Physics · Introduction to Modern Physics

Atomic Spectra

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questions	sets	pages

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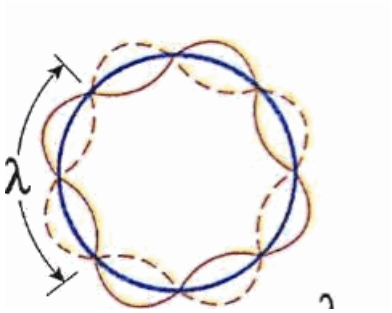
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Multiple choice questions — 101 questions

1 An electron moves in the energy shell (n = 4) around the nucleus of a hydrogen atom, accompanied by a standing wave of wavelength λ as in the opposite figure. The radius of the shell is .....



(A) $(4\lambda)/(\pi)$ (B) $(2\lambda)/(\pi)$ (C) $(\lambda)/(\pi)$ (D) $(\lambda)/(2\pi)$

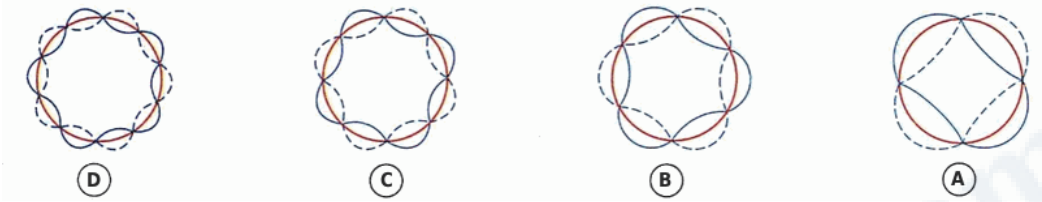
2 According to Bohr's model, if the wavelength of the wave accompanying the motion of an electron in one of the energy levels of a hydrogen atom equals πr, where (r) is the radius of the electron's level, then this electron revolves in the energy level .....

(A) K (B) L (C) M (D) N

3 Which of the following values can be the wavelength of the wave accompanying the motion of the electron in a hydrogen atom, given that (r) is the radius of the orbit?

(A) 5 πr (B) 3 πr (C) 2 πr (D) $4/3\ \pi r$

4 If the wavelength accompanying the motion of an electron in an orbit of a hydrogen atom is 13.32 Å and the circumference of this orbit is 53.3 Å according to Bohr's model, which of the following figures shows the standing wave accompanying the motion of the electron in this orbit?

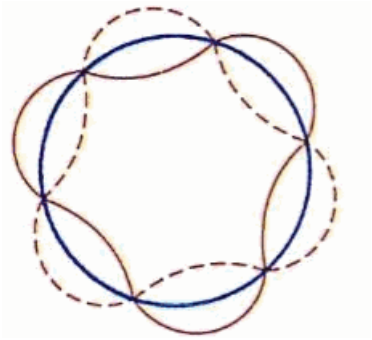


5 An electron moves at 7.28×10^5 m/s in the third orbit of a hydrogen atom. The radius of the third orbit equals .....

(A) 4.77×10^{-10} m (B) 9.54×10^{-10} m (C) 1×10^{-9} m (D) 47.7×10^{-9} m

6 The opposite figure shows the pattern of a standing wave accompanying the electron of a hydrogen atom in one of its energy shells according to Bohr's model:

(1) The order of the orbit (n) of this electron from the nucleus is .....

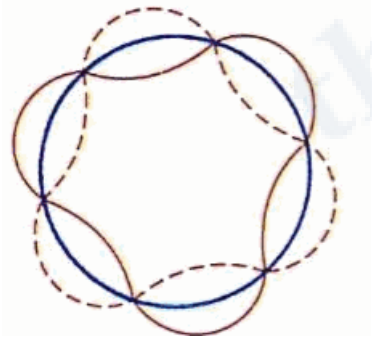


(A) 1 (B) 2 (C) 3 (D) 4

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7 The opposite figure shows the pattern of a standing wave accompanying the electron of a hydrogen atom in one of its energy shells according to Bohr's model:

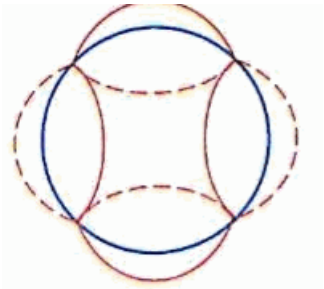
(2) If the radius of the shell of this electron is 4.761×10^{-10} m, the wavelength of the standing wave accompanying the electron equals .....



(A) 1.5×10^{-9} m (B) 3×10^{-9} m (C) 7.49×10^{-10} m (D) 9.98×10^{-10} m

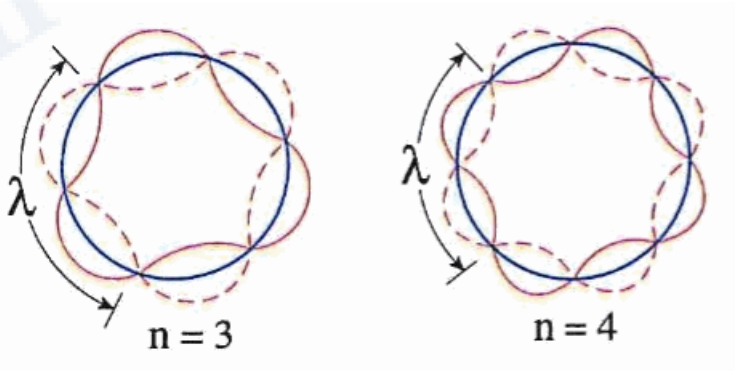
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8 The opposite figure shows the standing wave accompanying the motion of the electron of a hydrogen atom in one of the orbits. If the speed of the electron in this orbit is 1.09×10^{6} m/s, the radius of the orbit equals .....



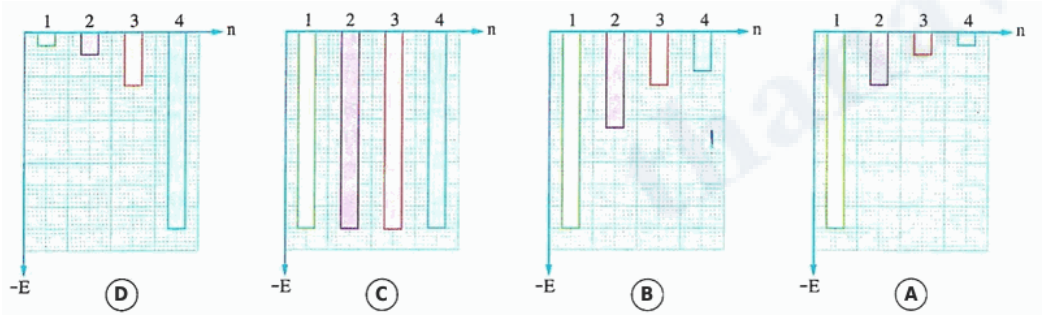
(A) 1.06×10^{-10} m (B) 2.13×10^{-10} m (C) 4.25×10^{-10} m (D) 6.68×10^{-10} m

9 The opposite figure represents two energy levels in a hydrogen atom. The ratio between the speeds of the electron in the two cases in terms of the radii of the two orbits (v_3/v_4) is .....



(A) $3r_3/4r_4$ (B) $4r_3/3r_4$ (C) $3r_4/4r_3$ (D) $4r_4/3r_3$

10 Which of the following graphs represents the relation between the energy of the level (– E) and the order of the level (n) for a hydrogen atom according to Bohr's model?



11 The electron stays stable in its ground energy level when it is .....

(A) gaining continuous energy (B) gaining quantized energy
(C) not gaining energy (D) losing continuous energy

12 For an electron to move from a lower energy level E_1 to a higher energy level E_2, the atom .....

(A) absorbs a photon of energy $(E_2 - E_1)$ (B) emits a photon of energy $(E_1 - E_2)$
(C) absorbs a photon of energy $(E_1 + E_2)$ (D) emits a photon of energy $(E_1 + E_2)$

13 The electron of a hydrogen atom moved from the level of energy −3.4 eV to the level of energy −13.6 eV. This means that the hydrogen atom .....

(A) absorbed a photon of energy 10.2 eV (B) absorbed a photon of energy 17 eV
(C) emitted a photon of energy 10.2 eV (D) emitted a photon of energy 17 eV

14 The electron of a hydrogen atom revolves in the first energy level (K):

(1) The least energy that frees the electron from the atom equals .....

(A) 13.6 eV (B) 10.2 eV (C) 0.85 eV (D) 3.4 eV

15 The electron of a hydrogen atom revolves in the first energy level (K):

(2) The longest wavelength of a photon absorbed by the hydrogen atom that ionizes it equals .....

(A) 9.1×10^{-8} m (B) 8.4×10^{-8} m (C) 8.1×10^{-8} m (D) 8.6×10^{-8} m

16 The least amount of energy enough to excite a hydrogen atom from the ground energy level equals .....

(A) 13.6 eV (B) 6.8 eV (C) 10.2 eV (D) 3.4 eV

17 An electron in an atom moved from the higher energy level E_2 to the lower energy level E_1. The wavelength of the emitted photon is found from the relation .....

(A) $(E_2 - E_1)/hc$ (B) $hc/E_2 - hc/E_1$ (C) $hc/(E_2 - E_1)$ (D) $c/(h(E_2 - E_1))$

18 The longest wavelength in the Lyman series is emitted when the electron moves between the levels .....

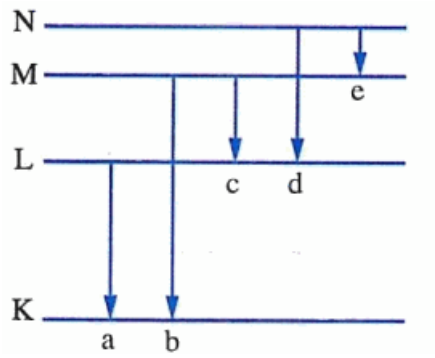
(A) $n = 3 \rightarrow n = 2$ (B) $n = \infty \rightarrow n = 2$ (C) $n = \infty \rightarrow n = 1$ (D) $n = 2 \rightarrow n = 1$

19 The highest frequency of a photon emitted in the Brackett series comes from the electron moving between the two energy levels .....

(A) $n = 5 \rightarrow n = 4$ (B) $n = 4 \rightarrow n = 3$ (C) $n = \infty \rightarrow n = 4$ (D) $n = \infty \rightarrow n = 3$

20 The opposite figure represents possible transitions of the electron in a hydrogen atom. The photon produced by:

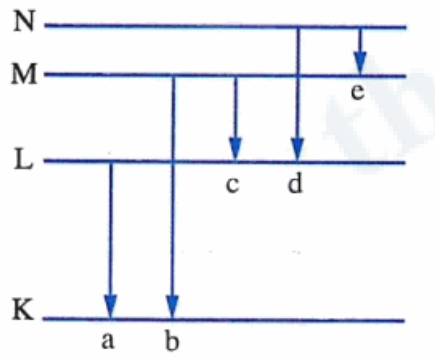
(1) transition (a) has an energy of .....



(A) 2.2×10^{-18} J (B) 1.9×10^{-18} J (C) 1.6×10^{-18} J (D) 1.1×10^{-18} J

21 The opposite figure represents possible transitions of the electron in a hydrogen atom. The photon produced by:

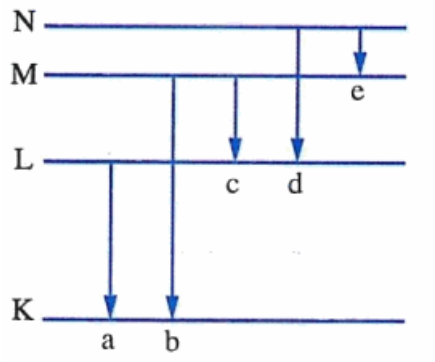
(2) transition (b) has a frequency of .....



(A) 1.5×10^{15} Hz (B) 2.1×10^{15} Hz (C) 2.5×10^{15} Hz (D) 2.9×10^{15} Hz

22 The opposite figure represents possible transitions of the electron in a hydrogen atom. The photon produced by:

(3) transition (c) has a wavelength of about .....

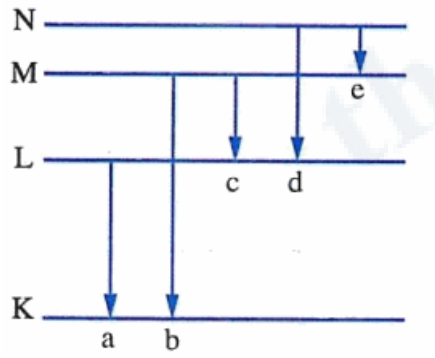


(A) 328 nm (B) 657 nm (C) 948 nm (D) 984 nm

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23 The opposite figure represents possible transitions of the electron in a hydrogen atom. The photon produced by:

(4) transition (d) has a momentum of .....



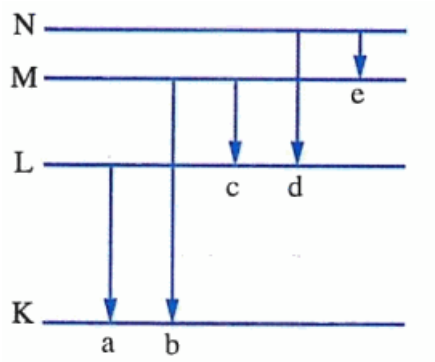
(A) 5.44×10^{-27} kg.m/s (B) 2.72×10^{-27} kg.m/s

(C) 1.36×10^{-27} kg.m/s (D) 1.12×10^{-27} kg.m/s

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24 The opposite figure represents possible transitions of the electron in a hydrogen atom. The photon produced by:

(5) transition (e) has an equivalent mass of .....



(A) 1.2×10^{-36} kg (B) 2.4×10^{-36} kg (C) 3.6×10^{-36} kg (D) 4.8×10^{-36} kg

25 The shortest wavelength in the Balmer series is about .....

(A) 3943 Å (B) 3850 Å (C) 3653 Å (D) 3450 Å

26 The shortest wavelength in the Pfund series equals .....

(A) 21652 Å (B) 22834 Å (C) 23161 Å (D) 23558 Å

27 The ratio between the longest wavelength in the Lyman series and the longest wavelength in the Balmer series of the hydrogen spectrum is .....

(A) *5/27* (B) *3/23* (C) *7/27* (D) *9/31*

28 The ratio of the longest wavelength to the shortest wavelength in the Lyman series of the hydrogen spectrum equals .....

(A) *25/9* (B) *17/6* (C) *9/5* (D) *4/3*

29 If the shortest wavelength in the Lyman series is (λ), the shortest wavelength in the Balmer series is .....

(A) $(\lambda)/4$ (B) $(\lambda)/2$ (C) $2\ \lambda$ (D) $4\ \lambda$

30 In a hydrogen atom, if ν_1 is the lowest frequency in the Paschen series and ν_2 is the lowest frequency in the Balmer series, the ratio $((\nu_1)/(\nu_2))$ is .....

(A) *7/20* (B) *4/3* (C) *20/7* (D) *5/2*

31 In a hydrogen atom, if the energy of the second level is (–E), the energy of the third level is .....

(A) –9 E (B) $-E/9$ (C) $-4/9$ E (D) $-9/4$ E

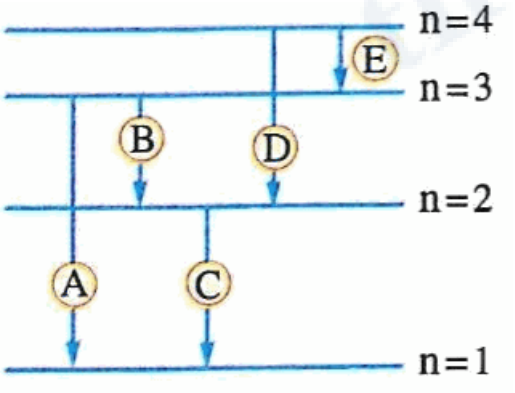
32 The electron of a hydrogen atom moves in a certain level of radius r_n. If the de Broglie wavelength accompanying its motion in this level equals $(2\pi r_n)/5$, the least energy that must be given to the electron so that it leaves the atom completely equals .....

(A) 0.544 eV (B) 0.942 eV (C) 2.72 eV (D) 3.4 eV

33 An electron in a hydrogen atom fell from an energy level of order n to the first level, and the atom emitted a photon of wavelength 9.51×10^{-8} m. If the energy of the first level is -2.176×10^{-18} J, then n equals .....

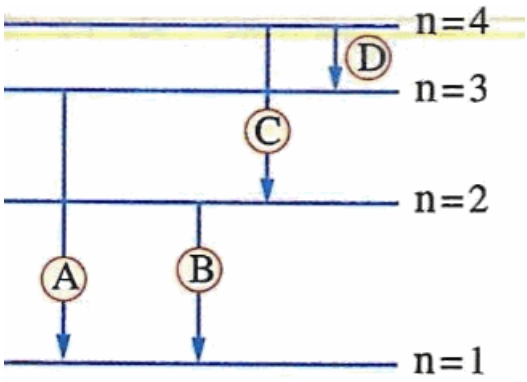
(A) 6 (B) 5 (C) 4 (D) 3

34 The opposite figure represents several transitions A, B, C, D, E of the electron of a hydrogen atom between energy levels. Which of these transitions give a spectral line in the Balmer series?



(A) A, B (B) A, C (C) E only (D) B, D

35 The opposite figure shows four transitions of the electron of a hydrogen atom between energy levels. Which of the following statements is correct?



(A) Transition D gives a spectral line of the shortest wavelength

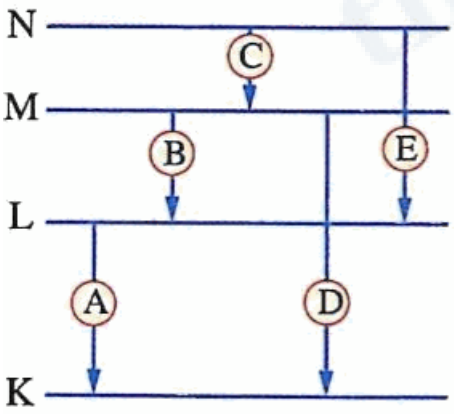
(B) Transition C gives a spectral line in the ultraviolet region

(C) Transition B gives a spectral line in the infrared region

(D) Transition A gives the highest frequency among these transitions

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36 The opposite figure represents several transitions A, B, C, D, E of the electron of a hydrogen atom between energy levels. Which of the following statements is NOT correct?



(A) Transition C gives a spectral line in the infrared region

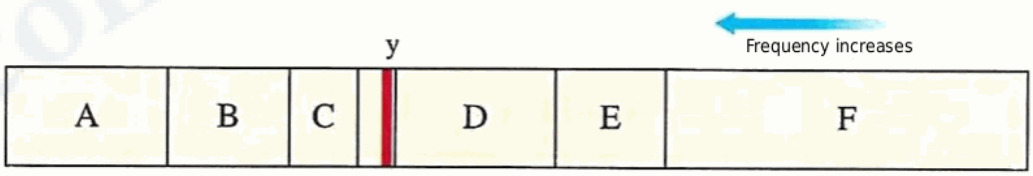
(B) Transition D gives the shortest wavelength among these transitions

(C) Transition E gives the highest frequency among these transitions

(D) Transition B gives a spectral line in the visible light region

---

37 The following figure represents the regions of the electromagnetic spectrum. If line y represents a red spectral line emitted from a hydrogen atom, in which of the regions shown does the spectrum emitted from a hydrogen atom lie when the electron moves from the energy level (O) to the energy level (M)?



(A) Region A (B) Region B (C) Region C (D) Region D

38 The photon that a hydrogen atom can absorb to be excited from its ground level to a higher level belongs to the region of .....

(A) radio waves (B) visible light (C) ultraviolet rays (D) infrared rays

39 When two photons (a) and (b) of energies 4.91 eV and 10.2 eV respectively pass by a hydrogen atom in its ground level, which of the two photons can the atom absorb and be excited?

(A) Photon (a) (B) Photon (b) (C) Both photons (D) Neither photon

40 The ratio between the momentum of a photon emitted in the Lyman series and the momentum of a photon emitted in the Balmer series is .....

(A) equal to one (B) greater than one
(C) less than one (D) the information is not enough to decide

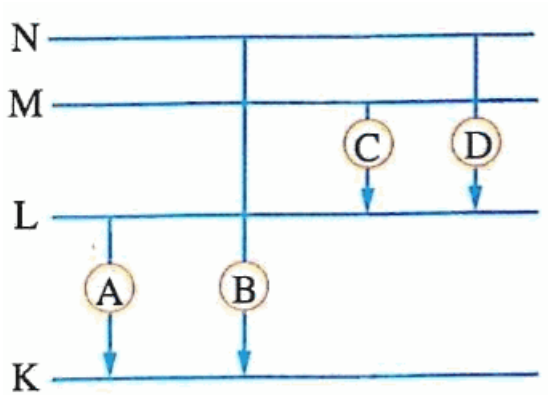
41 If an atom has four possible energy levels for the electron's motion, and the electron can move between any two of them, the number of spectral lines that can be emitted is .....

(A) 3 (B) 6 (C) 8 (D) 10

42 If the energy of the electron of a hydrogen atom in one of its levels equals −3.4 eV, and the radius of the orbit of this level is 2.13 Å, the de Broglie wavelength accompanying the motion of the electron in this level is .....

(A) 13.38 Å (B) 9.99 Å (C) 6.69 Å (D) 3.33 Å

43 The opposite figure shows several possible transitions of the electron in a hydrogen atom, each giving one of the wavelengths of the line spectrum of hydrogen. Which of the following choices is correct?



(A) $\lambda_A < \lambda_B$ (B) $\lambda_C < \lambda_D$ (C) $\lambda_D < \lambda_B$ (D) $\lambda_A < \lambda_D$

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44 If the shortest wavelength in one of the series of the hydrogen spectrum is 14610 Å, the name of this series and its longest wavelength are .....

(A) series: Paschen, longest wavelength: 9671 Å

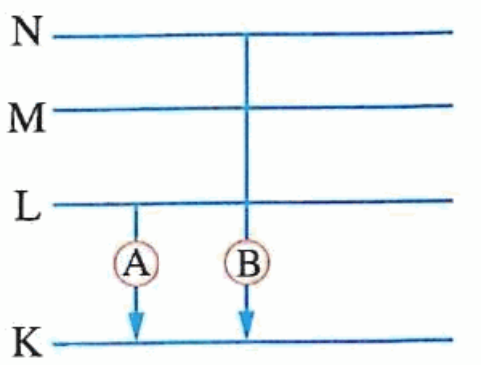
(B) series: Brackett, longest wavelength: 9671 Å

(C) series: Pfund, longest wavelength: 60443 Å

(D) series: Brackett, longest wavelength: 40594 Å

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45 The opposite figure shows two possible transitions of the electron in a hydrogen atom. The ratio of the wavelength of the photon from transition A to the wavelength of the photon from transition B $((\lambda_A)/(\lambda_B))$ equals .....



(A) $(E_L - E_K)/(E_N - E_K)$ (B) $(E_N - E_K)/(E_L - E_K)$

(C) E_L/E_N (D) E_N/E_L

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46 The opposite table shows the energies of some energy levels in a hydrogen atom. If the electron of a hydrogen atom is excited in an energy level of order n, and the equivalent mass of the photon emitted when it moves from level n to the first level is 2.267×10^{-35} kg, then n equals .....

Level	Level energy (eV)
K	– 13.6
L	– 3.4
M	– 1.51
N	– 0.85
O	– 0.544

(A) 2 (B) 3 (C) 4 (D) 5

47 When hydrogen atoms in the ground level are excited by monochromatic electromagnetic radiation whose photon energy is 12.75 eV, the number of spectral lines that may be emitted in:

(1) the Lyman series is .....

(A) 1 (B) 2 (C) 3 (D) 4

48 When hydrogen atoms in the ground level are excited by monochromatic electromagnetic radiation whose photon energy is 12.75 eV, the number of spectral lines that may be emitted in:

(2) the Balmer series is .....

(A) 1 (B) 2 (C) 3 (D) 4

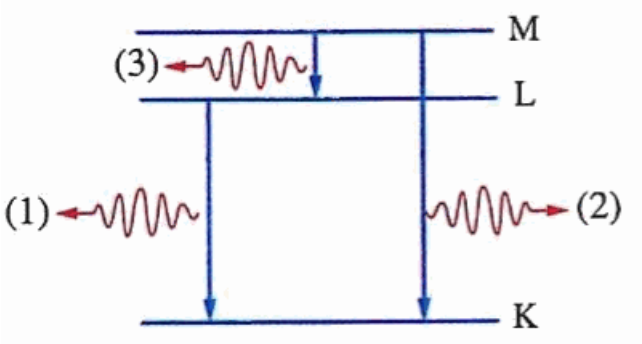
49 A hydrogen atom in the ground level was excited by a photon of wavelength 975 Å. The level the atom was excited to and the number of spectral lines that may be emitted when the atom relaxes are, respectively, ...

(A) L, 6 (B) L, 1 (C) N, 6 (D) N, 1

50 When the electron of a hydrogen atom moves from the fifth level to the second level, the wavelength of the emitted radiation is ..... (given that $E_1 = -13.6$ eV)

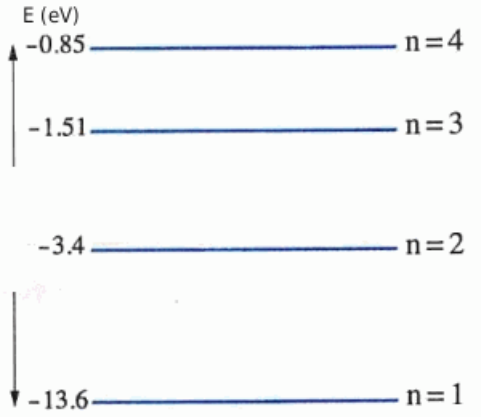
(A) 2283 Å (B) 4349.4 Å (C) 6959 Å (D) 12421.9 Å

51 The opposite figure represents the electron moving between energy levels in an atom of an element. If the wavelengths of photons (1) and (2) are 304.45 nm and 256.86 nm respectively, the wavelength of photon (3) equals .....



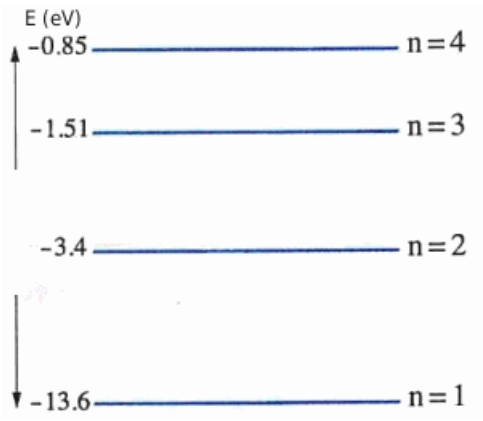
(A) 1643 nm (B) 1800 nm (C) 1928 nm (D) 2428 nm

52 From the opposite figure, when the electron of a hydrogen atom is in the fourth energy level: (1) the number of possible emissions of photons of different frequencies in this case equals .....



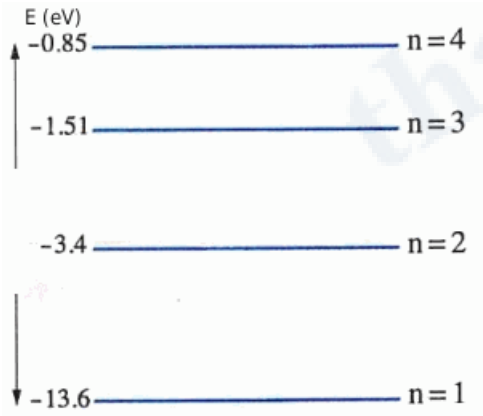
(A) 4 (B) 6 (C) 8 (D) 10

53 From the opposite figure, when the electron of a hydrogen atom is in the fourth energy level:
(2) the lowest frequency of a photon that can be emitted from the atom in this case is .....



(A) 1.3×10^{13} Hz (B) 9.96×10^{13} Hz (C) 3.08×10^{15} Hz (D) 1.59×10^{14} Hz

54 From the opposite figure, when the electron of a hydrogen atom is in the fourth energy level:
(3) the highest frequency of a photon that can be emitted from the atom in this case is .....

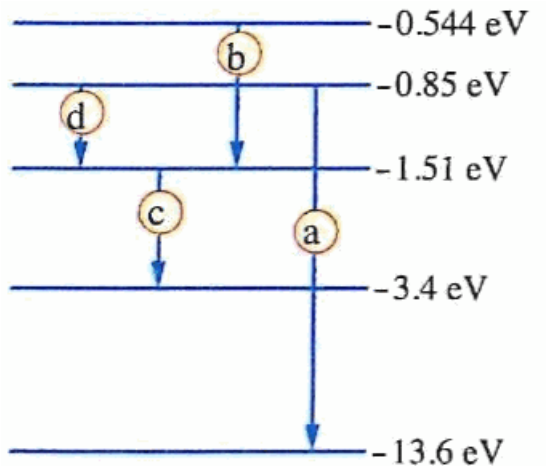


(A) 2.1×10^{13} Hz (B) 1.92×10^{14} Hz (C) 3.08×10^{15} Hz (D) 6.59×10^{15} Hz

55 When the photon produced by the electron of a hydrogen atom returning from the third orbit to the first orbit falls on the cathode of a photocell, an electron is emitted from the cathode with a kinetic energy of 9.79 eV. The work function of the cathode surface equals .....

(A) 2.1 eV (B) 2.3 eV (C) 4.3 eV (D) 4.7 eV

56 The opposite figure shows four transitions a, b, c, d of the electron of a hydrogen atom between energy levels. Which of these transitions produces a photon of wavelength 656 nm?



(A) Transition a (B) Transition b (C) Transition c (D) Transition d

57 A hydrogen atom emitted a photon of wavelength 486.3 nm:

(1) The energy of the photon equals .....

(A) 2 eV (B) 2.55 eV (C) 3 eV (D) 3.55 eV

58 A hydrogen atom emitted a photon of wavelength 486.3 nm:

(2) The two levels the electron moved between are .....

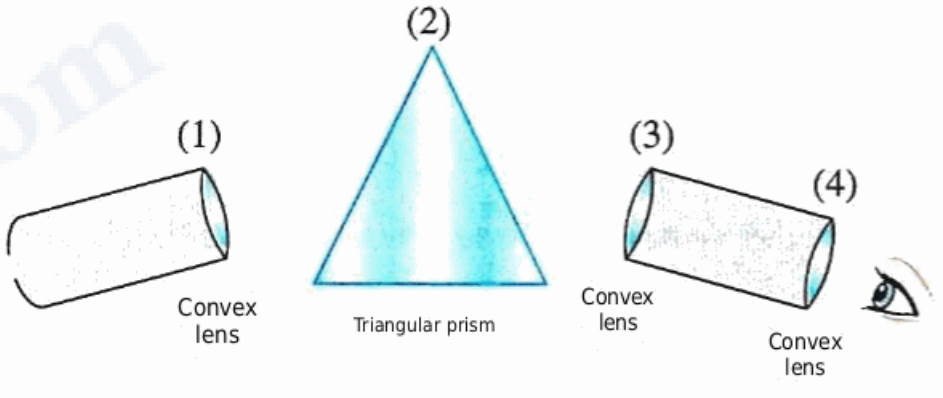
(A) the fourth level to the first level (B) the fourth level to the second level

(C) the third level to the first level (D) the third level to the second level

59 An excited electron in a hydrogen atom falls from one of the higher energy levels (x) to the ground energy level in two successive steps, emitting photons of wavelengths 2624 nm and 97.45 nm respectively. The order of the energy level (x) the excited electron fell from is .....

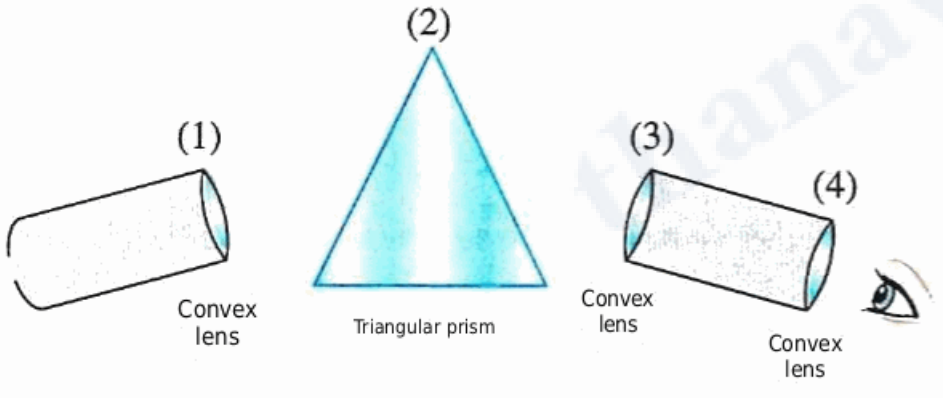
(A) 2 (B) 3 (C) 5 (D) 6

60 The opposite diagram shows the optical parts of a spectrometer. The part that:
(1) separates the spectra according to their wavelengths is .....



(A) (1) (B) (2) (C) (3) (D) (4)

61 The opposite diagram shows the optical parts of a spectrometer. The part that:
(2) collects the rays of each colour at its own focus on the focal plane is .....



(A) (1) (B) (2) (C) (3) (D) (4)

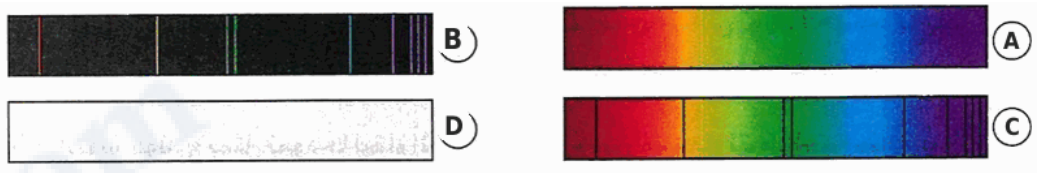
62 The emission spectrum of elements arises from an electron in the atom moving from .....

(A) a higher energy level to a lower level
(B) a lower energy level to a higher level
(C) the ground level to the nucleus
(D) the ground level to outside the atom

63 When light from a tungsten lamp passes through sodium vapour and the light coming out of the vapour is analysed, we get .....

(A) coloured lines on a dark background
(B) coloured lines on a white background
(C) dark lines on a coloured background
(D) a continuous coloured region

64 Which of the following drawings shows the absorption spectrum of an element?

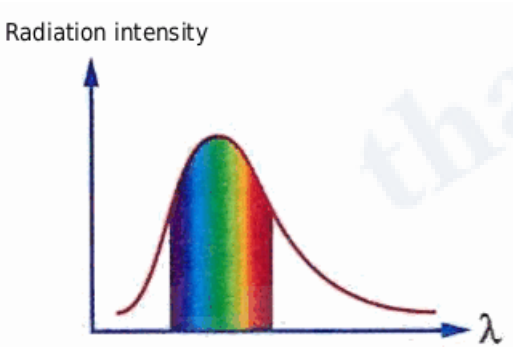


65 The opposite figure shows a spectrum produced by a spectrometer. Which of the following choices represents the source of this spectrum?



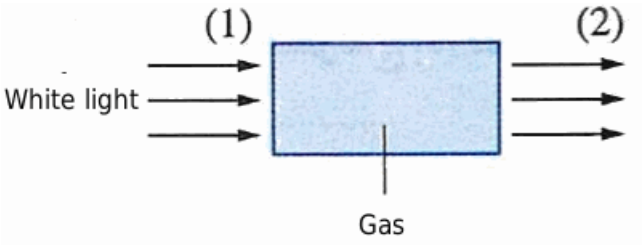
(A) a tungsten lamp
(B) a neon lamp
(C) a hot gas
(D) white light after passing through a gas

66 The opposite graph represents a ..... spectrum.



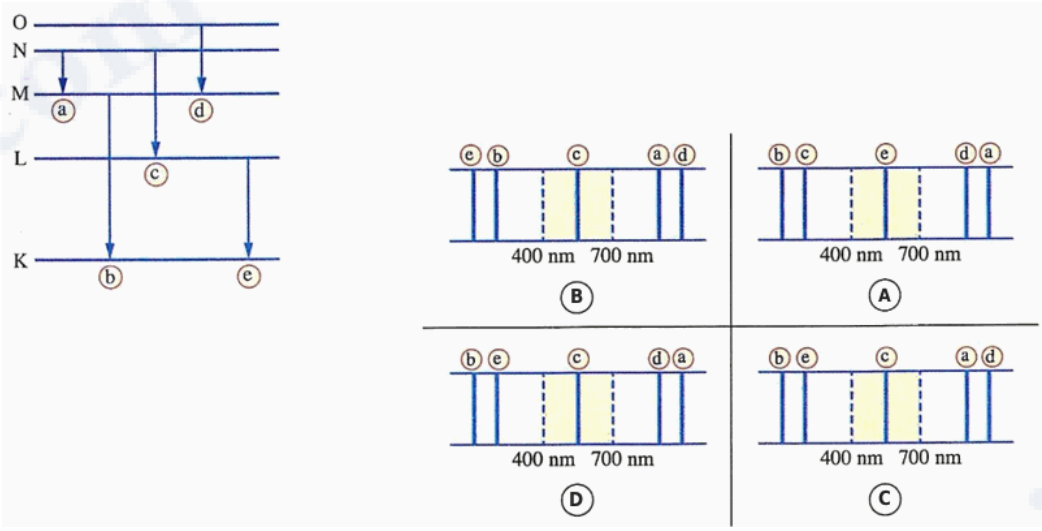
(A) continuous
(B) line emission
(C) line absorption
(D) monochromatic

67 When white light (spectrum (1)) passes through a gas as in the figure, and the resulting spectrum (spectrum (2)) is passed through a spectrometer, we get .....



(A) a continuous spectrum
(B) a line emission spectrum
(C) dark lines on a bright background
(D) bright lines on a dark background

68 The opposite figure represents possible transitions a, b, c, d, e of the electrons in hydrogen atoms. Which of the following choices represents the spectral lines formed in the spectrometer because of these transitions?



69 When X-rays pass perpendicular to a strong uniform magnetic field, they .....

(A) are not deflected from their path

(B) are deflected opposite to the direction of the field

(C) are deflected perpendicular to the direction of the field

(D) speed up

70 The penetrating power of the X-rays produced by a Coolidge tube does not depend on .....

(A) the range of wavelengths of the produced rays

(B) the energy of the electrons hitting the target

(C) the filament current

(D) the potential difference applied between the cathode and the anode

71 Producing X-rays in a Coolidge tube is an example of conservation of energy. What is the correct order of the energy changes, starting from the electrons leaving the filament until they hit the target?

(A) mechanical energy, then electrical energy, then electromagnetic energy

(B) electromagnetic energy, then mechanical energy, then electrical energy

(C) electrical energy, then mechanical energy, then electromagnetic energy

(D) electrical energy, then electromagnetic energy, then mechanical energy

72 An excited hydrogen atom cannot emit an X-ray spectrum because .....

(A) the energy of its K level is less than the energy of X-ray photons

(B) the energy of its K level is higher than the energy of X-ray photons

(C) the energy of its L level is higher than the energy of X-ray photons

(D) the energy of its M level is higher than the energy of X-ray photons

---

73 In a Coolidge tube, if the potential difference across the two ends of the filament is doubled, the wavelength of the line spectrum of the X-rays .....

(A) doubles

(B) is halved

(C) does not change

(D) becomes three times

---

74 The wavelength of the characteristic X-ray spectrum depends on .....

(A) the current through the filament

(B) the potential difference between the filament and the target

(C) the material of the target

(D) the air pressure inside the tube

---

75 Two X-ray photons z and y come from a Coolidge tube. Photon z came from an electron moving between two energy levels in a tungsten atom as in figure (1), and photon y came from an electron passing close to the nucleus of a tungsten atom as in figure (2). Which photon belongs to the continuous X-ray spectrum?



(A) Photon (y)

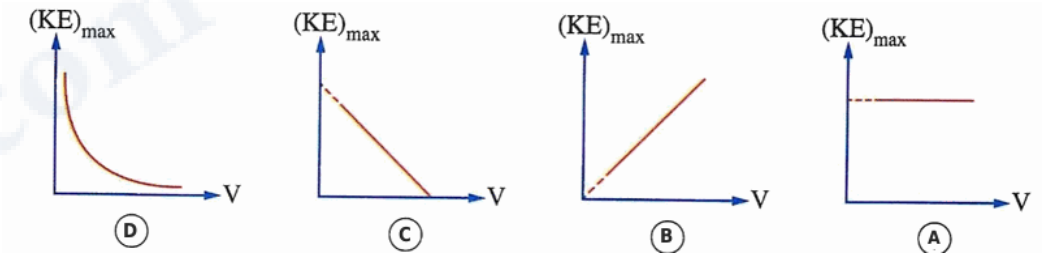
(B) Photon (z)

(C) Both photons

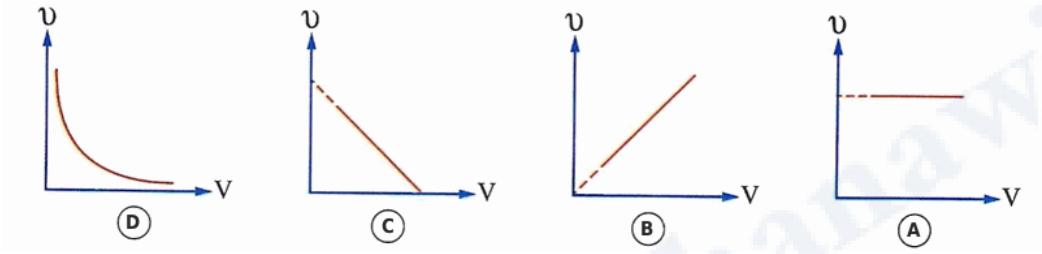
(D) Neither photon

---

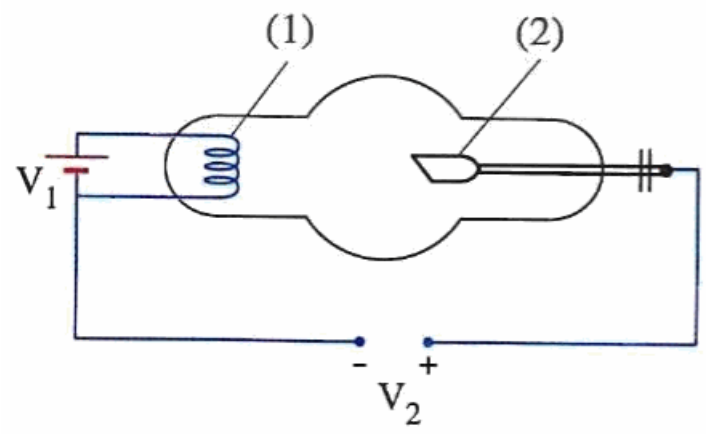
76 Which of the following graphs represents the relation between the maximum kinetic energy $(KE)_{max}$ of the electron emitted from the cathode in a Coolidge tube and the potential difference (V) between the anode and the cathode?



77 Which of the following graphs represents the relation between the maximum frequency (υ) of the photons of the continuous X-ray spectrum produced by a Coolidge tube and the potential difference (V) between the anode and the cathode?



78 The opposite figure represents a Coolidge tube. Which of the following choices changes the shortest wavelength of the continuous spectrum of the emitted X-rays?



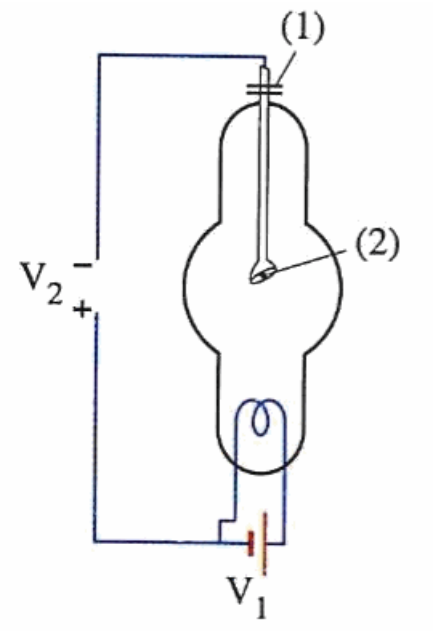
(A) Changing the potential difference V_1

(B) Changing the potential difference V_2

(C) Changing the material of component (1)

(D) Changing the material of component (2)

79 The opposite diagram shows a Coolidge tube that failed to produce X-rays although the values of the potential differences V_1 and V_2 are suitable. For the tube to produce X-rays, we must .....



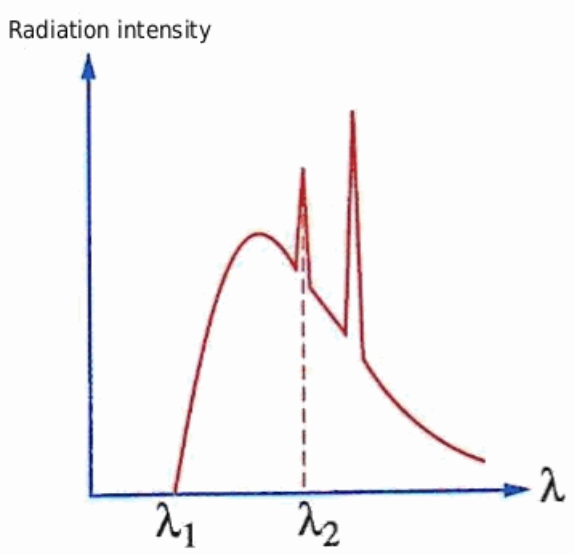
(A) make component (1) of a heating coil

(B) make component (2) of aluminium

(C) reverse the poles of the voltage source V_1

(D) reverse the poles of the voltage source V_2

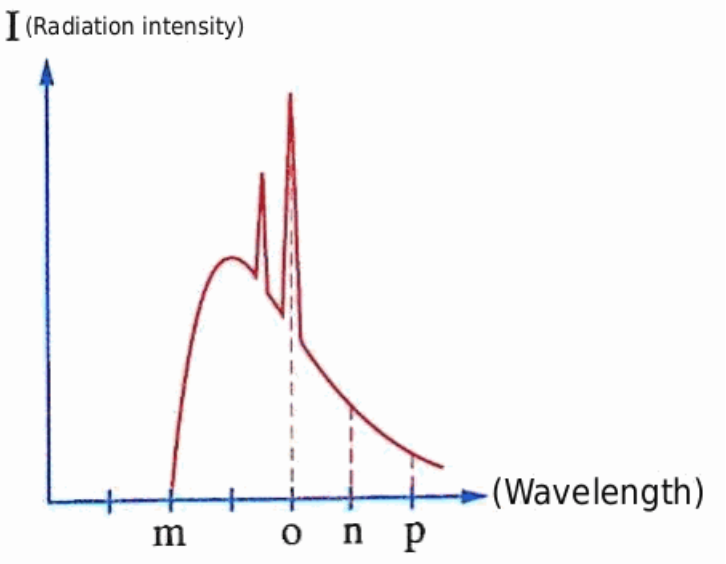
80 The opposite figure represents the relation between the wavelength (λ) of the X-rays produced by a Coolidge tube and their intensity. If the potential difference between the filament and the target increases, the value of ..... decreases.



(A) λ_1 only
(B) λ_2 only
(C) both λ_1 and λ_2
(D) neither λ_1 nor λ_2

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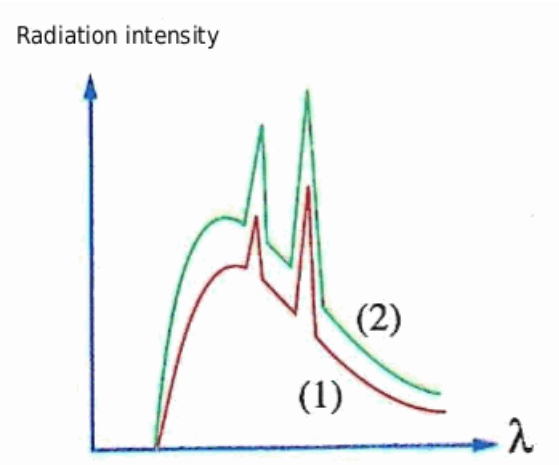
81 The figure represents the X-ray spectrum emitted from a Coolidge tube. Which wavelength is emitted because an electron in a target atom moves from a higher energy level to a level close to the nucleus?



(A) wavelength (m)
(B) wavelength (o)
(C) wavelength (n)
(D) wavelength (p)

---

82 The opposite graph represents the X-ray spectrum emitted from a Coolidge tube before and after a certain change, shown by curves (1) and (2) respectively. This change happened because of .....



(A) increasing both the potential difference between the anode and the cathode and the atomic number of the target material

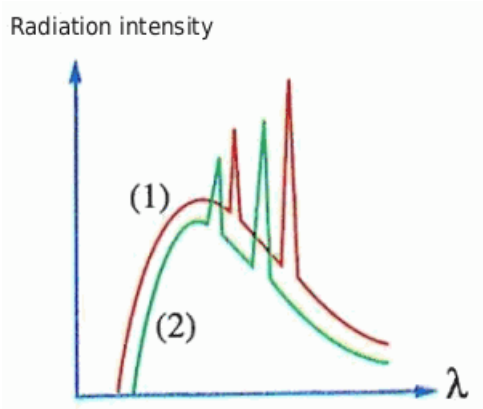
(B) decreasing both the potential difference between the anode and the cathode and the atomic number of the target material

(C) increasing the filament current and decreasing the atomic number of the target material

(D) increasing the filament current only

---

83 The opposite figure shows the relation between the intensity of the X-rays and their wavelength (λ) produced by two Coolidge tubes working at two different potential differences V_1, V_2 with targets of two different elements of atomic numbers Z_1, Z_2. So .....



(A) $V_1 > V_2$ and $Z_1 > Z_2$

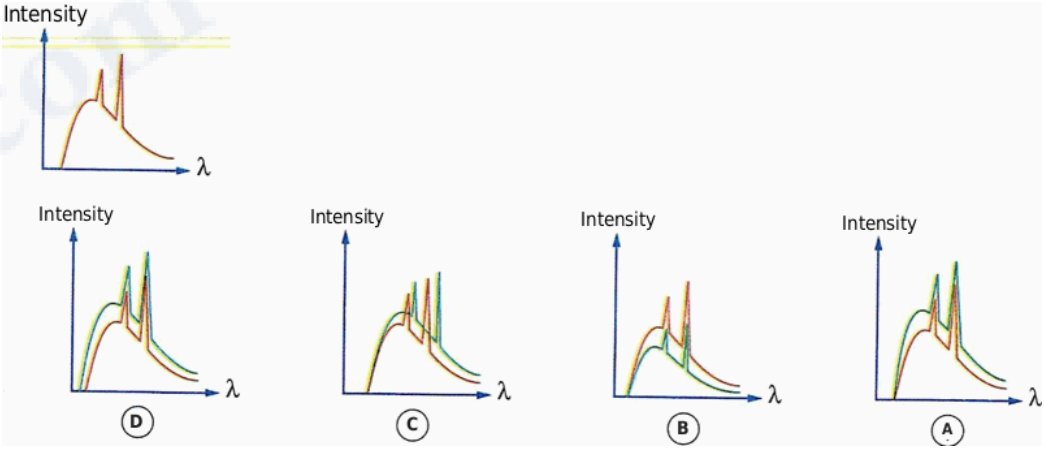
(B) $V_1 > V_2$ and $Z_1 < Z_2$

(C) $V_1 < V_2$ and $Z_1 = Z_2$

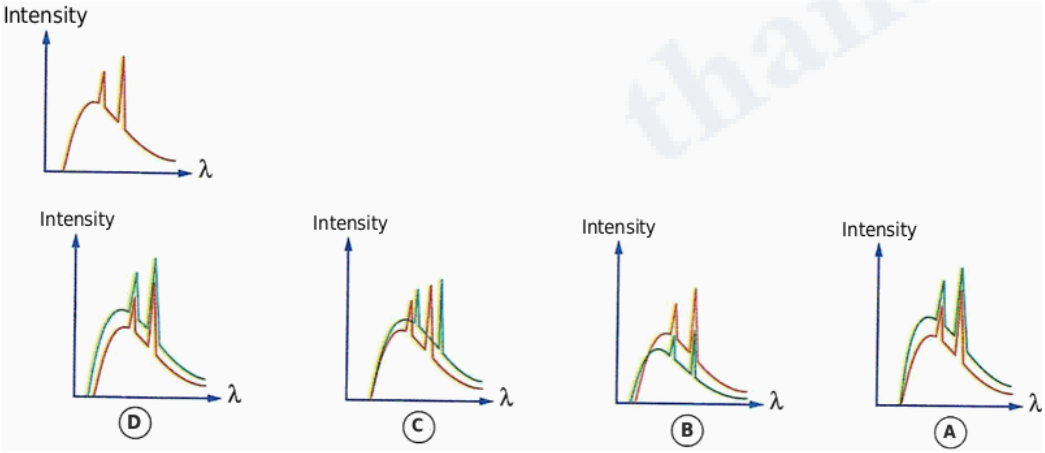
(D) $V_1 < V_2$ and $Z_1 < Z_2$

---

84 The opposite graph represents the X-ray spectrum emitted from a Coolidge tube. Which of the following graphs compares this spectrum with the spectrum of the tube after increasing the filament current?



85 The opposite graph represents the X-ray spectrum emitted from a Coolidge tube. Which of the following graphs compares this spectrum with the spectrum of the tube after increasing the potential difference between the anode and the cathode?



86 If the shortest wavelength of the X-rays emitted from a Coolidge tube is 0.414 Å:

(1) the highest energy of the X-ray photons equals .....

(A) 1.6×10^{-16} J (B) 4.8×10^{-16} J (C) 1.6×10^{-15} J (D) 4.8×10^{-15} J

87 If the shortest wavelength of the X-rays emitted from a Coolidge tube is 0.414 Å:

(2) the potential difference between the anode and the cathode equals .....

(A) 10×10^{3} V (B) 28×10^{3} V (C) 30×10^{3} V (D) 48×10^{3} V

88 If the potential difference between the anode and the cathode of an X-ray tube is 13255 V, the highest frequency of the continuous spectrum of these rays is .....

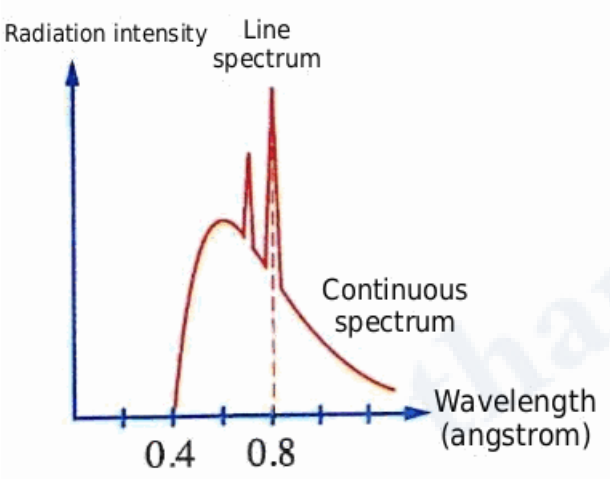
(A) 3.2×10^{19} Hz (B) 2×10^{19} Hz (C) 3.2×10^{18} Hz (D) 2×10^{18} Hz

89 In an X-ray tube the maximum kinetic energy of the accelerated electron was 5×10^{-18} J. The shortest wavelength of the produced rays equals .....

(A) 1.325×10^{-8} m (B) 3.975×10^{-8} m (C) 1.325×10^{-9} m (D) 3.975×10^{-9} m

90 The opposite figure shows the spectrum of X-rays emitted from a Coolidge tube:

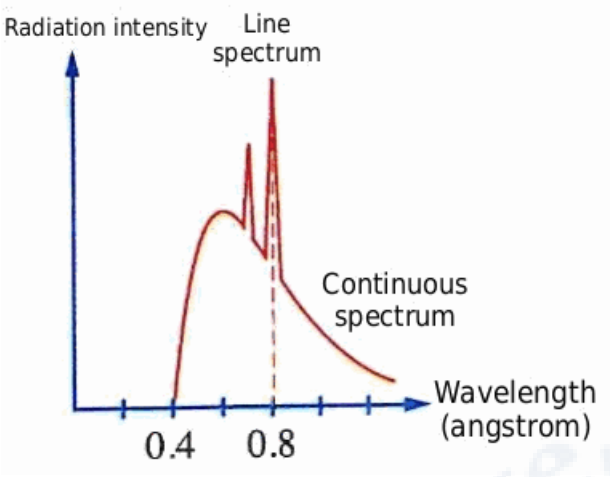
(1) The potential difference between the filament and the target equals .....



(A) 31.05×10^{3} V (B) 3.22×10^{3} V (C) 9.7×10^{4} V (D) 2.01×10^{4} V

91 The opposite figure shows the spectrum of X-rays emitted from a Coolidge tube:

(2) The highest frequency of the emitted X-rays is .....



(A) 3.75×10^{16} Hz (B) 3.75×10^{18} Hz (C) 7.5×10^{16} Hz (D) 7.5×10^{18} Hz

92 Figure (1) is a graph of the relation between the intensity of the X-rays emitted from a Coolidge tube and the energy (E) of their photons, and figure (2) shows the transitions inside one of the atoms of the target material used in that tube that cause the line spectrum shown in figure (1). Using figures (1) and (2):

(1) the potential difference between the anode and the cathode of the tube equals .....

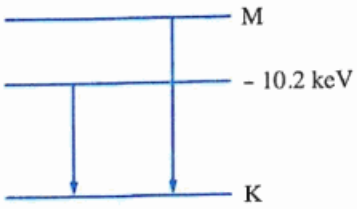


Figure (2)

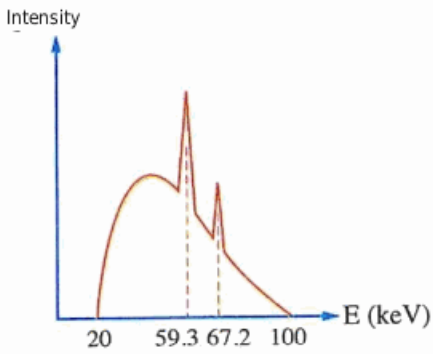


Figure (1)

(A) 20 kV (B) 59.3 kV (C) 67.2 kV (D) 100 kV

93 Figure (1) is a graph of the relation between the intensity of the X-rays emitted from a Coolidge tube and the energy (E) of their photons, and figure (2) shows the transitions inside one of the atoms of the target material used in that tube that cause the line spectrum shown in figure (1). Using figures (1) and (2):

(2) the energies of levels K and M in the atoms of the target material are, respectively, ...

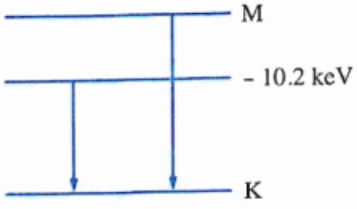


Figure (2)

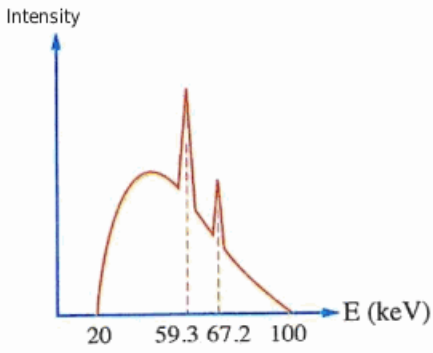


Figure (1)

(A) −57 keV, −2.3 keV (B) −69.5 keV, −2.3 keV

(C) −49.1 keV, −4.6 keV (D) −69.5 keV, −4.6 keV

94 If the current of the electron stream in a Coolidge tube is 7 mA with a potential difference of 30 kV between the filament and the target:

(1) the maximum energy of the electrons hitting the target equals .....

(A) 4.8×10^{-14} J (B) 4.8×10^{-15} J (C) 4.8×10^{-16} J (D) 4.8×10^{-18} J

---

95 If the current of the electron stream in a Coolidge tube is 7 mA with a potential difference of 30 kV between the filament and the target:

(2) the maximum speed of the electron when it reaches the target is .....

(A) 72.63×10^{6} m/s (B) 51.36×10^{6} m/s (C) 10.27×10^{7} m/s (D) 1.1×10^{8} m/s

---

96 If the current of the electron stream in a Coolidge tube is 7 mA with a potential difference of 30 kV between the filament and the target:

(3) the number of electrons reaching the target every second is .....

(A) 4.375×10^{13} electrons (B) 4.375×10^{16} electrons

(C) 4.375×10^{19} electrons (D) 4.375×10^{22} electrons

---

97 If the current of the electron stream in a Coolidge tube is 7 mA with a potential difference of 30 kV between the filament and the target:

(4) the shortest wavelength of the emitted X-rays equals .....

(A) 414 Å (B) 41.4 Å (C) 4.14 Å (D) 0.414 Å

---

98 In a Coolidge tube, if the shortest wavelength of the emitted X-rays is 25 pm, the wavelength accompanying the fastest electrons hitting the target is about .....

(A) 4 pm (B) 4.5 pm (C) 5 pm (D) 5.5 pm

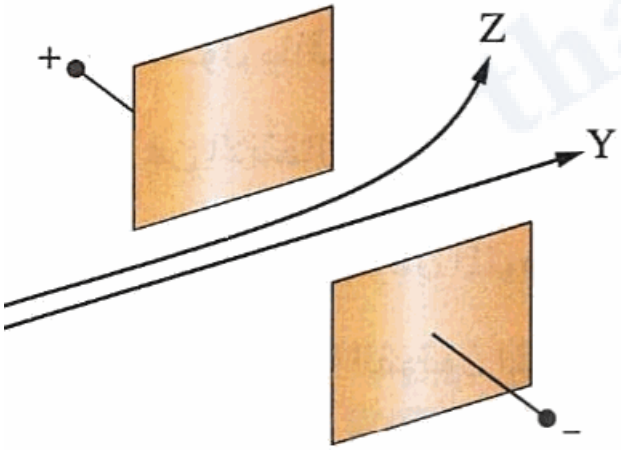
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99 The opposite figure shows an image of a hand taken with X-rays. Using X-rays to image bones and find fractures depends on .....



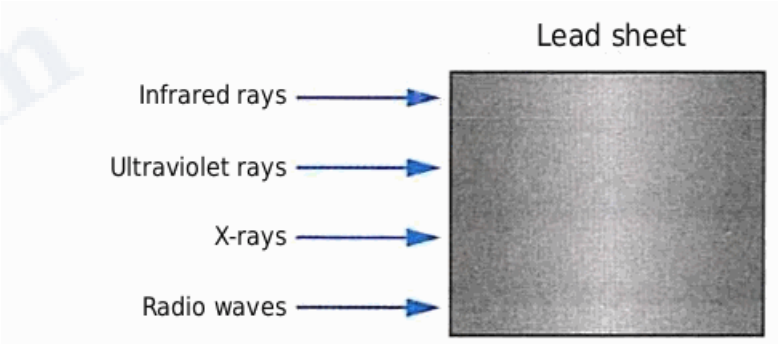
(A) their wide spectral range
(B) their high speed
(C) their short wavelength
(D) their wave nature

100 Two beams Z and Y pass between two parallel charged plates as in the opposite figure. The two beams are, respectively, ...



(A) cathode rays, X-rays
(B) X-rays, cathode rays
(C) X-rays, laser
(D) laser, cathode rays

101 Four different types of electromagnetic radiation fall on a thick lead plate as in the opposite figure. Which of these radiations travels the longest distance through the lead plate?



(A) infrared rays (B) ultraviolet rays (C) X-rays (D) radio waves

Essay questions — 27 questions

1 If the energy of the first level of a hydrogen atom is -13.6 eV and the radius of the electron's path in this level is 0.53 Å, calculate according to Bohr's model:

(1) the wavelength of the matter wave accompanying the electron in the first level.

(2) the speed of the electron in the first level.

(3) the wavelength of the photon needed to excite the electron from the first energy level to the third energy level.

2 What happens when hydrogen atoms are excited by different quanta of energy?

3 Explain: no spectral line in any spectral series of hydrogen has the same wavelength as another spectral line.

4 The electron of a hydrogen atom was excited to a certain level of energy -0.85 eV and radius 8.48 Å. According to Bohr's model, calculate:

(1) the order of the level counted from the nucleus.

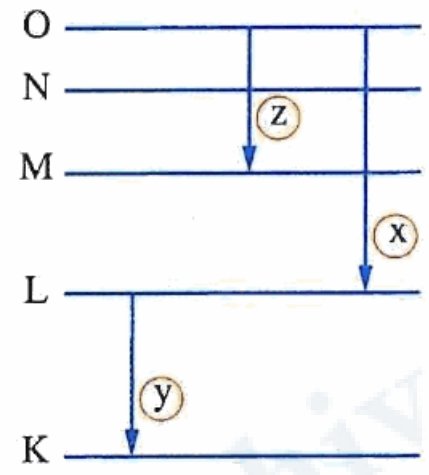
(2) the wavelength accompanying the electron in this level.

(3) the speed of the electron in this level.

5 The opposite figure represents three possible transitions (x), (y), (z) of the electron in a hydrogen atom. Explain why:

(1) the energy of the photon from transition (x) is less than the energy of the photon from transition (y).

(2) the two photons emitted from transitions (y) and (z) are in the range of invisible rays, while the photon emitted from transition (x) is in the range of visible rays.



6 What is the least equivalent mass of a photon that can be emitted from a hydrogen atom in the Lyman series?

7 What is the least momentum of a photon that can excite a hydrogen atom from the ground level?

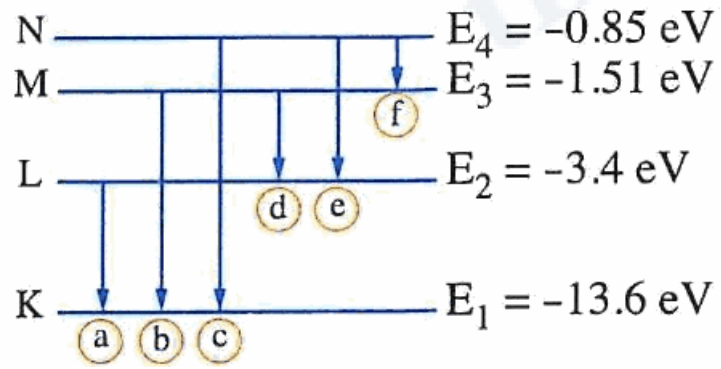
8 In a hydrogen atom, the electron moves in an energy level of radius r, and the wavelength accompanying its motion is $2\pi r$. Calculate the longest wavelength of a photon that can free this electron from the atom.

9 If the longest wavelength in the Lyman series is λ, find the longest wavelength in the Pfund series in terms of λ.

10 The opposite figure represents six transitions of the electron in a hydrogen atom from higher energy levels to lower ones. Suppose the emitted photons fall on the cathode surface of a photocell whose work function is 2.14 eV:

(1) How many electrons can be freed from the cathode?

(2) Which photon frees an electron with the greatest speed?

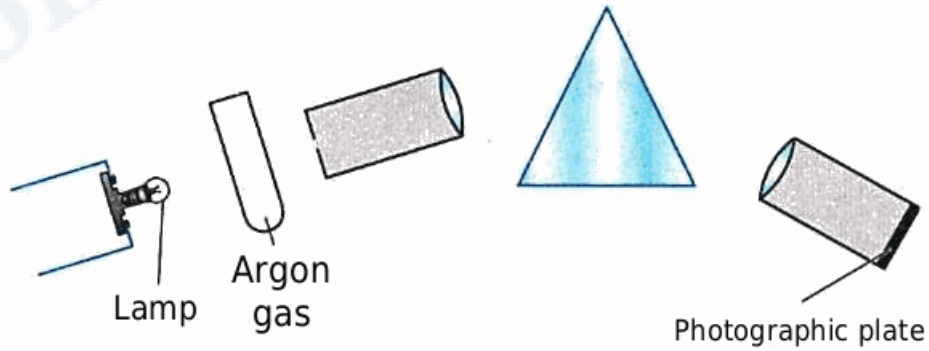


11 Compare: the line absorption spectrum and the line emission spectrum of an element.

12 The opposite figure shows a spectrometer used to analyse spectra. When the light source is switched on, describe the resulting spectrum when:

(1) the argon gas tube is between the lamp and the spectrometer.

(2) the argon gas tube is not between the lamp and the spectrometer.



13 How can the spectrometer be used to tell two different elements apart?

14 Explain how studying the atomic spectrum helped discover the composition of the Sun's atmosphere.

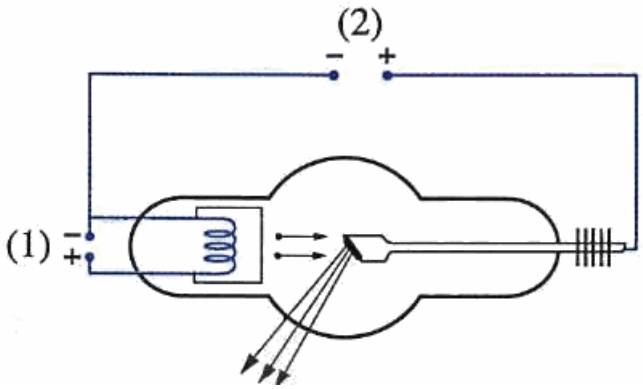
15 The opposite figure shows the structure of a Coolidge tube:

(1) Compare the values of potential differences (1) and (2) and the role of each.

(2) Show the energy changes that take place in the tube until X-rays are produced.

(3) What phenomenon is responsible for the emission of electrons from the cathode? Why are these electrons emitted?

(4) What are the properties of the material used for: (a) the target? (b) the filament?



16 In a Coolidge tube:

(1) Why is the positive electrode (anode) made of copper and fitted with cooling fins?

(2) How can you change the penetrating power of the produced X-rays through materials?

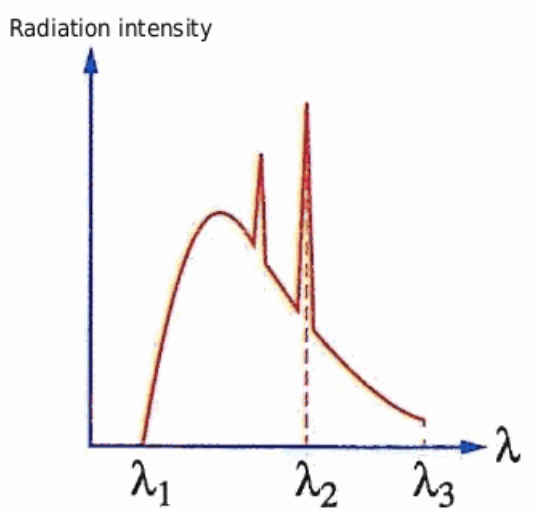
(3) How can you change the intensity of the produced X-rays?

17 Explain why the characteristic line spectrum of X-rays in a Coolidge tube is emitted only when the potential difference between the filament and the target is greater than a certain value.

18 The opposite graph represents the X-ray spectrum emitted from a Coolidge tube. Explain:

(1) the origin of the continuous range of wavelengths from λ_1 to λ_3

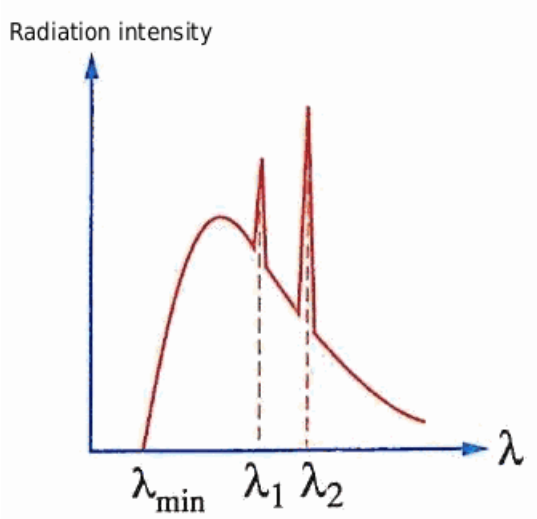
(2) the probable reason for the presence of radiation of wavelength: (a) λ_1 (b) λ_2



19 The opposite graph represents the X-ray spectrum. If the characteristic X-ray spectrum comes from electrons of the target material falling from levels n = 2 and n = 3 to level n = 1, state with explanation which of the two wavelengths λ_1, λ_2 comes from the transition:

(1) from n = 2 to n = 1

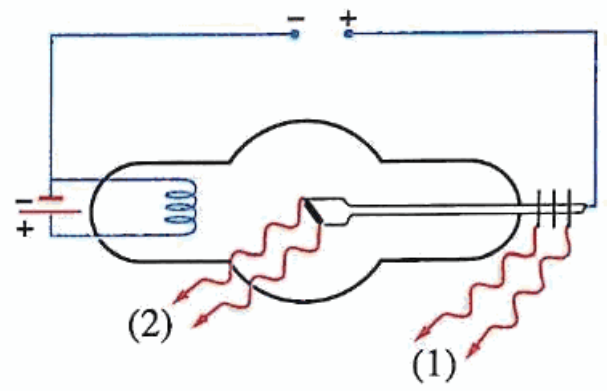
(2) from n = 3 to n = 1



20 The opposite figure shows a Coolidge tube that produces two different types of electromagnetic radiation (1) and (2). Which type:

(1) has photons of greater momentum?

(2) is used to find the crystal structure of solids?



21 What type of energy goes into a Coolidge tube and what type comes out of it? Which of these is wasted energy?

22 Give a reason: a Coolidge tube produces electromagnetic rays of very high frequencies.

23 In a Coolidge tube, if the maximum momentum of the electrons when they hit the target is $63.7 \times 10^{-25}\ kg.m/s$, calculate the shortest wavelength of the emitted X-rays.

24 An X-ray tube works at a potential difference of 40 kV. If the electron current through the tube is 5 mA, calculate:

(1) the number of electrons hitting the target per second.

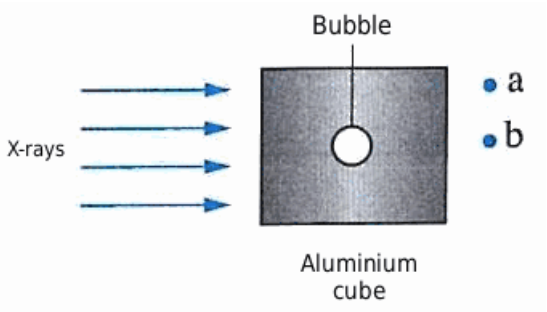
(2) the rate of electrical energy used in the tube.

(3) the rate of energy of the produced X-rays if the efficiency of the tube is 2%

25 What are the results of X-rays passing through a sample of gas?

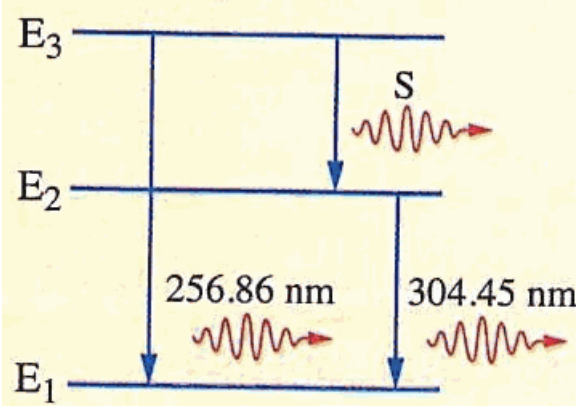
26 Explain why X-rays, rather than visible light, are used at ports and airports to inspect the contents of bags.

27 X-rays were directed at an aluminium cube with a gas bubble inside it, as in the opposite figure. Compare the intensity of the X-rays at points a and b, then explain how this can be used to detect internal structural defects in metals.



Past exam questions — 45 questions

1 The opposite diagram shows some energy levels of an excited atom that emits photons, each produced when an electron moves from a higher energy level to a lower one. The wavelength of photon (S) is about ..... (Trial exam 2023)



(A) 2250 nm (B) 1643 nm (C) 3000 nm (D) 450 nm

---

2 A photon fell on an electron in the ground level of a hydrogen atom, and the electron moved to the energy level (N). The wavelength of the incident photon = ... (1st session 2023)

(A) $1.56 \times 10^{-26}\ m$ (B) $1.56 \times 10^{-8}\ m$ (C) $9.74 \times 10^{-26}\ m$ (D) $9.74 \times 10^{-8}\ m$

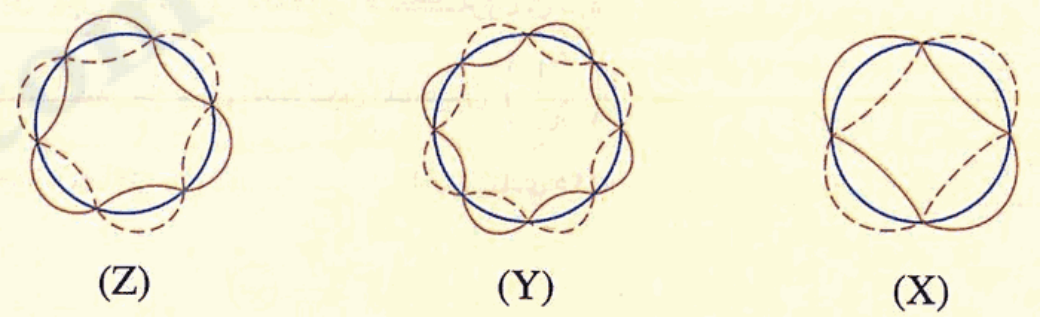
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3 The longest wavelength of the visible spectrum emitted from a hydrogen atom is about ..... (2nd session 2023)

(A) 6760 Å (B) 5670 Å (C) 6576 Å (D) 7570 Å

---

4 The following figures show the standing wave accompanying the motion of the electron in three energy levels X, Y, Z according to Bohr's model of the hydrogen atom. Which of the following choices is correct? (1st session 2024)



(A) A visible light photon is released when the electron moves from level (Y) to level (Z)

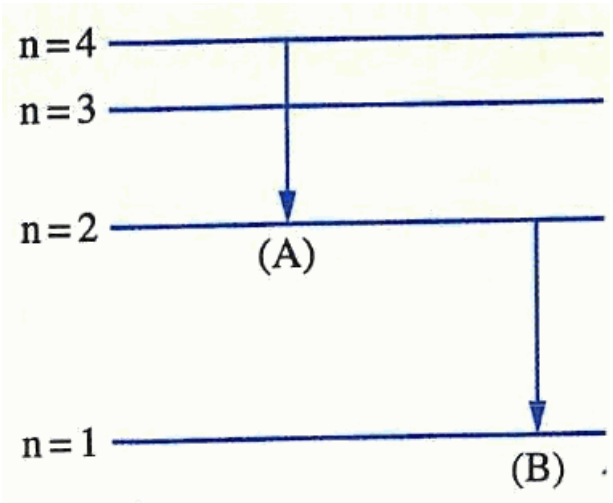
(B) The energy of level (Z) is less than the energy of level (X)

(C) The energy difference between levels (Z, X) is greater than the energy difference between levels (Y, Z)

(D) The energy of level (X) is greater than the energy of level (Y)

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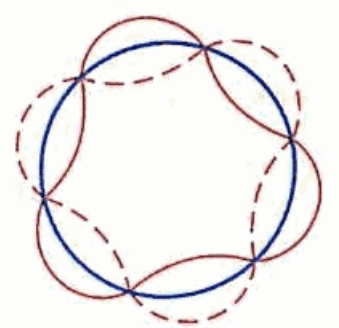
5 The figure shows possible transitions of the electron between energy levels in a hydrogen atom. The ratio of the frequency of the spectrum from transition A $(upsilon_A)$ to the frequency of the spectrum from transition B $(upsilon_B)$ equals ..... (1st session 2024)



(A) *4/1* (B) *1/4* (C) *2/1* (D) *1/2*

---

6 According to Bohr's model of the hydrogen atom and the figure shown, which of the following choices is correct when the electron returns from one of the higher energy levels to this level? (2nd session 2024)



(A) A photon in the ultraviolet region is produced

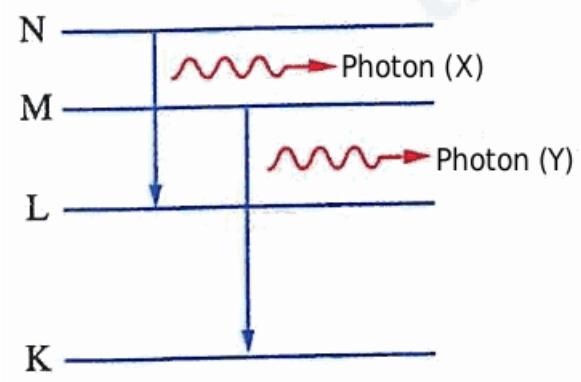
(B) A photon in the infrared region is produced

(C) A photon in the visible spectrum is produced

(D) A photon in the X-ray region is produced

---

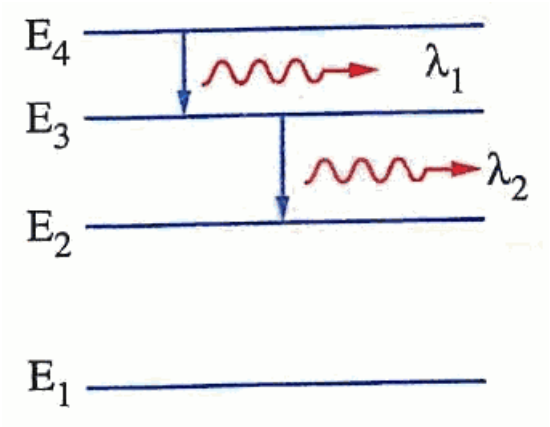
7 The opposite diagram represents two possible transitions of the electron in a hydrogen atom. The ratio of the momentum of photon (X) to the momentum of photon (Y) = ... (2nd session 2024)



(A) *55.5/148* (B) *128/7* (C) *27/128* (D) *148/55.5*

---

8 The opposite figure shows two possible transitions of the electron in a hydrogen atom. The ratio between the two wavelengths $((\lambda_1)/(\lambda_2))$ of the two produced photons equals ..... (Sample exam 2025)

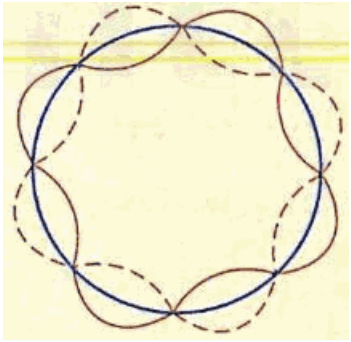


(A) *20/7* (B) *7/20* (C) *9/4* (D) *27/5*

9 From your study, the longest wavelength in the five series of the hydrogen spectrum is when the excited electron returns from level ..... (Sample exam 2025)

(A) ∞ to the first level (B) ∞ to the fifth level
(C) the sixth to the fifth level (D) the second to the first level

10 The opposite figure represents the standing wave accompanying the motion of the electron of a hydrogen atom in one of its energy levels. The energy of this level equals ..... (Sample exam 2025)

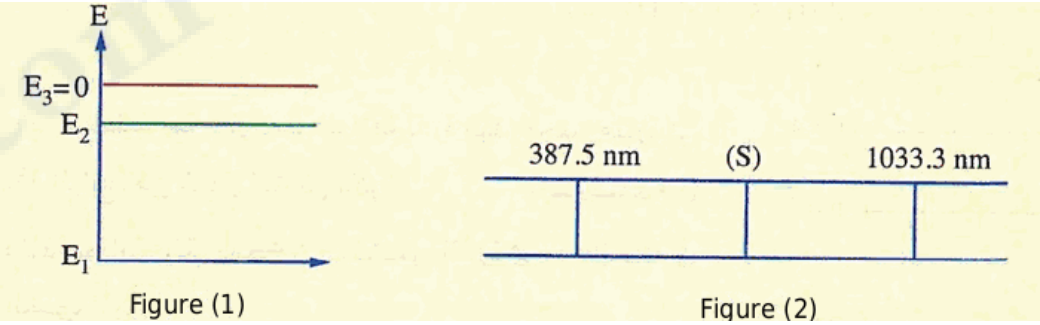


(A) – 13.6 eV (B) – 3.4 eV (C) – 0.544 eV (D) – 0.85 eV

11 A group of hydrogen atoms was excited so that the electron in each of them is in the fifth energy level, and the electron can move between any two of the levels. The number of spectral series that can be emitted from the atom is ..... (Sample exam 2025)

(A) 4 (B) 6 (C) 8 (D) 10

12 Figure (1) shows the energy diagram of an excited atom that gives wavelengths when the electron moves from a higher energy level to a lower one, and figure (2) shows these wavelengths. The wavelength (S) equals ..... (Sample exam 2025)



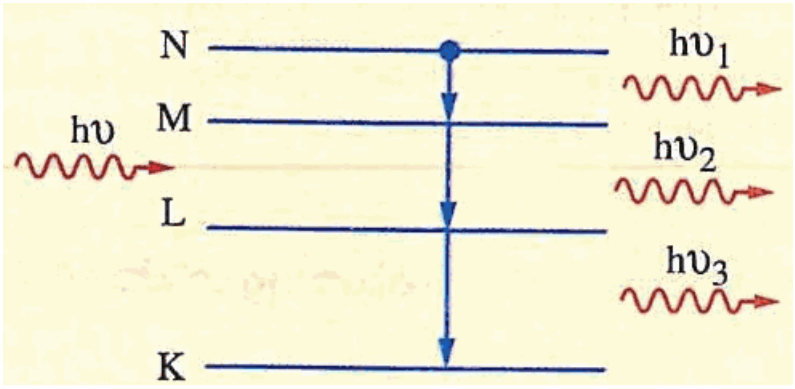
(A) 620 nm (B) 775 nm (C) 516.7 nm (D) 710.4 nm

---

13 The electron of a hydrogen atom in energy level K absorbed a photon of energy E and frequency υ and moved to level N. After a certain time the electron fell to level K passing through levels L and M as in the opposite figure, so that when the electron moved:

- from level N to level M, a photon of frequency $(upsilon_1)$ was emitted
- from level M to level L, a photon of frequency $(upsilon_2)$ was emitted
- from level L to level K, a photon of frequency $(upsilon_3)$ was emitted

Which of the following relations correctly describes the relation between the frequency of the absorbed photon and the frequencies of the released photons? (Sample exam 2025)



(A) $upsilon > (upsilon_1 + upsilon_2 + upsilon_3)$

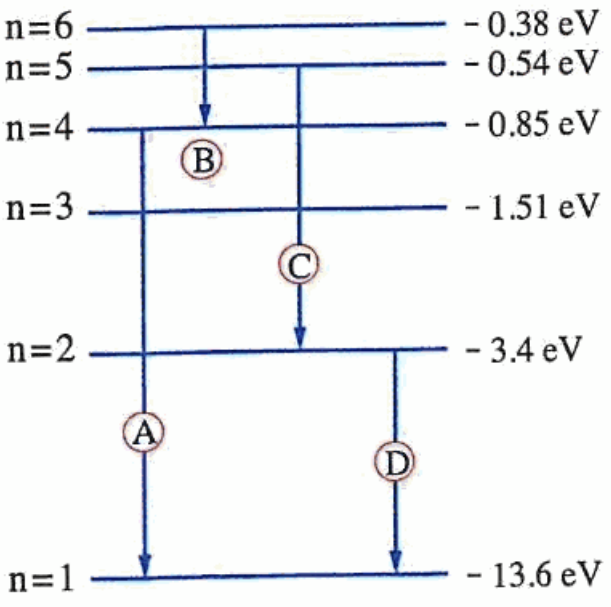
(B) $upsilon = upsilon_1 + upsilon_2 + upsilon_3$

(C) $upsilon < (upsilon_1 + upsilon_2 + upsilon_3)$

(D) $upsilon = upsilon_2 + upsilon_3 - upsilon_1$

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14 The diagram shows some possible transitions of the electron between energy levels in a hydrogen atom. Which of the transitions shown emits one of the photons of a spectrum of wavelength 974 Å? (1st session 2025)

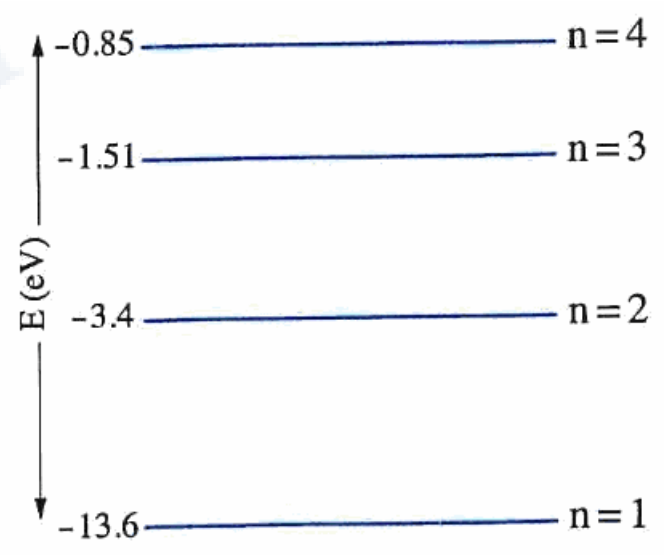


(A) Transition C (B) Transition B (C) Transition D (D) Transition A

15 When an electron in an atom moves from the third energy level (M) to the second energy level (L), a photon of energy $3 \times 10^{-19}\ J$ is emitted, and when it moves from the second energy level (L) to the first energy level (K), a photon of energy $1.634 \times 10^{-18}\ J$ is emitted. What is the frequency of the photon emitted when the electron moves from the third energy level (M) to the first energy level (K)? (2nd session 2025)

(A) $2.92 \times 10^{15}\ Hz$ (B) $4.54 \times 10^{14}\ Hz$ (C) $2.47 \times 10^{14}\ Hz$ (D) $2.01 \times 10^{15}\ Hz$

16 The figure shows the energy level diagram of a hydrogen atom excited in the fourth energy level. From the figure, ... (Sample exam 2026)



(A) the lowest frequency of the photons the atom can emit in this case is in the visible light region

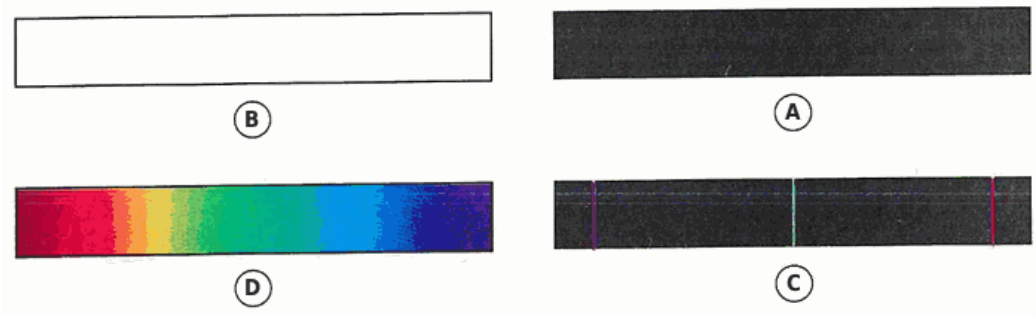
(B) the highest frequency of the photons the atom can emit in this case is $1.6 \times 10^{14}\ Hz$

(C) the shortest wavelength of the visible light photons the atom can emit in this case is 487.1 nm

(D) the shortest wavelength of the photons the atom can emit in this case is in the infrared region

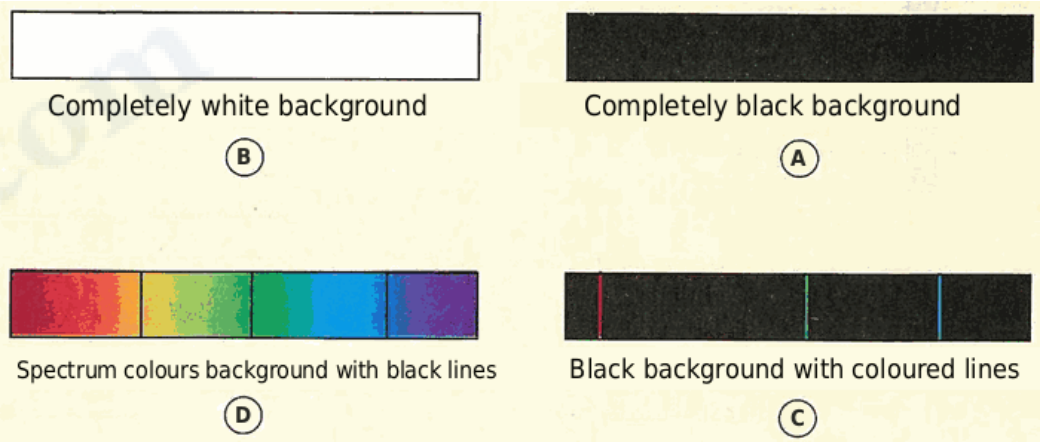
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17 Which of the following figures shows the emission spectrum produced by hydrogen gas? (Trial exam / June 2021)

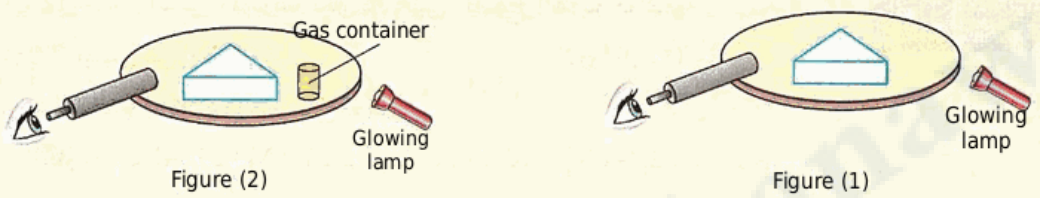


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18 When white light passes through a gas, which of the following figures shows the resulting spectrum? (2nd session 2021)



19 Looking through the eyepiece of each spectrometer, we observe ..... (1st session 2022)



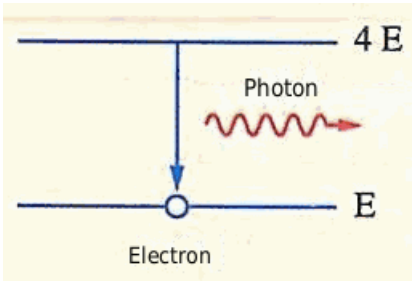
(A) in figure (1): a line absorption spectrum, in figure (2): a line emission spectrum

(B) in figure (1): a line emission spectrum, in figure (2): a continuous spectrum

(C) in figure (1): a continuous spectrum, in figure (2): a line absorption spectrum

(D) in figure (1): a line absorption spectrum, in figure (2): a continuous spectrum

20 An electron moves between two energy levels in an atom, releasing a photon. Assuming the energies of the two levels are as shown in the figure, the type of spectrum and the energy of the photon are ..... (2nd session 2022)



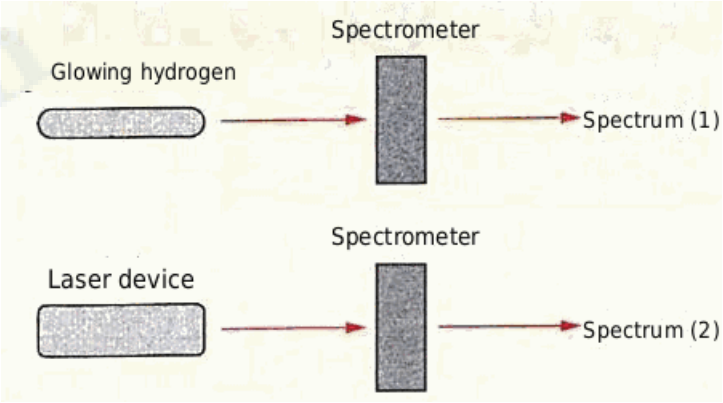
(A) type of spectrum: line absorption, photon energy: 3 E

(B) type of spectrum: line emission, photon energy: 3 E

(C) type of spectrum: continuous, photon energy: 5 E

(D) type of spectrum: line emission, photon energy: 5 E

21 From the opposite figure, the types of spectrum (1) and spectrum (2) are, respectively, ... (1st session 2023)



(A) continuous spectrum, continuous spectrum

(B) continuous spectrum, line spectrum

(C) line spectrum, line spectrum

(D) line spectrum, continuous spectrum

---

22 Fraunhofer lines in the solar spectrum represent a ..... (Sample exam 2025)

(A) line emission spectrum

(B) line absorption spectrum

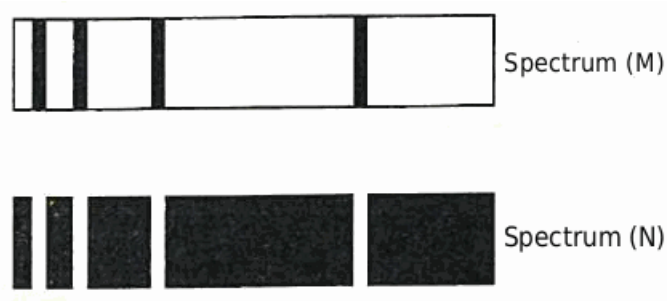
(C) continuous spectrum

(D) monochromatic spectrum

---

23 The figure shows two spectra (N) and (M), each received separately on the photographic plate of a spectrometer. The two spectra are ..... (1st session 2025)

(Note: the parts that appeared coloured on the photographic plate are shown in white in the figure.)



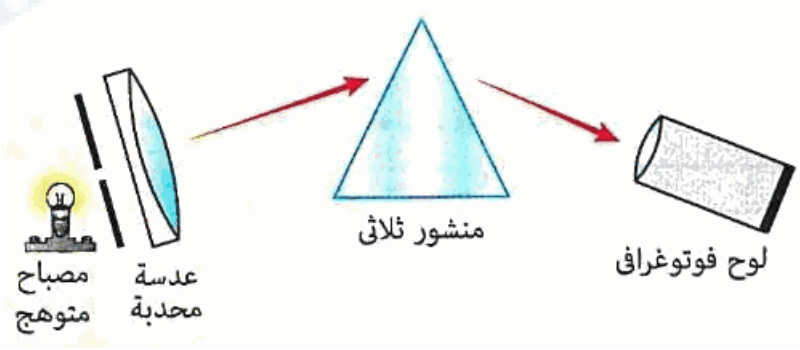
(A) of two different gases, and both are absorption spectra

(B) of the same gas, where spectrum (M) is an emission spectrum and spectrum (N) is an absorption spectrum

(C) of two different gases, and both are emission spectra

(D) of the same gas, where spectrum (N) is an emission spectrum and spectrum (M) is an absorption spectrum

24 The diagram shows a parallel light beam from a glowing tungsten lamp. The beam passes through a triangular prism and then falls on a sensitive photographic plate. What happens to the spectrum formed on the plate when a sample of cold gas is placed between the lamp and the prism in the path of the lamp's light? (2nd session 2025)



(A) The continuous spectrum of the lamp disappears, and black lines characteristic of the gas appear

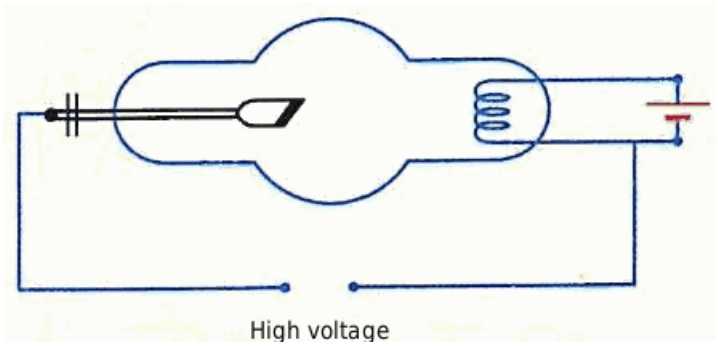
(B) The continuous spectrum of the lamp disappears, and coloured spectral lines characteristic of the gas appear

(C) Coloured spectral lines characteristic of the gas appear in addition to the continuous spectrum of the lamp

(D) Black lines characteristic of the gas appear within the continuous spectrum of the lamp

---

25 In the Coolidge tube shown in the figure for producing X-rays, the target was made of an element of atomic number 42. To get longer wavelengths of the characteristic X-ray spectrum, the target must be changed to an element of atomic number ..... (Trial exam / June 2021)



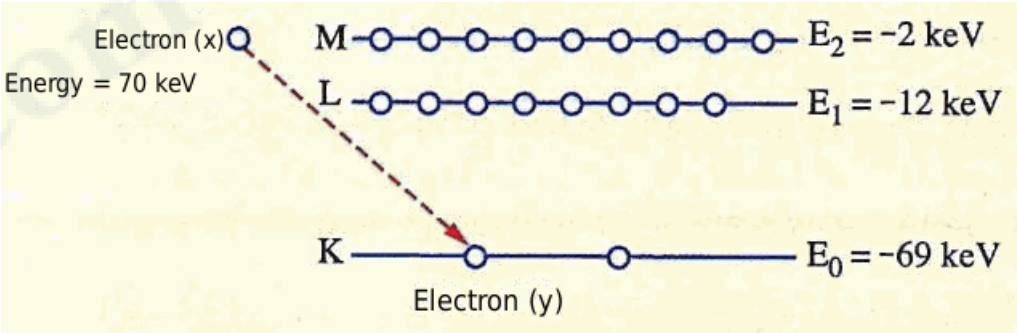
(A) 29 (B) 74 (C) 82 (D) 55

---

26 In a Coolidge tube, if the maximum speed of the electrons when they hit the target material is $7.34 \times 10^6\ m/s$, the shortest wavelength of the range of the produced X-rays equals ..... (Trial exam / June 2021)

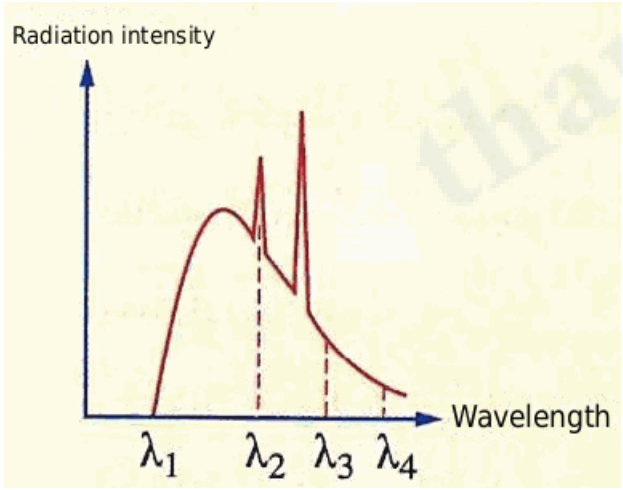
(A) 8.11 nm (B) $0.811 \times 10^{-9}\ m$ (C) 0.059 nm (D) $5.9 \times 10^{-10}\ m$

27 The diagram shows some energy levels of tungsten used as a target in a Coolidge tube. The collision of electron (x) with electron (y) knocked electron (y) out of the atom. What are the possible energies of the photons of the resulting characteristic spectrum? (1st session 2021)



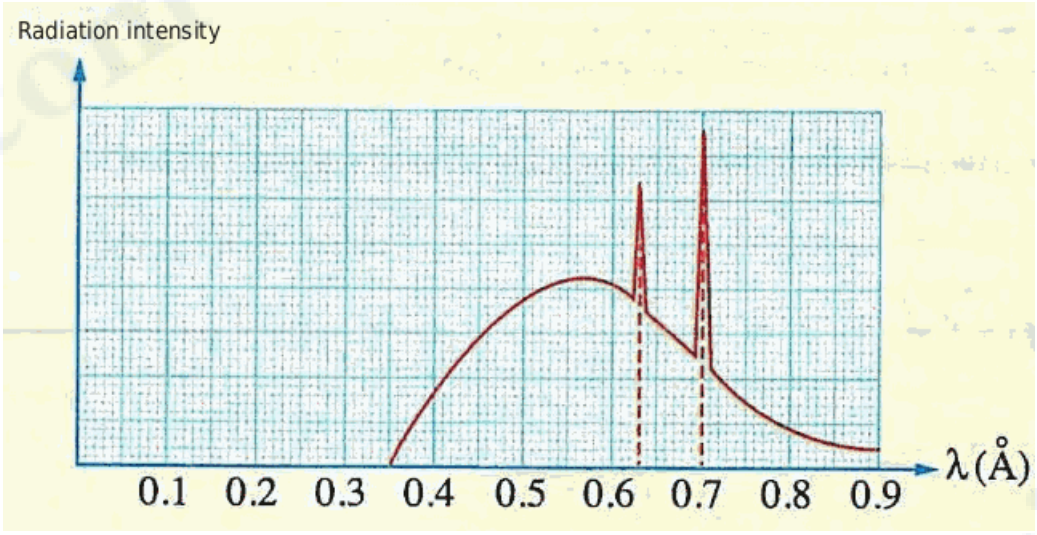
(A) 70 keV , 69 keV (B) 68 keV , 14 keV (C) 72 keV , 1 keV (D) 57 keV , 67 keV

28 The opposite figure is a graph of the relation between radiation intensity and wavelength for the X-ray spectrum. The wavelength that decreases as the atomic number of the target material increases is ..... (1st session 2021)



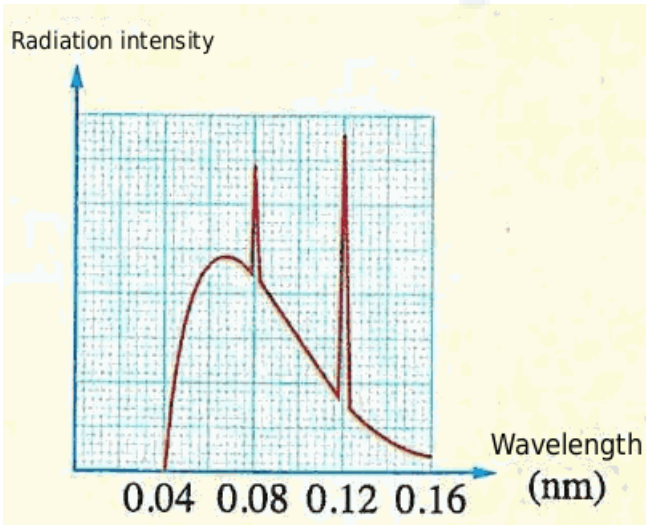
(A) λ_2 (B) λ_4 (C) λ_1 (D) λ_3

29 The opposite graph represents the relation between radiation intensity and wavelength of the X-rays from a Coolidge tube. The ratio of the lowest frequency of the characteristic spectrum to the highest frequency of the continuous spectrum equals ..... (2nd session 2021)



(A) 0.58 (B) 1.75 (C) 2 (D) 0.5

30 The opposite figure represents the relation between the intensity of X-rays and their wavelength. The wavelength of the characteristic X-rays that matches the maximum momentum of their photons is ..... (2nd session 2021)

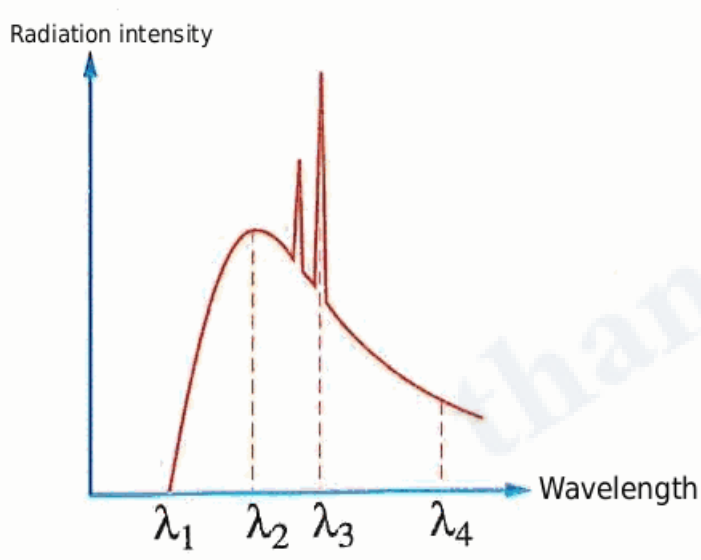


(A) 0.04 nm (B) 0.08 nm (C) 0.12 nm (D) 0.16 nm

31 An element was used as a target in a Coolidge tube to produce X-rays, and a photon of frequency 5.43×10^{18} Hz was released when an electron in an excited atom moved between two of its levels, one of which has an energy of −1.5 keV. The energy of the other level equals ..... (1st session 2022)

(A) − 24 keV (B) − 22.5 keV (C) − 27 keV (D) − 25.5 keV

32 The opposite graph represents the relation between radiation intensity and wavelength for the X-ray spectrum. The wavelength of the X-ray spectrum produced by electrons inside the atoms of the target material moving from a high energy level (E_2) to a lower energy level (E_1) is ..... (1st session 2022)

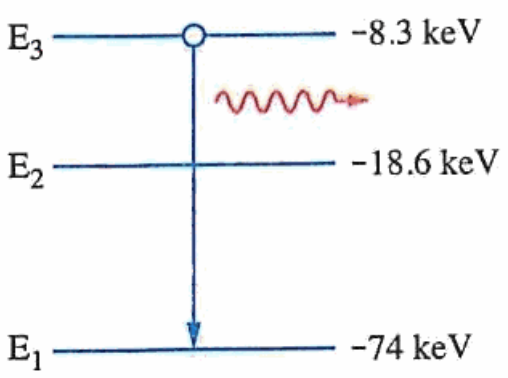


(A) λ_1 (B) λ_3 (C) λ_2 (D) λ_4

33 In a Coolidge tube for producing X-rays, if an electron moves towards the target with an energy of 70 keV and its energy becomes 54.5 keV because it is scattered, the wavelength of the continuous X-ray photon produced in this case equals ..... (2nd session 2022)

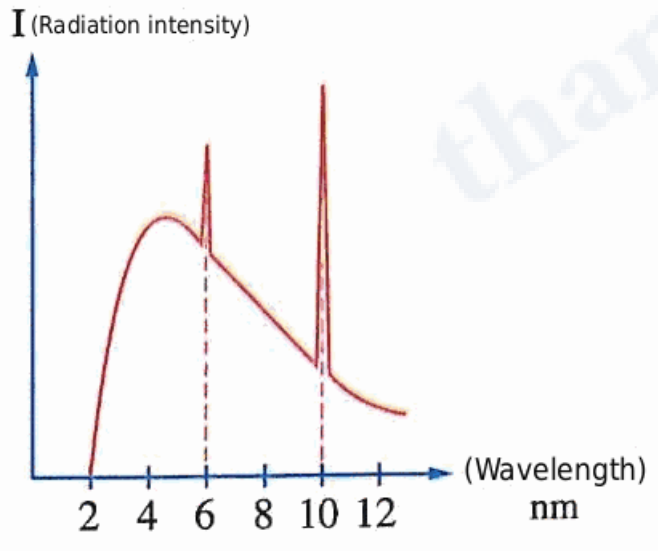
(A) 1.01×10^{-11} m (B) 2.28×10^{-11} m (C) 8.01×10^{-11} m (D) 8.77×10^{-11} m

34 The figure shows the values of some energy levels of an element used as a target in a Coolidge tube. When an electron moves as in the figure, the wavelength of the produced X-ray photon = ... (2nd session 2022)



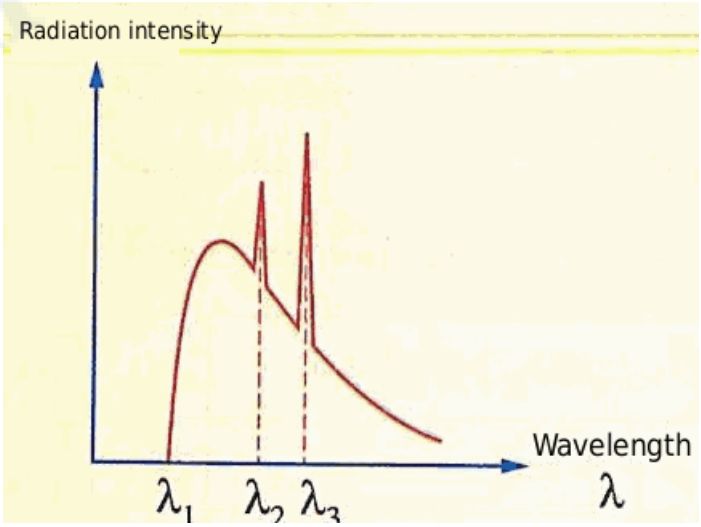
(A) $9 \times 10^{-10}\ m$ (B) $3.6 \times 10^{-11}\ m$ (C) $6 \times 10^{-10}\ m$ (D) $1.9 \times 10^{-11}\ m$

35 The shortest characteristic wavelength of the X-rays in the opposite figure is ..... (Trial exam 2023)



(A) 8 nm (B) 10 nm (C) 4 nm (D) 6 nm

36 The graph shows the relation between the intensity of the X-rays from a Coolidge tube and their wavelength. When both the filament current and the potential difference between the anode and the cathode of the tube are increased, ... (1st session 2023)



(A) λ_1 : increases , λ_2 : does not change , λ_3 : does not change , radiation intensity : decreases

(B) λ_1 : decreases , λ_2 : increases , λ_3 : does not change , radiation intensity : does not change

(C) λ_1 : decreases , λ_2 : does not change , λ_3 : does not change , radiation intensity : increases

(D) λ_1 : increases , λ_2 : does not change , λ_3 : does not change , radiation intensity : increases

---

37 The scientific basis of using X-rays to study the crystal structure of solids depends on ..... (2nd session 2023)

(A) their ability to diffract when passing through crystals

(B) their intensity

(C) their wide spectral range

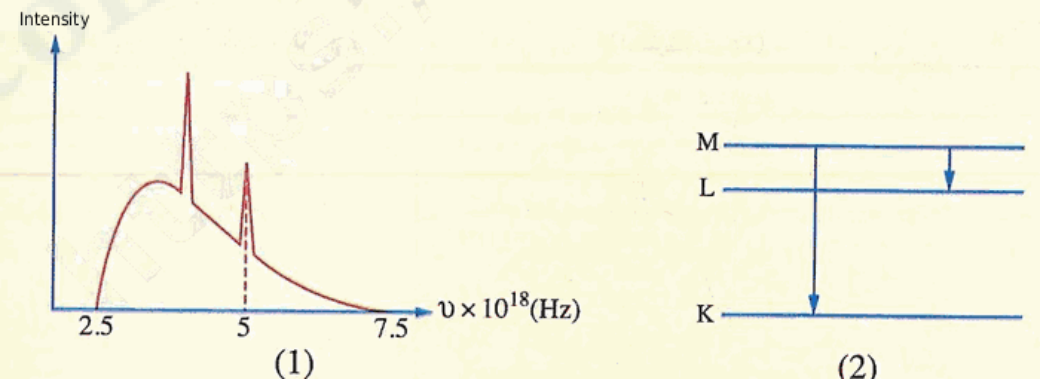
(D) their quantum nature

---

38 In a Coolidge tube a tungsten target $W_{(74)}$ was used to produce X-rays, and one of the characteristic X-ray wavelengths was 1.8×10^{-11} m. If the target is replaced by molybdenum $Mo_{(42)}$, one of the possible characteristic X-ray wavelengths equals ..... (2nd session 2023)

(A) 1.5×10^{-3} nm (B) 4.9×10^{-3} nm (C) 2.8×10^{-4} nm (D) 7.1×10^{-2} nm

39 Figure (1) is a graph of the X-ray spectrum emitted from a Coolidge tube, while figure (2) shows some transitions of electrons between energy levels in a target atom. Which of the following choices gives a characteristic X-ray frequency and the transition that causes it? (1st session 2024)



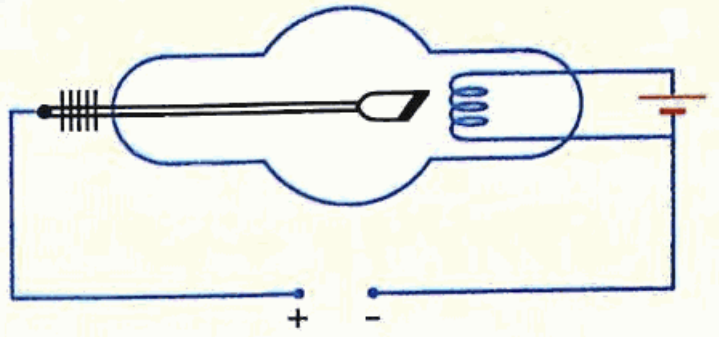
(A) $5 \times 10^{18}\ Hz$, from level (M) to level (K)

(B) $5 \times 10^{18}\ Hz$, from level (M) to level (L)

(C) $5.3 \times 10^{18}\ Hz$, from level (M) to level (K)

(D) $5.3 \times 10^{18}\ Hz$, from level (M) to level (L)

40 In the Coolidge tube shown in the opposite figure, the target was made of an element of atomic number 42. If the experiment is repeated using another target of atomic number 76 while increasing the potential difference across the tube, which of the following choices is correct? (2nd session 2024)



(A) wavelength of the characteristic spectrum: increases, shortest wavelength of the continuous spectrum: increases

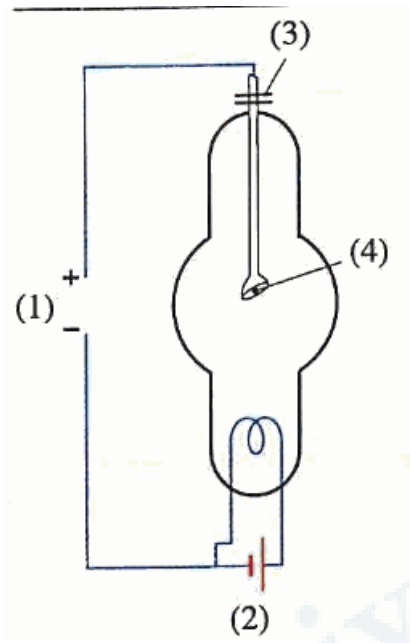
(B) wavelength of the characteristic spectrum: decreases, shortest wavelength of the continuous spectrum: decreases

(C) wavelength of the characteristic spectrum: decreases, shortest wavelength of the continuous spectrum: increases

(D) wavelength of the characteristic spectrum: increases, shortest wavelength of the continuous spectrum: decreases

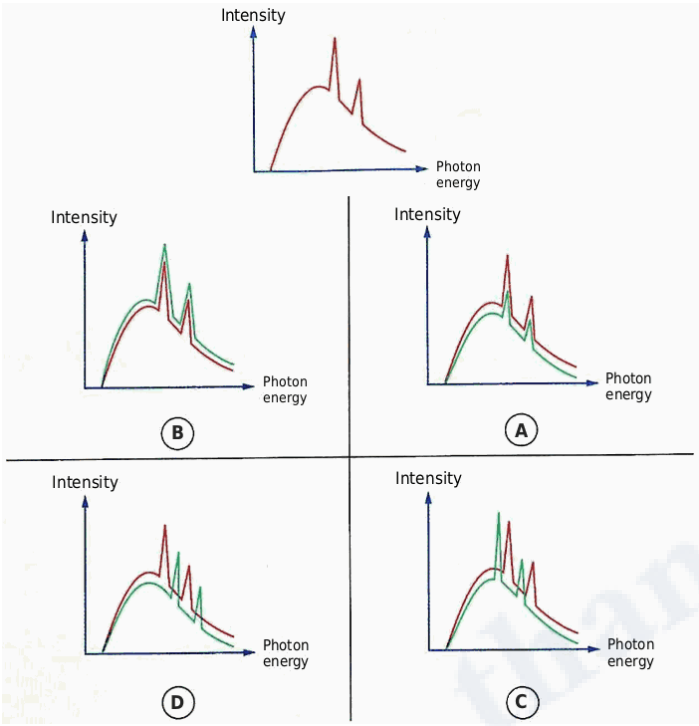
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41 The opposite figure is a diagram of a Coolidge tube for producing X-rays. The part responsible for accelerating the electrons emitted from the filament is ..... (Sample exam 2025)

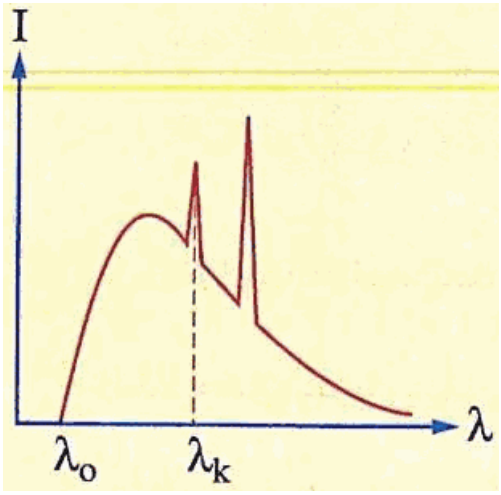


(A) (1) (B) (2) (C) (3) (D) (4)

42 The opposite graph shows the relation between the intensity of the X-rays and the energy of the photons produced by a Coolidge tube. If the target material is replaced by another of smaller atomic number while the potential difference between the cathode and the anode stays the same, which of the following figures can show the resulting spectrum? (Sample exam 2025)

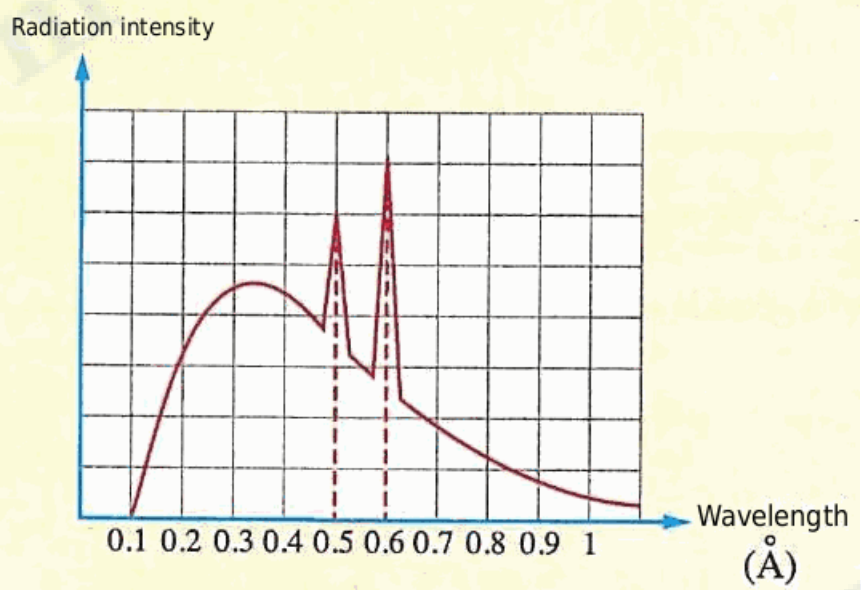


43 The graph shows the relation between the intensity (I) of the X-rays from a Coolidge tube and their wavelength (λ). When the potential difference between the target and the filament is increased, the difference between the values (λ_k) and (λ_o) ..... (1st session 2025)



(A) becomes equal to (λ_o)
(B) decreases
(C) does not change
(D) increases

44 The graph represents the relation between the intensity of X-rays and the wavelength of the rays produced in a Coolidge tube. Which wavelengths in the figure represent the characteristic spectrum of the target material? (2nd session 2025)



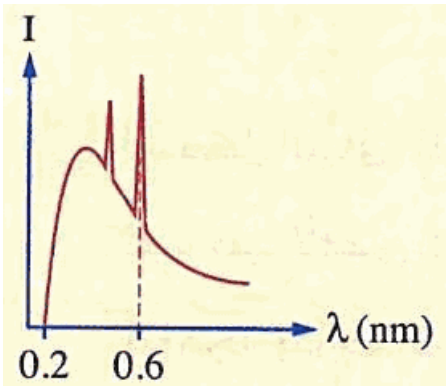
(A) 0.1 Å , 0.5 Å (B) 0.6 Å , 0.5 Å (C) 0.1 Å , 0.6 Å (D) 0.6 Å , 1 Å

---

45 The graph shows the relation between the radiation intensity (I) and the wavelength (λ) of X-rays emitted from a Coolidge tube. Calculate: (Trial exam 2023)

(1) the greatest energy of the released photons.

(2) the energy of one of the released photons of the characteristic rays.



Answer key and solutions

Multiple choice questions

1 B	2 B	3 C	4 C	5 A	6 C	7 D	8 B	9 C	10 A
11 C	12 A	13 C	14 A	15 A	16 C	17 C	18 D	19 C	20 C
21 D	22 B	23 C	24 A	25 C	26 B	27 A	28 D	29 D	30 A
31 C	32 A	33 B	34 D	35 D	36 C	37 D	38 C	39 B	40 B
41 B	42 C	43 D	44 D	45 B	46 C	47 C	48 B	49 C	50 B
51 A	52 B	53 D	54 C	55 B	56 C	57 B	58 B	59 D	60 B
61 C	62 A	63 C	64 C	65 A	66 A	67 C	68 D	69 A	70 C
71 C	72 A	73 C	74 C	75 A	76 B	77 B	78 B	79 D	80 A
81 B	82 D	83 B	84 A	85 D	86 D	87 C	88 C	89 B	90 A
91 D	92 D	93 B	94 B	95 C	96 B	97 D	98 D	99 C	100 A
101 C									

1 **Answer (B)**

The electron is a standing wave around the orbit: the circumference equals a whole number of wavelengths.

$2\pi r = n\lambda$

At $n = 4$:

$r = (2\lambda)/(\pi)$

2 **Answer (B)**

The standing wave condition:

$2\pi r = n\lambda$

Substituting $\lambda = \pi r$ gives $n=2$

that is, the second orbit (L).

3 **Answer (C)**

The wavelength equals the circumference of the orbit

$\lambda = 2\pi r$

that is, $n=1$ (the first orbit).

4 **Answer (C)**

Number of antinodes (crests and troughs) = $2n$

8 antinodes means $n=4$

5 **Answer (A)**

From de Broglie:

$\lambda = h/mv = (6.625\times10^{-34})/(9.1\times10^{-31}\times7.28\times10^{5}) = 10^{-9}\ m$

$2\pi r = n\lambda$

$r = (3\times10^{-9})/(2\pi) = 4.77\times10^{-10}\ m$

6 **Answer (C)**

The wave completes 3 wavelengths around the orbit

$2\pi r = n\lambda$

$n=3$

7 **Answer (D)**

$2\pi r = n\lambda$ with $n=3$ (3 wavelengths in the figure)

$\lambda = (2\pi\times4.761\times10^{-10})/3 = 9.98\times10^{-10}\ m$

8 **Answer (B)**

The figure shows $n=2$

$\lambda = h/mv = (6.625\times10^{-34})/(9.1\times10^{-31}\times1.09\times10^{6}) = 6.68\times10^{-10}\ m$

$r = (n\lambda)/(2\pi) = 2.13\times10^{-10}\ m$

9 **Answer (C)**

From Bohr's condition:

$mvr = nh/(2\pi)$

$v = nh/(2\pi\, m\, r)$

$v_3/v_4 = 3/4cdotr_4/r_3$

10 **Answer (A)**

The energy is negative and rises (gets closer to zero) as n increases

$E_n = -13.6/(n^2)\ eV$

and the gaps between the levels get smaller as n increases, so graph (A).

11 **Answer (C)**

The stable state: the electron is in the lowest level (K) and does not radiate energy,

because there is no lower level it can move to.

12 **Answer (A)**

The atom absorbs a photon whose energy equals the energy difference between the two levels.

$h\nu = E_2 - E_1$

13 **Answer (C)**

The transition from L to K emits a photon of energy

$E = 13.6 - 3.4 = 10.2\ eV$

14 **Answer (A)**

The ionization energy from the stable state

$E = 13.6\ eV$

15 **Answer (A)**

Ionization from K needs an energy of 13.6 eV

$\lambda = hc/E = 12400/13.6 \approx 910\ mathringA = 9.1 \times 10^{-8}\ m$

16 **Answer (C)**

The least energy that excites the atom from K is

$E_2 - E_1 = 10.2\ eV$

17 **Answer (C)**

$h\nu = E_2 - E_1$

$\lambda = hc/(E_2 - E_1)$

18 **Answer (D)**

Longest wavelength = least energy

In the Lyman series: the transition from $n=2$ to $n=1$

19 **Answer (C)**

Highest frequency = largest energy difference

In Brackett (ending at $n=4$): the transition from ∞ to 4

20 **Answer (C)**

Transition (a) from L to K:

$\Delta E = 13.6 - 3.4 = 10.2\ eV$

$E = 10.2 \times 1.6 \times 10^{-19} = 1.6 \times 10^{-18}\ J$

21 **Answer (D)**

Transition (b) from M to K:

$\Delta E = 13.6 - 1.51 = 12.09\ eV$

$\nu = E/h = (12.09 \times 1.6 \times 10^{-19})/(6.625 \times 10^{-34}) = 2.9 \times 10^{15}\ Hz$

22 **Answer (B)**

Transition (c) from M to L:

$\Delta E = 3.4 - 1.51 = 1.89\ eV$

$\lambda = 1240/1.89 \approx 657\ nm$

23 **Answer (C)**

Transition (d) from N to L:

$\Delta E = 3.4 - 0.85 = 2.55\ eV$

$p = E/c = (2.55 \times 1.6 \times 10^{-19})/(3 \times 10^{8}) = 1.36 \times 10^{-27}\ kg \cdot m/s$

24 **Answer (A)**

Transition (e) from N to M:

$\Delta E = 1.51 - 0.85 = 0.66\ eV$

$m = E/(c^2) = (0.66 \times 1.6 \times 10^{-19})/(9 \times 10^{16}) = 1.2 \times 10^{-36}\ kg$

25 **Answer (C)**

Shortest wavelength in Balmer = largest energy (from ∞ to 2)

$\lambda = 12400/3.4 \approx 3653\ mathringA$

26 **Answer (B)**

Shortest wavelength in Pfund (from ∞ to 5)

$\lambda = 12400/0.544 \approx 22834\ mathringA$

27 **Answer (A)**

Longest λ in each series = least energy

$(\lambda_L)/(\lambda_B) = (\Delta E_{3\to2})/(\Delta E_{2\to1})$

$= (1/4-1/9)/(1-1/4) = 5/27$

28 **Answer (D)**

In Lyman the longest λ is from $2\to1$ and the shortest λ from $\infty\to1$

$(\lambda_{max})/(\lambda_{min}) = (\Delta E_{\infty\to1})/(\Delta E_{2\to1}) = 1/(3/4) = 4/3$

29 **Answer (D)**

Shortest λ in Lyman:

$\lambda = hc/13.6$

and in Balmer:

$\lambda' = hc/3.4 = 4\lambda$

30 **Answer (A)**

The lowest frequency in Paschen is $(4\to3)$ and the lowest frequency in Balmer is $(3\to2)$

$(\nu_1)/(\nu_2) = (1/9-1/16)/(1/4-1/9) = 7/20$

31 **Answer (C)**

$E_n \propto 1/(n^2)$

$E_3/E_2 = 4/9$

$E_3 = -4/9E$

32 **Answer (A)**

$2\pi r_n = n\lambda$ with $\lambda = (2\pi r_n)/5$

$n=5$

The ionization energy from this level:

$E = 13.6/25 = 0.544\ eV$

33 **Answer (B)**

The energy of the photon:

$E = hc/(\lambda) = 2.09 \times 10^{-18}\ J$

$E = E_1(1\text{-}1/(n^2))$

$n^2 \approx 25 \Rightarrow n = 5$

34 **Answer (D)**

Balmer lines end at the second level:

they are lines B $(3 \rightarrow 2)$ and D $(4 \rightarrow 2)$.

35 **Answer (D)**

Highest frequency = largest energy difference,

which is transition A (from 3 to 1).

36 **Answer (C)**

The false statement is: line E has the highest frequency,

because the highest frequency is that of line D.

37 **Answer (D)**

The transition from 5 to 3 belongs to the Paschen series,

which is in the infrared region, so it is region D.

38 **Answer (C)**

Transitions to level K (Lyman)

are in the ultraviolet region.

39 **Answer (B)**

The atom absorbs only a photon whose energy equals exactly the energy difference between two levels.

$E_2 - E_1 = 10.2\ eV$

So only photon (b) is absorbed.

40 **Answer (B)**

Lyman energy differences are larger than Balmer ones.

$p = E/c$

So the momentum of a Lyman photon is larger.

41 **Answer (B)**

The number of lines when moving down from level n:

$(n(n-1))/2 = 6$

42 **Answer (C)**

$E = -3.4\ eV$, that is $n=2$

$2\pi r = n\lambda$

$\lambda = (2\pi \times 2.13)/2 = 6.69\ mathringA$

43 **Answer (D)**

$\lambda = hc/(\Delta E)$

Transition A (from L to K) has a larger energy difference than transition D (from N to L),

so $\lambda_A < \lambda_D$

44 **Answer (D)**

$E = 12400/14610 = 0.85\ eV$, that is the transition from ∞ to $n=4$,

which is the Brackett series,

and its longest wavelength (from 5 to 4):

$\lambda = 40594\ mathringA$

45 **Answer (B)**

$\lambda = hc/(\Delta E)$

$(\lambda_A)/(\lambda_B) = (\Delta E_B)/(\Delta E_A) = (E_N - E_K)/(E_L - E_K)$

46 **Answer (C)**

$E = mc^2 = 2.267 \times 10^{-35} \times 9 \times 10^{16} = 2.04 \times 10^{-18}\ J$

$E = 12.75\ eV$

which is the difference between K and $n=4$ (N)

$n = 4$

47 **Answer (C)**

The highest level the electron reaches: $-13.6 + 12.75 = -0.85\ eV$

that is, $n=4$

Lyman lines: 4→1, 3→1 and 2→1

they are 3.

48 **Answer (B)**

The electron is at $n=4$

Balmer lines: 4→2 and 3→2

they are 2.

49 **Answer (C)**

$E = 12400/975 = 12.72\ eV$

Level $n=4$ (N)

Number of possible lines:

$(4\times3)/2 = 6$

50 **Answer (B)**

The transition from 5 to 2:

$\Delta E = 3.4 - 0.544 = 2.856\ eV$

$\lambda = 12400/2.856 \approx 4349\ mathringA$

51 **Answer (A)**

$1/(\lambda_3) = 1/(\lambda_1) - 1/(\lambda_2)$

$1/(\lambda_3) = 1/256.86 - 1/304.45$

$\lambda_3 = 1643\ nm$

52 **Answer (B)**

The number of transitions from $n=4$:

$(4\times3)/2 = 6$

53 **Answer (D)**

Lowest frequency = smallest energy difference $(4\to3)$:

$\Delta E = 1.51 - 0.85 = 0.66\ eV$

$\nu = (0.66\times1.6\times10^{-19})/(6.625\times10^{-34}) = 1.59\times10^{14}\ Hz$

54 **Answer (C)**

Highest frequency = largest energy difference $(4\to1)$:

$\Delta E = 13.6 - 0.85 = 12.75\ eV$

$\nu = (12.75\times1.6\times10^{-19})/(6.625\times10^{-34}) = 3.08\times10^{15}\ Hz$

55 **Answer (B)**

The photon energy (from 3 to 1):

$E = 13.6 - 1.51 = 12.09\ eV$

$\varphi = E - KE = 12.09 - 9.79 = 2.3\ eV$

56 **Answer (C)**

$E = 1240/656 = 1.89\ eV$

which is the energy difference between -1.51 and -3.4

so it is transition (c).

57 **Answer (B)**

$E = hc/(\lambda) = 1240/486.3 \approx 2.55\ eV$

58 **Answer (B)**

The photon energy is 2.55 eV

$E_4 - E_2 = 3.4 - 0.85 = 2.55\ eV$

so the transition is from the fourth level to the second.

59 **Answer (D)**

The first photon:

$E_1 = 1240/2624 = 0.4726\ eV$

which is the transition from 6 to 4.

The second photon:

$E_2 = 1240/97.45 = 12.72\ eV$

which is the transition from 4 to 1.

So $x = 6$

60 **Answer (B)**

The prism (2) separates the spectra according to their wavelength because its refractive index differs for each.

61 **Answer (C)**

The lens (3) collects the rays of each colour at its own focus on the focal plane.

62 **Answer (A)**

The emission spectrum comes from an electron moving from a higher energy level to a lower one.

63 **Answer (C)**

White (continuous) light passes through sodium vapour, which absorbs certain wavelengths, so we get dark lines on a coloured background.

64 **Answer (C)**

Absorption spectrum: dark lines on a coloured background.

65 **Answer (A)**

A continuous spectrum comes from glowing solid bodies, such as a tungsten lamp.

66 **Answer (A)**

The graph shows radiation intensity for all wavelengths without a break, so it is a continuous spectrum.

67 **Answer (C)**

White light is continuous; it passes through a gas, which absorbs certain wavelengths, so the absorption spectrum appears: dark lines on a bright background.

68 **Answer (D)**

We identify the transitions:

a: 4 → 3 d: 5 → 3 c: 4 → 2 b: 3 → 1 e: 2 → 1

Only line (c) is in the visible region.

(b) and (e) are ultraviolet: the shorter λ on the left and the longer on the right.

(d) and (a) are infrared.

The order: b e | c | d a

69 **Answer (A)**

X-rays are not charged (electromagnetic waves), so they are not deflected in a magnetic field.

70 **Answer (C)**

The penetrating power depends on the photon energy (the potential difference) and does not depend on the current (which affects the intensity only).

71 **Answer (C)**

The electrical energy of the source changes into kinetic energy of the electrons, which changes on impact into electromagnetic energy (X-rays).

72 **Answer (A)**

X-rays need a large energy (thousands of eV),
and the energy of K in hydrogen $(13.6$ eV) is much less than the energy of X-ray photons.

73 **Answer (C)**

The minimum wavelength depends on the potential difference between the filament and the target,
while the heating voltage of the filament does not affect it,
so it does not change.

74 **Answer (C)**

The characteristic (line) spectrum depends on the material of the target,
because it comes from transitions inside the atoms of the target.

75 **Answer (A)**

Photon z comes from a transition between two levels (characteristic line spectrum).
Photon y comes from the electron slowing down near the nucleus (continuous spectrum).
So photon (y) belongs to the continuous spectrum.

76 **Answer (B)**

$KE_{\max} = eV$
A direct linear relation through the origin.

77 **Answer (B)**

$\nu_{\max} = eV/h$
A direct linear relation through the origin.

78 **Answer (B)**

Shortest wavelength:
$\lambda_{\min} = hc/eV_2$
so it changes when the potential difference V_2 between the filament and the target changes.

79 **Answer (D)**

The electrons must be accelerated towards the target,
so the target must be the anode (positive).
In the figure the target is connected to the negative pole,
so we reverse the poles of the source V_2.

80 **Answer (A)**

Increasing the potential difference decreases λ_{min} only (λ_1),
while the characteristic lines (λ_2) depend on the material of the target.

81 **Answer (B)**

The characteristic line is the sharp peak (o).
It comes from an electron moving from a higher level to a level close to the nucleus.

82 **Answer (D)**

The two curves have the same λ_{min} and the same peak positions,
and the intensity of (2) is greater,
so only the filament current changed.

83 **Answer (B)**

(1) has a smaller λ_{min}, so $V_1 > V_2$
The lines of (2) are at shorter wavelengths, so it is for an element of larger atomic number:
$Z_1 < Z_2$

84 **Answer (A)**

Increasing the filament current increases the number of electrons, so the intensity of the rays increases,
while λ_{min} and the peak positions stay the same.

85 **Answer (D)**

Increasing the potential difference decreases λ_{min} and increases the intensity,
while the peak positions stay fixed.

86 **Answer (D)**

$E_{max} = hc/(\lambda_{min}) = 12400/0.414 \approx 3\times10^4\ eV$
$E = 3\times10^4 \times 1.6\times10^{-19} = 4.8\times10^{-15}\ J$

87 **Answer (C)**

$V = hc/(e\lambda_{min}) = 12400/0.414$
$V = 30\times10^3\ V$

88 **Answer (C)**

$\nu_{max} = eV/h$
$\nu_{max} = (1.6\times10^{-19}\times13255)/(6.625\times10^{-34}) = 3.2\times10^{18}\ Hz$

89 **Answer (B)**

$\lambda_{min} = hc/KE$

$\lambda_{min} = (6.625\times10^{-34}\times3\times10^{8})/(5\times10^{-18}) = 3.975\times10^{-8}\ m$

90 **Answer (A)**

$V = hc/(e\lambda_{min})$

$V = (6.625\times10^{-34}\times3\times10^{8})/(1.6\times10^{-19}\times0.4\times10^{-10}) = 31.05\times10^{3}\ V$

91 **Answer (D)**

$\nu_{max} = c/(\lambda_{min})$

$\nu_{max} = (3\times10^{8})/(0.4\times10^{-10}) = 7.5\times10^{18}\ Hz$

92 **Answer (D)**

The highest photon energy in the continuous spectrum is 100 keV

$eV = 100\ keV$

$V = 100\ kV$

93 **Answer (B)**

The first transition is 59.3 keV and the second 67.2 keV

$E_K = -10.2 - 59.3 = -69.5\ keV$

$E_M = -69.5 + 67.2 = -2.3\ keV$

94 **Answer (B)**

$KE_{max} = eV$

$KE_{max} = 1.6\times10^{-19}\times30\times10^{3} = 4.8\times10^{-15}\ J$

95 **Answer (C)**

$1/2\ m\ v^2 = eV$

$v = \sqrt{(2eV/m)} = \sqrt{((2\times4.8\times10^{-15})/(9.11\times10^{-31}))}$

$v = 10.27\times10^{7}\ m/s$

96 **Answer (B)**

The number of electrons per second

$n = I/e = (7\times10^{-3})/(1.6\times10^{-19})$

$n = 4.375\times10^{16}$

97 **Answer (D)**

$\lambda_{min} = hc/eV = 12400/30000$

$\lambda_{min} = 0.414\ mathringA$

98 **Answer (D)**

The maximum energy of the electron:

$KE = hc/(\lambda_{min})$

The wavelength accompanying the electron:

$\lambda_e = h/(\sqrt{(2\ m\ KE)}) = \sqrt{((h\lambda_{min})/2mc)}$

$\lambda_e \approx 5.5\ pm$

99 **Answer (C)**

X-rays have a short wavelength,

so they pass through soft tissue and are absorbed in the bones.

100 **Answer (A)**

Beam Y is not deflected, so it is X-rays.

Beam Z is deflected towards the positive plate, so it is cathode rays (electrons).

101 **Answer (C)**

X-rays have higher energy than the other radiations in the figure,

so they are the most penetrating and travel the longest distance inside the lead.

Essay questions

1 **Model answer**

(1) $\lambda = (2\pi\ r)/n = (2 \times 22/7 \times 0.53 \times 10^{-10})/1 = 3.33 \times 10^{-10}\ m$

(2) $v = h/(m_e\ \lambda) = (6.625 \times 10^{-34})/(9.1 \times 10^{-31} \times 3.33 \times 10^{-10}) = 2.19 \times 10^{6}\ m/s$

(3) $E_3 - E_1 = [(-13.6)/(3^2) - (-13.6)] = 12.09\ eV$

$\lambda = hc/(E_3 - E_1) = (6.625 \times 10^{-34} \times 3 \times 10^{8})/(12.09 \times 1.6 \times 10^{-19}) = 1.03 \times 10^{-7}\ m$

2 **Model answer**

The atoms move to different excited levels (n = 2 , 3 , 4 , ...), then after a very short time they return to lower energy levels and emit photons of different energies, forming the series of the atomic spectrum of hydrogen.

3 **Model answer**

Because the energy difference between any two levels in the atom is different from the energy difference between any other two levels.

4 **Model answer**

(1) $E_n = (-13.6)/(n^2)$, so $n^2 = (-13.6)/(-0.85) = 16$, n = 4

(2) $n\lambda = 2\pi r : 4\lambda = 2 \times 22/7 \times 8.48 \times 10^{-10}$, so $\lambda = 1.33 \times 10^{-9}\ m = 1.33\ nm$

(3) $v = h/(m_e \lambda) = (6.625 \times 10^{-34})/(9.1 \times 10^{-31} \times 1.33 \times 10^{-9}) = 5.47 \times 10^5\ m/s$

5 **Model answer**

(1) Because the photon emitted from transition (x) is in the Balmer series, that is in the visible light range, while the photon emitted from transition (y) is in the Lyman series, that is in the ultraviolet range, and the energy of visible light photons is less than the energy of ultraviolet photons.

(2) Because the photon emitted from transition (y) is in the ultraviolet range and the photon emitted from transition (z) is in the infrared range, and both are invisible, while the photon emitted from transition (x) is in the visible light range.

6 **Model answer**

$m = (\Delta E)/(c^2) = (E_L - E_K)/(c^2) = (((-13.6)/(2^2) - (-13.6)) \times 1.6 \times 10^{-19})/((3 \times 10^8)^2) = 1.81 \times 10^{-35}\ kg$

7 **Model answer**

$\Delta E = E_2 - E_1 = (-13.6)/(2^2) - (-13.6) = 10.2\ eV$

$P_L = (\Delta E)/c = (10.2 \times 1.6 \times 10^{-19})/(3 \times 10^8) = 5.44 \times 10^{-27}\ kg.m/s$

8 **Model answer**

$n\lambda = 2\pi r : n \times 2\pi r = 2\pi r$, so n = 1

$hc/(\lambda) = E_\infty - E_1$

$(6.625 \times 10^{-34} \times 3 \times 10^8)/(\lambda) = (0 - (-13.6)) \times 1.6 \times 10^{-19}$

$\lambda = 9.134 \times 10^{-8}\ m = 913.4\ AA$

9 **Model answer**

The longest wavelength in the Lyman series is from level L (n = 2) to K (n = 1):

$\lambda = hc/((-13.6)/(2^2) - (-13.6)) = hc/10.2$

The longest wavelength in the Pfund series is from level P (n = 6) to O (n = 5):

$\lambda_{Pfund} = hc/((-13.6)/(6^2) - (-13.6)/(5^2)) = hc/0.17$

Dividing: $\lambda_{Pfund} = 10.2/0.17\lambda = 60\lambda$

10 **Model answer**

(1) The energies of the emitted photons, starting from the smallest:

$\Delta E_f = -0.85 - (-1.51) = 0.66\ eV$, $\Delta E_d = -1.51 - (-3.4) = 1.89\ eV$, $\Delta E_e = -0.85 - (-3.4) = 2.55\ eV$

The energy of photon (e) is greater than the work function of the surface (2.14 eV), and the energies of photons (a), (b), (c) are greater than that of photon (e).

Each of photons (a), (b), (c), (e) causes the emission of an electron, so four electrons leave the surface.

(2) Photon (c), because it has the greatest energy.

11 **Model answer**

Line absorption spectrum: produced when a continuous spectrum passes through a gas or vapour of an element, so some wavelengths disappear from the continuous spectrum after it is analysed by the spectrometer. It appears as black lines on a coloured background.

Line emission spectrum: produced when an excited atom moves from a higher energy level to a lower one. It appears as coloured lines on a black background.

12 **Model answer**

(1) Dark lines on a coloured background; these dark lines are the characteristic line absorption spectrum of argon.

(2) A coloured region, which is the continuous spectrum produced by the glowing filament of the lamp.

13 **Model answer**

By passing white light (a continuous spectrum) through each of the two elements in the gaseous state and passing the resulting spectrum through a spectrometer. The characteristic line absorption spectrum of each element appears, and from it the two elements can be identified.

14 **Model answer**

By analysing the solar spectrum, the characteristic wavelengths of hydrogen and helium were found to be absorbed from it, appearing as dark lines on a coloured background (Fraunhofer lines).

15 **Model answer**

(1) Potential difference (2) is greater than potential difference (1).

Potential difference (1) heats the filament so that electrons leave it, and potential difference (2) accelerates the electrons emitted from the filament.

(2) From electrical energy to heat energy to mechanical energy to electromagnetic energy: an electric current flows in the filament (electrical energy), so its temperature rises (heat energy), which makes electrons leave it. They are accelerated by the high potential difference between the target and the filament and gain kinetic energy (mechanical energy), and when they hit the target the electrons lose their energy as X-rays (electromagnetic energy).

(3) Thermionic emission: when the cathode is heated using a high DC potential difference, the electrons gain enough energy to overcome the surface potential barrier of the cathode material, so electrons leave the filament.

(4) (a) The target: a material of large atomic number and high melting point, such as tungsten.

(b) The filament: a material of high melting point, such as tungsten.

16 **Model answer**

(1) Because of its high thermal conductivity, which carries most of the heat produced to the cooling fins, which get rid of it by radiation.

(2) By changing the potential difference between the anode and the cathode.

(3) By changing the filament current or the potential difference between the anode and the cathode.

17 **Model answer**

So that the accelerated electron has enough energy to knock out an electron close to the nucleus of the target material.

18 **Model answer**

(1) When the accelerated electrons emitted from the cathode pass near the electrons of the atoms of the target material, their speed and energy decrease because of collisions and scattering. According to Maxwell–Hertz theory, the energy lost by the electrons appears as electromagnetic radiation containing all possible wavelengths.

(2) (a) Some accelerated electrons lose all of their energy when they hit the target.

(b) One of the accelerated electrons from the cathode collides with one of the electrons close to the nucleus of a target atom, so that electron gains energy that moves it out of the atom or to levels farther from the nucleus. Another electron from a higher energy level takes its place, and the energy difference between the two levels appears as radiation of a definite wavelength (λ_2).

19 **Model answer**

The larger the energy difference between the two levels the electron moves between, the higher the frequency of the emitted radiation and the shorter its wavelength, so:

(1) λ_2

(2) λ_1

20 **Model answer**

Radiation (1) is infrared rays, and radiation (2) is X-rays.

(1) and (2): radiation (2), because its energy is greater.

21 **Model answer**

Energy in: electrical energy.

Energy out: electromagnetic energy.

Wasted energy: part of the electromagnetic energy turns into heat energy.

22 **Model answer**

Because the free electrons inside the tube gain high energy from the high potential difference between the target and the filament, and when they hit the target they lose part or all of this energy, which appears as a spectrum of very short wavelengths (very high frequencies).

23 **Model answer**

$v = P_L/m_e = (63.7 \times 10^{-25})/(9.1 \times 10^{-31}) = 7 \times 10^6\ m/s$

$E = 1/2 m_e v^2 = 1/2 \times 9.1 \times 10^{-31} \times (7 \times 10^6)^2 = 2.23 \times 10^{-17}\ J$

$\lambda = hc/E = (6.625 \times 10^{-34} \times 3 \times 10^8)/(2.23 \times 10^{-17}) = 8.91 \times 10^{-9}\ m$

24 **Model answer**

(1) $N = It/e = (5 \times 10^{-3} \times 1)/(1.6 \times 10^{-19}) = 3.125 \times 10^{16}$ electrons

(2) $P_w = VI = 40 \times 10^3 \times 5 \times 10^{-3} = 200\ W$

(3) $(P_w)_{x\text{-ray}} = 200 \times 2/100 = 4\ W$

25 **Model answer**

The gas atoms are ionized because of the high energy of X-rays.

26 **Model answer**

Because X-rays penetrate materials better than visible light, and they penetrate to different degrees depending on what is inside the bags, so they can be used to reveal those contents.

27 **Model answer**

The intensity of the X-rays at point a is greater than at point b.

This is used by exposing metals to X-rays and receiving the rays that pass through on a photographic plate, so gas bubbles or internal cracks in the metal are detected from the differences in intensity from one region to another.

Past exam questions

1	2	3	4	5	6	7	8	9	10
B	D	C	C	B	B	C	A	C	D
11	12	13	14	15	16	17	18	19	20
A	A	B	D	A	C	C	D	C	B
21	22	23	24	25	26	27	28	29	30
C	B	D	D	A	A	D	A	D	B
31	32	33	34	35	36	37	38	39	40
A	B	C	D	D	C	A	D	A	B
41	42	43	44	45					
A	C	D	B	—					

1 **Answer (B)**

The energy of (S) = $E_3 - E_2$, so $1/(\lambda_S) = 1/256.86 - 1/304.45$

$\lambda_S \approx 1643\ nm$

2 **Answer (D)**

$\Delta E = 13.6(1 - 1/16) = 12.75\ eV$

$\lambda = hc/(\Delta E) = (6.625 \times 10^{-34} \times 3 \times 10^{8})/(12.75 \times 1.6 \times 10^{-19}) = 9.74 \times 10^{-8}\ m$

3 **Answer (C)**

The longest wavelength in the visible spectrum (Balmer) is for the transition from n = 3 to n = 2

$\Delta E = 13.6(1/4 - 1/9) = 1.89\ eV$, $\lambda \approx 6576\ AA$

4 **Answer (C)**

The number of waves around the orbit = the number of the level: (X) n = 2 , (Z) n = 5 , (Y) n = 6

$E_Z - E_X = 13.6(1/4 - 1/25) = 2.86\ eV$ is greater than $E_Y - E_Z = 13.6(1/25 - 1/36) = 0.17\ eV$

5 **Answer (B)**

$\Delta E_A = 13.6(1/4 - 1/16) = 2.55\ eV$, $\Delta E_B = 13.6(1 - 1/4) = 10.2\ eV$

$(upsilon_A)/(upsilon_B) = 2.55/10.2 = 1/4$

6 **Answer (B)**

The number of waves around the orbit is 5, so it is level n = 5

Returning to n = 5 (Pfund series) gives infrared rays.

7 **Answer (C)**

$P_L = E/c$, so the ratio = the ratio of the energies

$\Delta E_X = 13.6(1/4 - 1/16) = 13.6 \times 3/16$, $\Delta E_Y = 13.6(1 - 1/9) = 13.6 \times 8/9$

$((P_L)_X)/((P_L)_Y) = 3/16 \times 9/8 = 27/128$

8 **Answer (A)**

$\Delta E_1 = 13.6(1/9 - 1/16) = 13.6 \times 7/144$, $\Delta E_2 = 13.6(1/4 - 1/9) = 13.6 \times 20/144$

$(\lambda_1)/(\lambda_2) = (\Delta E_2)/(\Delta E_1) = 20/7$

9 **Answer (C)**

Longest wavelength = smallest energy difference, which is the transition from the sixth level to the fifth (Pfund series).

10 **Answer (D)**

The number of waves around the orbit is 4, so it is level n = 4

$E_4 = (-13.6)/16 = -0.85\ eV$

11 **Answer (A)**

From the fifth level the electron can return to levels 4, 3, 2, 1,

so 4 series are emitted (Pfund needs n = 6, so it is not emitted).

12 **Answer (A)**

387.5 nm is the shortest wavelength, so it is the transition $E_3 \rightarrow E_1$, and 1033.3 nm is the longest, $E_3 \rightarrow E_2$

(S) is $E_2 \rightarrow E_1$: $1/(\lambda_S) = 1/387.5 - 1/1033.3$

$\lambda_S = 620\ nm$

13 **Answer (B)**

The energy of the absorbed photon = the sum of the energies of the emitted photons (conservation of energy).

$hupsilon = hupsilon_1 + hupsilon_2 + hupsilon_3$, so $upsilon = upsilon_1 + upsilon_2 + upsilon_3$

14 **Answer (D)**

$E = hc/(\lambda) = (6.625 \times 10^{-34} \times 3 \times 10^8)/(974 \times 10^{-10} \times 1.6 \times 10^{-19}) = 12.75\ eV$

which is the difference between n = 4 and n = 1, that is transition A.

15 **Answer (A)**

$E_{M \to K} = 3 \times 10^{-19} + 1.634 \times 10^{-18} = 1.934 \times 10^{-18}\ J$

$upsilon = E/h = (1.934 \times 10^{-18})/(6.625 \times 10^{-34}) = 2.92 \times 10^{15}\ Hz$

16 **Answer (C)**

The shortest wavelength of visible light is from the transition n = 4 to n = 2:

$\Delta E = -0.85 - (-3.4) = 2.55\ eV\ ,\ \lambda = hc/(\Delta E) \approx 487.1\ nm$

17 **Answer (C)**

The line emission spectrum of hydrogen gas is coloured lines on a black background.

18 **Answer (D)**

White light passing through a gas gives a line absorption spectrum: a background of the spectrum colours with black lines in it.

19 **Answer (C)**

Figure (1): the light of the glowing lamp directly gives a continuous spectrum.

Figure (2): the light of the lamp passes through the gas and gives a line absorption spectrum.

20 **Answer (B)**

An electron moving from a higher level to a lower one gives a line emission spectrum.

The photon energy $= 4E - E = 3E$

21 **Answer (C)**

Glowing hydrogen gives a line spectrum, and the laser has almost a single wavelength, so its spectrum is a line spectrum.

22 **Answer (B)**

Fraunhofer lines are dark lines in the solar spectrum caused by absorption by the gases around the Sun, so they are a line absorption spectrum.

23 **Answer (D)**

Spectrum (N) is coloured lines on a black background: an emission spectrum. Spectrum (M) is black lines on a coloured background: an absorption spectrum.

The lines are at the same positions, so they are of the same gas.

24 **Answer (D)**

The cold gas absorbs its characteristic wavelengths from the continuous spectrum, so black lines appear within the continuous spectrum.

25 **Answer (A)**

The wavelength of the characteristic spectrum decreases as the atomic number of the target increases, so to get longer wavelengths we use a smaller atomic number: 29

26 **Answer (A)**

$KE = 1/2mv^2 = 1/2 \times 9.1 \times 10^{-31} \times (7.34 \times 10^6)^2 = 2.45 \times 10^{-17}\ J$

$\lambda_{min} = hc/KE = (6.625 \times 10^{-34} \times 3 \times 10^8)/(2.45 \times 10^{-17}) = 8.11 \times 10^{-9}\ m = 8.11\ nm$

27 **Answer (D)**

Electron (y) is knocked out of level K, so an electron from a higher level moves into it:

from L : $-12 - (-69) = 57\ keV$, from M : $-2 - (-69) = 67\ keV$

28 **Answer (A)**

λ_2 is at a sharp peak, so it belongs to the characteristic spectrum, whose wavelength decreases as the atomic number of the target increases.

λ_1 depends only on the potential difference.

29 **Answer (D)**

The lowest frequency of the characteristic spectrum matches the longest characteristic wavelength, 0.7 Å, and the highest frequency of the continuous spectrum matches the shortest wavelength, 0.35 Å

$(upsilon_1)/(upsilon_2) = 0.35/0.7 = 0.5$

30 **Answer (B)**

$P_L = h/(\lambda)$, so the maximum momentum matches the shortest characteristic wavelength: 0.08 nm

31 **Answer (A)**

$E = hupsilon = 6.625 \times 10^{-34} \times 5.43 \times 10^{18} = 3.6 \times 10^{-15}\ J = 22.5\ keV$

The energy of the other level $= -1.5 - 22.5 = -24\ keV$

32 **Answer (B)**

A transition between two levels gives the characteristic spectrum (a sharp peak), which is λ_3

33 **Answer (C)**

The energy lost $= 70 - 54.5 = 15.5\ keV$

$\lambda = hc/E = (6.625 \times 10^{-34} \times 3 \times 10^{8})/(15.5 \times 10^{3} \times 1.6 \times 10^{-19}) = 8.01 \times 10^{-11}\ m$

34 **Answer (D)**

$\Delta E = -8.3 - (-74) = 65.7\ keV$

$\lambda = hc/(\Delta E) = (6.625 \times 10^{-34} \times 3 \times 10^{8})/(65.7 \times 10^{3} \times 1.6 \times 10^{-19}) = 1.9 \times 10^{-11}\ m$

35 **Answer (D)**

The sharp peaks are at 6 nm and 10 nm, so the shortest characteristic wavelength is 6 nm

36 **Answer (C)**

Increasing the potential difference decreases λ_1 (the shortest wavelength), and the characteristic spectrum λ_2 , λ_3 does not change.

Increasing the filament current and the potential difference increases the radiation intensity.

37 **Answer (A)**

Studying crystal structure depends on the diffraction of X-rays when they pass through crystals.

38 **Answer (D)**

Molybdenum has a smaller atomic number, so its characteristic wavelength is longer than $1.8 \times 10^{-11}\ m = 1.8 \times 10^{-2}\ nm$

and the only longer choice is $7.1 \times 10^{-2}\ nm$

39 **Answer (A)**

The peak of the higher frequency, $5 \times 10^{18}\ Hz$, matches the transition of larger energy, from M to K

40 **Answer (B)**

Increasing the atomic number decreases the wavelength of the characteristic spectrum.

Increasing the potential difference decreases the shortest wavelength of the continuous spectrum.

41 **Answer (A)**

The high potential difference (1) between the filament and the target accelerates the electrons emitted from the filament.

The battery (2) heats the filament.

42 **Answer (C)**

With the same potential difference, the maximum energy of the continuous spectrum stays the same.

The smaller atomic number puts the peaks of the characteristic spectrum at lower energies (they shift to the left).

43 **Answer (D)**

Increasing the potential difference decreases λ_o while λ_k does not change, so the difference between them increases.

44 **Answer (B)**

The characteristic spectrum is the sharp peaks at 0.5 Å and 0.6 Å

45 **Model answer**

(1) $E_{max} = hc/(\lambda_{min}) = (6.625 \times 10^{-34} \times 3 \times 10^{8})/(0.2 \times 10^{-9}) = 9.94 \times 10^{-16}\ J$

(2) $E = hc/(\lambda) = (6.625 \times 10^{-34} \times 3 \times 10^{8})/(0.6 \times 10^{-9}) = 3.31 \times 10^{-16}\ J$