# OPERATING INSTRUCTIONS

AND TABLES OF SELECTED SPECTRAL LINES

## SPECTRUM TUBES

### DESCRIPTION

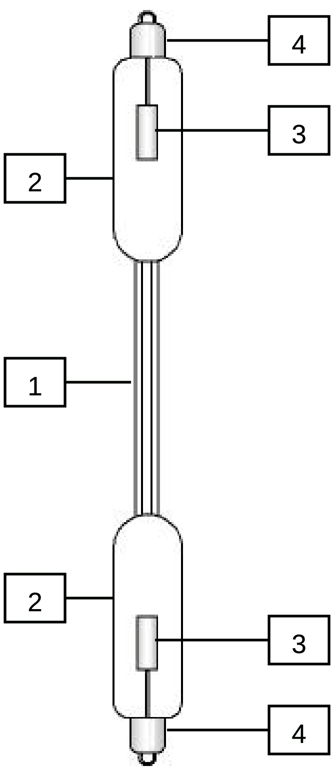


*Figure 1*

Spectrum tubes are light sources for examining emission spectra with a spectroscope or spectrometer. The light is emitted by a high voltage discharge through a low pressure gas or vapor.
The construction of the spectrum tubes is shown in *Figure 1*. The area of observation is a glass capillary tube (1) that has a bulb (2) at each end. The bulbs contain cylindrical metal electrodes (3) connected through the glass wall of the bulbs to metal end caps (4) which are used both to hold the tube and to apply the high voltage to energize it. During manufacture, the tubes are evacuated to a good vacuum then a small amount of the substance to be examined—a gas or a volatile liquid or solid— is introduced to create a low pressure. The tube is then sealed off permanently.

In use, the tubes are initially energized with about 5000VAC to establish the discharge. Once this occurs, the power supply is effectively short-circuited and the voltage falls to the maintenance voltage of the discharge, typically about 1000V. The current drawn is limited by the power supply, and is typically about 10 mA. During use, the spectrum tubes become hot, and the internal gas pressure rises. This is important for substances that are liquid or solid at room temperature, since the increased vapor pressure of the substance then gives a brighter discharge.

### LINE SPECTRA

Extensive research at the end of the 19th and the beginning of the 20th century revealed the electronic structure of atoms and molecules. Very detailed examination of many spectra using spectrum tubes and spectrometers played a major role in unraveling these structures and laid the foundations of much of modern Physics and Chemistry.

Within atoms and molecules there are many possible states for electrons to occupy. Occupying these states requires the electrons to have varying, but very specific levels of energy, and each individual energy state can only accommodate one electron.

When atoms and molecules are at normal temperatures, the electrons all occupy the available states with the lowest energies, leaving possible states with higher energies vacant. However, when a lot of energy is supplied to an atom or molecule, as in a flame, a gas discharge, or a spark, some electrons can use part of this energy to move—"jump"—to higher–energy states, leaving their previous states vacant. This process is called "excitation", and an atom or molecule in this state is said to be "excited." Excited states are unstable because of the empty lower-energy electron states that offer electrons in higher states the opportunity to "fall back" into a lower-energy state. To do this, they must give up the extra energy, which they do by emitting a photon (light bundle.)

Because all the atomic and molecular states have very specific energies, the photons emitted by these "transitions" also have very specific energies, or, according to the quantum theory, very specific frequencies. The relationship between the energy and frequency of a photon, first described by the famous German researcher Max Planck, is $E = h\nu$ where E is the "extra" energy given up in emitting the photon, $\nu$ is the frequency of the light wave, and h is a constant—Planck's Constant. There is an inverse relationship between the frequency $\nu$ and the wavelength $\lambda$ of any wave: $\lambda = c/\nu$, where c is the speed the wave travels, in this case, the speed of light. So the light emitted by a discharge tube—a spectrum tube—consists of a series of bright lines at very specific wavelengths, reflecting the various amounts of "extra" energy given up by the electrons making transitions.

By studying these line spectra, researchers were able to formulate rules for describing which lines would appear in a given spectrum, and to use these rules to unravel the electronic structure of atoms and molecules. Also, the line spectrum of an unknown substance can be used as a "fingerprint" to identify the substance.

## SAFETY

**DANGER!**

- **High voltage is applied to the metal end caps of the spectrum tubes. Physical contact with this voltage can cause serious injury.**
  **Use ONLY a specially-designed power supply with shielded connectors to energize the spectrum tubes.**
  **Make sure the POWER SUPPLY IS SWITCHED OFF when inserting or removing tubes.**
- **The tubes become very hot in operation and can cause serious burns if touched.**
  **DO NOT TOUCH the tubes during operation.**
  **ALLOW TUBES TO COOL AFTER USE before removing from the power supply.**

## OPERATION

Operating the spectrum tubes requires a special Spectrum Tube Power Supply, available from many commercial retailers, and a device for dispersing the emitted light to observe the line structure. A spectroscope or spectrometer with a high dispersion prism or a diffraction grating, or a simple diffraction grating with >200 lines/mm are suitable.

- Make sure the Spectrum Tube Power Supply is turned off.