavelength of $k\alpha$ rays =21.3 pm

wavelength of $k\beta$ rays =141 pm

Energy of $k\alpha$ rays E1 is given by

$$E1 = \frac{1242}{21.3 \times 10^{-3}} = 58.309 \times 10^3 eV$$

Energy of $l\alpha$ rays E2 is given by

$$E2 = \frac{1242}{141 \times 10^{-5}}$$

$= 8.8085 \times 10^3 eV$

Energy of $k\beta$ rays E3 is given by

$E3 = E1 + E2$

$E3 = (58.309 + 8.809) \times 10^3 eV$

$E3 = 67.118 \times 10^3 eV$

wavelength of $k\beta$ is given by

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

$$= \frac{1242}{67.118 \times 10^3}$$

$= 18.5\ pm$

Answer.20

Given:

Energy of electron in the K shell Ek= 25.31 KeV

Energy of electron in the L shell EL=3.56 Kev

Energy of the electron in the M shell Em=0.530 keV

let v1 be the frequency of $k\alpha$ x-ray , v2 and v3 be of the $k\beta\ and\ l\alpha$ x-rays

kα x-ray is emitted when the transition takes place between $l\ and\ k\ shells$

$$K\alpha = Ek - EL = hv1v1 = \frac{Ek - EL}{h}v1 = \frac{25.31 - 3.56}{6.63 \times 10^{-34}} \times 1.6 \times 10^{-19} \times 10^3 v1 = 5.25 \times 10^{18} hz$$

kβ x-ray is emitted when the transition takes place between k and m shells

$$k\beta = Ek - Em = hv2v2 = \frac{25.31 - 0.53}{6.63 \times 10^{-34}} \times 1.6 \times 10^{-19} \times 10^3 v2 = 5.985 \times 10^{18} hz$$

Lα x-ray is emitted when the transition takes place between l and m shells

$$Kl = El - Em = hv3v3 = \frac{El - Em}{h}v3 = \frac{3.56 - 0.530}{6.63 \times 10^{-34}} \times 1.6 \times 10^{-19} \times 10^3 v3 = 7.32 \times 10^{17} hz$$

v1=5.25×10^{18} hz

v2=5.985×10^{18} hz

v3=7.32×10^{17} hz

v1,v2 and v3 are the frequencies of $K\alpha, k\beta\ and\ L\alpha$ x-rays

Answer.21

Given:

Cell containing vacancy	K	L	M
Energy in keV	69.5	11.3	2.3

The potential that must be set across the X ray tube without emitting any characteristic K or l rays be 'V'

Energy of the electron relation, is given by

$E = eV$

This is the energy gap that L shells sit in. Therefore, If the voltage were to be set to a point without emitting any characteristic X rays,

The maximum potential difference that can be applied will be

11.3 eV, which corresponds to L shell.

Answer.22

Given:

operating voltage= 40Kv

current = 10mA

1% of total kinetic energy gives X-rays

$$i = ne \text{ or } n = \frac{10^{-2}}{1.6 \times 10^{-19}}$$

n=0.625×10^{17} (number of electrons)K.E of one electron=eV=$1.6\times10^{-19}\times40\times10^{3}$=$6.4\times10^{-15}$ joulesT_{ke}= $0.625\times6.4\times10^{17}\times10^{-15}$$T_{ke}$= 4×10^{2} joules

b) Heat produced in the target per second

=400-4=396 Joules of heat

Answer.23

Given:

Heat produced per second= power(P)=200W

operating potential= 20Kv

we have to find the current in the circuit

power is given by the equation, P=VI

V- potential difference and I- current

$I = \frac{ne}{t}$ ∵ since current is number of electrons passing per unit time

where, e= charge on an electron

n - no. of electrons

$P = \frac{neV}{t} 200 = \frac{neV}{t}\left(\frac{ne}{t}\right) V = 200$this gives,

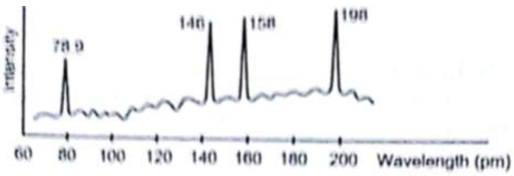
$$I = \frac{200}{v}$$

$I = \frac{200}{20\times10^{3}} = 10\ mA$, is the current in the circuit.

Answer.24

Given:

v = (25 × 10^{14} HZ) $(Z – 1)^2$.



Using Moseley's equation

v = (25 × 10^{14} HZ) (Z – $1)^2$ $or \frac{c}{\lambda} = (25 \times 10^{14})(Z-1)^2$

I case

λ = 78.9× 10^{-12} mTherefore, $\frac{3 \times 10^8}{78.9 \times 10^{-12} \times 25 \times 10^{14}} = (Z-1)^2$

$(Z-1)^2 = 0.00152 \times 10^6 = 1520$

$z = 39.98 = 40(approx.)$Element with z = 40 is Zr - zirconium

II case

$\lambda = 146 \times 10^{-12} m$

$therefore,$

$$\frac{3 \times 10^8}{146 \times 10^{-12} \times 25 \times 10^{14}} = (Z-1)^2$$

$(Z-1)^2 = 0.000822 \times 10^6$

$z = 29.669 = 30(approx.)$Element with z =30 is Zn-zinc

III case

$\lambda = 158 \times 10^{-12} m$

Therefore,

$$\frac{3 \times 10^8}{158 \times 10^{-12} \times 25 \times 10^{14}} = (Z-1)^2$$

$(Z-1)^2 = 0.000759 \times 10^6$

$z = 28.5589 = 29(approx.)$Element with z = 29 is Cu-copper

VI case

$\lambda = 198 \times 10^{-12} m$

therefore,

$$\frac{3 \times 10^8}{198 \times 10^{-12} \times 25 \times 10^{14}} = (Z-1)^2$$

$(Z-1)^2 = 0.000606 \times 10^6$

Z = 25.6162 = 26(approx.)Element with Z = 26 is Fe-Iron

The elements Present in the polluted water are Zirconium, Zinc, Copper and Iron.

Answer.25

Given:

Energy of the X-ray= 6.4 keV

E= 6.4 KeV = $6.4 \times 10^3 eV$

Mass M an iron atom = 9.3 × 10^{-26} kg.

Momentum of the photon is given by

$$= \frac{E}{c} = \frac{6.4 \times 10^3}{3 \times 10^8}$$

=3.41×10^{-24} kg/sec

According to conservation of momentum,

momentum of photon= momentum of atom

Hence, momentum of the atom

p=3.41×10^{-24} kg/sec

Recoil K.E of the atom, given by

$$= \frac{P^2}{2M}$$

$$= \frac{(3.41 \times 10^{-24})^2}{2 \times 9.3 \times 10^{-26} \times 1.6 \times 10^{-19}} \because wkt\ 1\ joule = 1.6 \times 10^{-19} eV$$

Recoil K.E of the atom = 3.9 eV

Answer.26

Given:

Stopping potential is proportional to inverse of wavelength (1/λ)

let Vo be the stopping potential

v_1 and λ_1 be the operating frequency and voltage of the x-ray tubev_2 and λ_2 be the cut- off frequency and voltage of the x-ray tube$eV_0 = hv_1 - hv_2$since ,

$$\lambda 1 = \frac{hc}{eV}\text{and}$$

$$eV_0 = \frac{hc}{\lambda_2} V\lambda_1 = \frac{hc}{e}\ and\ V_0\lambda_2 = \frac{hc}{e}$$

in the above equations, slopes are the same

$\therefore V_0\lambda_2 = V\lambda_1$

$$= \frac{hc}{e} = \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{1.6 \times 10^{-19}}$$

Value of the slope= 1.242×10^{-6} Vm

Answer.27

wavelength of mono-chromatic beam $(\lambda) = 100 \times 10^{-12} m$

distance of screen from the slit $(D) = 40 \times 10^{-2}\ m$

Distance between successive maxima $(\beta) = 0.1 \times 10^{-3} m$

formula relating λ, D and β, given by

$$\beta = \frac{\lambda D}{d}$$

here, d is the separation between the slits

$= \frac{100 \times 10^{-12} \times 40 \times 10^{-2}}{10^{-3} \times 0.1}$ Distance between separation of each slit $= 4 \times 10^{-7} m$