Hydrogen Spectrum Chemistry Questions with Solutions

Q1. The transition from the third shell to any other shell is known as
(a) Balmer series
(b) Paschen series
(c) Pfund series
(d) None of the above
Answer: (b) The transition from the third shell to any other shell is known as Paschen series.

Q2. What is the term for band of colours?
(a) Dispersion
(b) Spectrum
(c) Spectral lines
(d) None of the above
Answer: (b) Spectrum is the term for a band of colours.

Q3. The hydrogen emission spectrum comprises radiation of discrete
(a) Frequency
(b) Wavelength
(c) Energy
(d) None of the above
Answer: (a) The hydrogen emission spectrum comprises radiation of discrete frequencies.

Q4. Atomic hydrogen displays
(a) Emission spectrum
(b) Absorption spectrum
(c) Dispersion spectrum
(d) None of the above
Answer: (a) Atomic hydrogen displays emission spectrum.

Q5. Which spectral series of the hydrogen spectrum lies in the ultraviolet region?
(a) Lyman series
(b) Paschen series
(c) Pfund series
(d) None of the above
Answer: (a) Lyman series of the hydrogen spectrum lies in the ultraviolet region.

Q6. What is the ratio of the energies of the hydrogen atom in its first to a second excited state?

Answer: 1st excited state corresponds to n = 2
2nd excited state corresponds to n = 3
Hence,

$$\frac{E_1}{E_2} = \frac{n_2^2}{n_1^2} = \frac{3^2}{2^2} = \frac{9}{4}$$

Hence, the ratio of the energies of the hydrogen atom in its first to a second excited state is equivalent to 9 / 4.

Q7. The ground state energy of the hydrogen atom is −13.6eV. What will be its potential energy?

Answer: The ground state energy of the hydrogen atom = − 13.6 eV
The kinetic energy of the hydrogen atom = - The ground state energy of the hydrogen atom
The kinetic energy of the hydrogen atom = 13.6 eV
The potential energy of the hydrogen atom = - 2 X (The kinetic energy of the hydrogen atom)
The potential energy of the hydrogen atom = - 2 X (13.6 eV)
The potential energy of the hydrogen atom = - 27.2 eV

Q8. What are the different series of hydrogen spectra?
Answer: The primary spectral series of hydrogen spectra are mentioned below.
1. Lyman series
2. Balmer series
3. Paschen series
4. Brackett series
5. Pfund series
6. Humphreys series

Q9. What will happen to Bohr's formula of a Hydrogen atom if the proton acquires a charge of (+ 4 / 3 e) and the electron acquires a charge of (- 3 / 4) e where e = 1.6 X 10^{-19} C?

Answer: In accordance with Bohr's model of an atom the electrostatic force supplies the required centripetal force fo the electron revolving around the stationary nucleus.
$q_1q_2 / 4 \pi \varepsilon r^2 = mv^2 / r$
Therefore, the electrostatic force is directly proportional to the q_1q_2.
If the proton acquires a charge of (+ 4 / 3 e) and the electron acquires a charge of (- 3 / 4) e, then Bohr's formula of a Hydrogen atom will remain the same.
As the product of 3 / 4 and 4 / 3 is equivalent to unity.

Q10. State any two limitations of Bohr's model of an atom.

Answer: Bohr's model of an atom states that an atom has a tiny positively charged particle known as a nucleus surrounded by the negatively charged particle known as electrons. Electrons revolve around the nucleus in a fixed orbit.
The limitations of Bohr's model of an atom are mentioned below.
1. He could not explain the structure of a large atom.
2. He could not explain the Zeeman effect.

Q11. Fetch an expression for the frequency of radiation emitted when a hydrogen atom deexcites from level n to level (n_1). For large n, show that this frequency equals the classical frequency of the revolution of the electron in orbit.

Answer:

$$v = \frac{me^4}{(4\pi^3)\varepsilon^2(h/2\pi)^3}[\frac{1}{(n-1)^2} - \frac{1}{n^2}]$$

$$v = \frac{me^4(2n-1)}{(4\pi^2)\varepsilon^2(h/2\pi)^3 n^2(n-1)^2}$$

For large n,

$$v \cong \frac{me^4}{32\pi^3\varepsilon^2(h/2\pi)^3 n^3}$$

Orbital frequency v_e = (v / 2πr).
In Bohr model,

$$v = \frac{n(h/2\pi)}{mr}$$

$$r = \frac{4\pi\varepsilon(h/2\pi)^2}{me^2}n^2$$

This gives,

$$v_e = \frac{n(h/2\pi))}{2\pi mr^2} = \frac{me^4}{32\pi^3\varepsilon^2(h/2\pi)^3 n^3}$$

Which is same for large n.

Q12. What is the wavelength of light emitted when the electron in a hydrogen atom transitions from an energy level with n = 4 to an energy level with n = 2?

Answer:

The expression for the wavelength of radiation is,

$$\frac{1}{\lambda} = R(\frac{1}{n_1^2} - \frac{1}{n_2^2}$$

Substitute values in the above expression,

$$\frac{1}{\lambda} = 109677(\frac{1}{2^2} - \frac{1}{4^2}$$

$$\frac{1}{\lambda} = 109677(\frac{1}{4} - \frac{1}{16}$$

$$\frac{1}{\lambda} = 109677X(\frac{12}{64})$$

$\lambda = 4.86 X 10^{-5}$ cm

$\lambda = 486 X 10^{-9}$ m

λ = 486 nm.

The line belongs to a bluish-green colour.

Q13. A hydrogen atom initially at the ground level absorbs a photon, which excites it to the n = 4 th level. Calculate the frequency and wavelength of the photon.

Answer:

For the ground level,

$n_1 = 1$

$E_1 = - 13.67 / n_1^2$

$E_1 = 13.67$ eV

The atom is excited to a higher level, $n_2 = 4$

$E_2 = - 13.67 / n_2^2$

$E_2 = - 13.67 / 16$ eV

$E = E_1 - E_2$

$E = hc / \lambda$

$\lambda = hc / E_1 - E_2$

$$\lambda = \frac{6.6X10^{-34}X3X10^8}{13.67 - \frac{13.67}{16}}$$

λ = 97 nm

$c = \lambda v$

$V = 3.1 X 10^{15}$ Hz.

Q14. Calculate the shortest and longest wavelengths in the hydrogen spectrum of the Lyman series.

Answer:

For the Lyman series, $n_1 = 1$.
For the shortest wavelength in the Lyman series (i.e., series limit), the energy difference in two states showing transition should be maximum, i.e., n_1 = infinity.
So,

$$\frac{1}{\lambda} = R_H[\frac{1}{1^2} - \frac{1}{\infty^2}] = R_H$$

$$\lambda = \frac{1}{109678}$$

$\lambda = 9.117 \times 10^{-6}$ cm
λ = 911.7 A
For longest wavelength in Lyman series (i.e., first-line), the energy difference in two states showing transition should be minimum, i.e., $n_2 = 2$.
So,

$$\frac{1}{\lambda} = R_H[\frac{1}{1^2} - \frac{1}{2^2}] = \frac{3}{4}R_H$$

Or

$$\lambda = \frac{4}{3}R_H = \frac{4}{3X109678}$$

$\lambda = 1215.7 \times 10^{-8}$ cm
λ = 1215.7 A

Q15. Match the following.

Column A	Column B
Lyman series	Visible region
Balmer series	Infrared region
Paschen series	Absorption spectrum
Brackett series	Ultraviolet region

Answer:

Column A	Column B
Lyman series	Ultraviolet region

Balmer series	**Visible region**
Paschen series	**Infrared region**
Brackett series	**Infrared region**

Practise Questions on Hydrogen Spectrum

Q1. Describe Bohr's model of an atom.

Answer:

According to the Bohr Atomic model, a small positively charged nucleus is surrounded by revolving negatively charged electrons in fixed orbits. He concluded that an electron would have more energy if it is located away from the nucleus, whereas the electrons will have less energy if it is located near the nucleus.

The postulates given by Neils Bohr are:

- Electrons revolve around the nucleus in a fixed circular path termed as "orbits" or "shells" or "energy level." The orbits are termed "stationary orbits."
- Every circular orbit will have a certain amount of fixed energy, and these circular orbits are termed orbital shells. The electrons will not radiate energy as long as they continue to revolve around the nucleus in the fixed orbital shells.
- The different energy levels are denoted by integers such as n = 1 or n = 2 or n = 3, and so on. These are called quantum numbers. The range of quantum numbers may vary and begin from the lowest energy level (nucleus side n = 1) to the highest energy level.
- The different energy levels or orbits are represented in two ways, such as 1, 2, 3, 4… or K, L, M, N….. shells. The lowest energy level of the electron is called the ground state.

Q2. Explain Bohr's postulates for the hydrogen atom model.

Answer:

According to the Bohr Atomic model, a small positively charged nucleus is surrounded by revolving negatively charged electrons in fixed orbits. He concluded that an electron would have more energy if it is located away from the nucleus, whereas the electrons will have less energy if it is located near the nucleus.
The postulates given by Neils Bohr are

First Postulate: The electron revolves around the nucleus in discrete circular orbits called stationary orbits without emission of radiant energy. These orbits are called stable orbits or non-radiating orbits.
Second Postulate: Electrons revolve around the nucleus only in orbits whose angular momentum is an integral multiple of h/2π.
Third Postulate: When an electron transitions from one of its non-radiating orbits to another of lower energy, a photon is emitted having energy equal to the energy difference between the two states. The frequency of the emitted photon is then given by
$v = E_i - E_f / h$

Q3. What is the quantisation of charge?

Answer:

The quantisation of charge implies that charge can assume only specific discrete values. That is to say, the observed value of a particle's electric charge (q) will be integral multiples of (e) 1.6×10^{-19} coulombs.
i.e. q = ne where n = 0, 1, 2, ... (both positive and negative integers).
The charge cannot assume any value between the integers.

Q4. Explain the line spectrum of hydrogen.
Answer: The emission spectrum of hydrogen is divided into a number of spectral lines with wavelengths given by the Rydberg formula. These observed spectral lines are due to the electron-making transitions between the energy levels in an atom.

Q5. Why are there multiple lines in the hydrogen line spectrum?

Answer: There are multiple lines in the hydrogen line spectrum because the hydrogen atoms absorb diverse amounts of energy and go to distinct excited states. From there, it takes different paths and comes back to the ground state. Since distinct paths are associated with diverse energies, various spectral lines are formed in the hydrogen line spectrum.