Solutions of the Tutorial Sheet: Atomic Spectroscopy – Part I

Q.1. What is spectroscopy?

Ans. Spectroscopy is the branch of science that deals with the study of interaction of matter with light or in other words, spectroscopy may be defined as the study of interaction of electromagnetic radiation with matter.

Q.2. What is atomic spectroscopy?

Ans. Atomic spectroscopy is defined as the spectroscopic analysis of elements in a qualitative and quantitative manner. It works on the principle of excitation or emission of valence electrons of a metal atom. Typically, the analysis can be carried out either in the absorption mode which is known as Atomic Absorption Spectroscopy (AAS) or in the emission mode which is known as Atomic Emission Spectroscopy (AES) or Flame Photometry.

Q3. What is the difference between atomic absorption and emission spectra?

Ans.

13.6 Differences Between Atomic Absorption Spectroscopy and Flame

The main differences between atomic absorption spectroscopy and as follows :

reaching the unexcited state. The measurement of this emitted radi emission spectroscopy. Analytical signal in flame emission is the excited atoms drop to the ground state. The signal comes entirely

In atomic absorption spectroscopy, the signal is obtained from the of the source in the absence of metallic elements present in the liq obtained when metallic elements are present in the optical path.

(b) In flame emission spectroscopy, the emission intensity is depende atoms and is, therefore, greatly influenced by temperature variatio

In atomic absorption spectroscopy, atomic absorption depends upon

Q. 4. What is an "atomizer"?

Ans. Atomizer is a component of the atomic spectrometer which atomizes the molecules under investigation. An atomizer consists of a nebulizer and a burner and it can be of two types: Flame atomizer and Graphite or electrothermal atomizer.

Q.5. What kind of light is detected in atomic absorption spectroscopy (AAS) and atomic emission spectroscopy (AES)?

Ans. In atomic absorption spectroscopy (AAS), the intensity of the transmitted light is detected whereas, in atomic emission spectroscopy (AES), the intensity of the emitted light is detected.

Q.6. Why is the color of a flame containing sodium atoms different from that of a flame containing potassium atoms?

Ans. In flame photometry, the color of a flame depends upon the wavelength of the emitted radiation that occurs due to relaxation of electrons from a higher electronic energy level to a lower electronic energy level. The electronic configurations of sodium (Na) is $1s^2 2s^2 2p^6 3s^1$ and that of potassium (K) is $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1$. So, in case of sodium, the electron from 3s level requires higher energy for excitation (which subsequently relaxes back) compared to the energy required for 4s level electron of potassium. Consequently, the flame colors are different.

Q. 7. What is the difference between a total consumption burner and a premix burner? Which one is used for which technique?

Ans. In a flame atomizer, two types of burner designs are commonly used:

(i) Total consumption burner: In this, the fuel, oxidant and sample meet together at the base of the flame. The fuel (usually acetylene) and the oxidant (usually air) are forced into the flame by applying pressure whereas the sample is drawn into the flame by aspiration. As a result, the flame is turbulent and non-homogeneous. This type of burner is used in Flame Photometry or Atomic Emission Spectroscopy (AES).

(ii) Premix burner: In this, the sample is nebulized at first and then mixed thoroughly with both the fuel and the oxidant before it is introduced into the flame. Consequently, atomization occurs efficiently and the resultant flame is non-turbulent (laminar flow), noise-free and stable. Therefore, this type of burner is used in Atomic Absorption Spectroscopy (AAS).

Q.8. What is the principle of atomic emission spectrophotometry?

Ans. A sample solution containing metal or metallic salt is introduced into the flame. In flame, the sample goes under a complex process of atomization where it (the metal in the molecule or its coresponding salt) is converted to its own atoms in the gaseous state.

Mathematically : $E_1 - E_0 = h\nu \quad (\nu = c/\lambda)$

$$E_1 - E_0 = hc/\lambda$$

FOR EXAMPLE

$$Na \xrightarrow{\text{Flame}} Na^*$$

$$Na^* \longrightarrow Na + h\nu \ (589\ nm)$$

$$\boxed{\lambda = hc / E_1 - E_0}$$

Q. 9. List various steps involved until the detection of analyte using AES.

Ans. All of the steps are listed below:

(i) Nebulization: The sample solution is converted into very fine droplets; forms aerosol which is aspirated into flame

(ii) Desolvation: removal of solvent present around the molecules which leaves behind dry sample,

(iii) Sublimation: transition of the molecules from solid to gaseous state,

(iv) Atomization: dissociation of molecules into atoms, and

(v) Ionization: removal of valence electrons of an atom.

(vi) Relaxation: excited electron relaxes from the higher energy electronic state to the lower energy

(vii) Measurement of the wavelength and the intensity of the emitted radiation

Q. 10. Name the factors that affect the intensity of emitted radiation in AES?

Ans. Following factors are responsible for affecting the intensity of the emitted radiation in AES:

(i) Number of atoms in the excited electronic state

(ii) Flame temperature: Higher the temperature $\Rightarrow$ More atoms will be excited

(iii) Solution viscosity: Increase in the viscosity $\Rightarrow$ atomization efficiency decreases

(iv) Presence of other metals: Interferes with the metal sample and affects the emitted intensity

(v) Presence of acid: Modifies the initial dissociation equilibrium $\Rightarrow$ affects emission intensity

Q. 11. What are the main limitation of flame photometry (AES)?

Ans. Following are the limitations of the flame photometry (AES):

(i) It gives information only about the atomic state of the metal; not about the molecular state which is originally taken as a sample.

(ii) The sample should be present in the liquid form or as a solution.

(iii) All the metal atoms cannot be analyzed/detected.

Q. 12. If E_1 and E_2 are the energies of ground state and excited state for a metal M, then what is the wavelength of emitted radiation?

Ans. The wavelength (λ) of the emitted radiation will depend on the energy difference:

Given: E_1: Energy of the ground state and, E_2: Energy of the excited state

Since, $E = h\nu = hc/\lambda \qquad \Rightarrow \; E_2 - E_1 = hc/\lambda$

where, h: Planck's constant, and c: velocity of light

Q.13. What temperature can be achieved by each of the following flames?

(a) air/natural gas

(b) air/acetylene

(c) N_2O/acetylene

(d) oxygen/acetylene

Ans. Following are the temperature values that can be achieved by each flame:

(a) air/natural gas: 1700 – 1900 °C, (b) air/acetylene: 2125 - 2400 °C

(c) N_2O/acetylene: 2600 – 2800 °C, (d) oxygen/acetylene: 3100 °C

Q.14. What is the purpose of the high-energy flame, discharge, or plasma source in atomic spectroscopy?

Ans. The purpose of the high-energy flame, discharge, or plasma source in atomic spectroscopy is to desolvate the molecules followed by atomization. Once the metal atoms are formed, the flame excites the atoms to higher energy electronic states.