1 Spectra

Spectrum

Spectrum: The separation of incoming radiation into its individual wavelengths

Continuous Spectrum

- The spectrum that corresponds to blackbody radiation is an example of a continuous spectrum
- In a continuous spectrum there is no interruption in the distribution of wavelengths

1.1 absorption spectrum

Absorption Spectrum

- 1802 William Wollaston noticed dark gaps in the spectrum of sunlight
- 1814 Joseph von Fraunhofer listed over 500 of these lines
- These lines are called absorption lines
Absorption Spectra

- Scientists discovered that passing a continuous spectrum of light through a cold gas would produce absorption lines.

1.2 emission spectra

Emission Spectra

- Scientists discovered that hot gases produced spectra of a few narrow lines.
- This type of spectrum is called an emission-line spectrum.

Connection between emission and absorption lines

- Emission lines produced when a specific gas is heated are precisely at the same wavelengths of the absorption lines associated with that gas.

2 Kirchoff’s Laws

Kirchoff’s Laws

In 1859 Gustav Kirchoff and Robert Bunsen proposed three rules to explain the types of spectra.
Kirchhoff’s Laws
1. Hot thin gas will emit a spectrum consisting of bright emission lines characteristic of the elements making up the gas

Kirchhoff’s Laws
2. Cool thin gas will absorb certain wavelengths from a continuous spectrum passing through the gas. These lines occur at precisely the same wavelengths as the emission lines produced by the gas at higher temperatures

Kirchhoff’s Laws
3. A hot substance that is opaque (solid, liquid, or dense thick layer of gas) will emit a continuous spectrum containing light of all wavelengths

3 Spectroscopy

Spectroscopy: Study of spectra to determine chemical composition and physical conditions in the material where the light originated

Spectrograph or Spectrometer: Scientific instrument used to analyze spectra

   Consists of
   • Dispersing device (usually a diffraction grating)
   • Detector (usually a CCD; before invention of the CCD, photographic plates were used)

Important Concept
By observing the spectra of stars we can determine the composition of their surface layers
4 atoms and photons

4.1 Bohr Atom

Bohr Atom

- In 1912 Danish physicist Niels Bohr developed a model of the atom which explains absorption and emission spectra
- The model is known as the **Bohr model**
- **nucleus** of an consists of protons (positively charged particles) and neutrons
- the nucleus is surrounded by electrons (negatively charged particles)

Quantization

- electron “orbits” are **quantized**
- Electrons can only exist in specific states with specific energies; these are called electron **orbitals**
- In the Bohr model electron orbitals have specific radii

Ground State

- Lowest energy state is called the **ground state**
- This is the “normal” state of an electron
- $n = 1$ state

Excited State
If the electron is given energy it can move into an excited state

$n \geq 2$

Excited State

For a hydrogen atom the radius of orbit is given by

$r = (5.3 \times 10^{-11} \text{ m})n^2$

Energy

For a hydrogen atom the energy of an orbit is given by

$E_n = -\frac{13.6}{n^2} \text{ eV}$

Photon
• When an electron drops from a higher to lower energy state a **photon** of light is emitted.

• The energy of a photon is given by

\[ E = hf = \frac{hc}{\lambda} \]

• \( h \) is Planck’s constant. \( h = 6.63 \times 10^{-34} \text{ J} \cdot \text{s} \)

**Photon**

• The change in the energy of the electron is equal to the energy of the photon

\[ \Delta E = E_{\text{upper}} - E_{\text{lower}} = E_{\text{photon}} \]

• Thus for hydrogen

\[ \frac{hc}{\lambda} = 13.6 \left( \frac{1}{n_{\text{lower}}^2} - \frac{1}{n_{\text{upper}}^2} \right) \text{ eV} \]

**Example: Hydrogen**

Example:
Hydrogen \( n = 3 \to n = 2 \) transition

\[ \frac{hc}{\lambda} = 13.6 \left( \frac{1}{3^2} - \frac{1}{2^2} \right) \text{ eV} \]