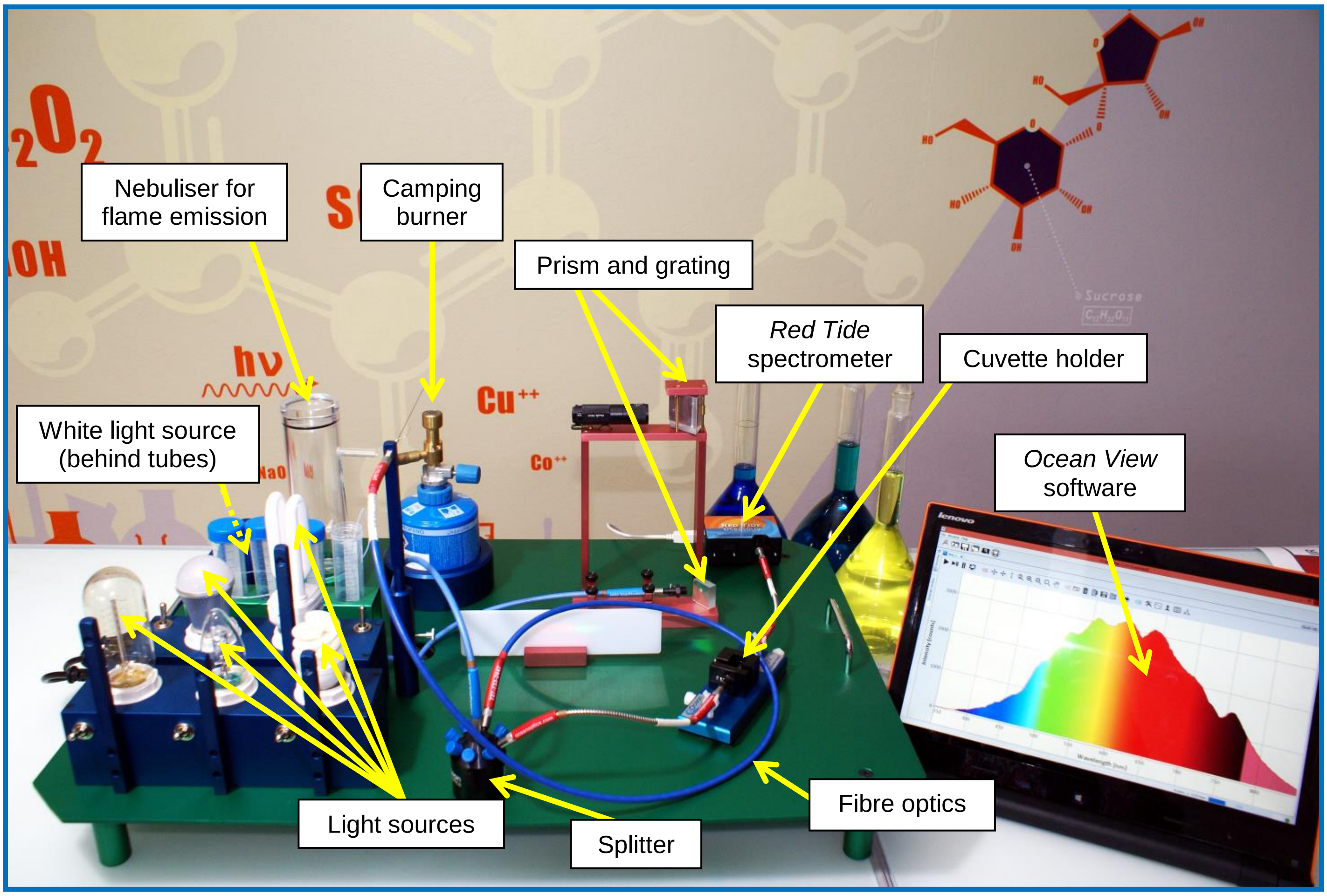
«*UNDER THE SHARP EYE OF THE SPECTR-O-MATIC*»

APPLICATION NOTE FOR EDUCATIONAL PURPOSES



1. SCOPE

- UV-VIS spectroscopy is used in analytical labs to identify unknowns present in all types of samples and quantify them. Scholars usually have no or only limited knowledge on the basics that hide behind a classical UV-VIS spectrometer, which they consider as a black box used to perform qualitative and quantitative analyses. **The main educational goal of the *Spectr-o-Matic*** (see image above) **is to play with light and chemicals in order to understand the background of radiation-matter interactions**.
- The *Spectr-o-Matic* is a home-made all-in-one UV-VIS spectrometer kit developed by the *Chimiscope*, the edutainment platform of the University of Geneva, Switzerland, and aimed at introducing to scholars aged 12-18 the concepts of light, wavelength and energy, radiation-matter interactions, and the use of these concept to identify and quantify food additives.
- The *Spectr-o-Matic* consists in a prism and a grating, a set of light sources used in the everyday life (tungsten, halogen, fluorescent, LEDs, plant-growing tube), a nebuliser and a camping-based burner, a series of interconnected optical fibres, an educational *Red Tide* spectrometer, and the OceanView software running on a touch screen computer to control the kit, display the spectra and perform quantification.
- The complete sequence of use of the *Spectr-o-Matic* can be presented between 1 hour and 3 hours, depending on the age and background of the scholars, and on the level of sophistication of the explanations that can be given by the instructor.

2. GENERAL SEQUENCE OF USE OF THE *SPECTR-O-MATIC*

- The show starts with a short theoretical presentation (Powerpoint, available on request) on the structure of the eye, the rods and cones that build up the retina and their sensitiveness to red, green and blue.
  Then an animated scheme shows how white light is dispersed into its components when passing through a prism, and how each colour is associated to a radiation which is described by a wavelength and an energy.
  Then, the principle of the observed colour of an object is discussed with a wheel of complementary colours.
  Finally, the presentation introduces the basics of the Beer-Lambert law when a radiation of a given wavelength is absorbed by a chromophore in solution.

- After this theoretical introduction, the strong light of a LED pocket lamp mounted on the *Spectr-o-Matic* is focussed on a dispersive equilateral prism that allows to show the rainbow of colours obtained at the outlet of the prism, directly on a translucent white plastic plate over a long distance in dimmed ambient light.
  The white light source (Ocean Optics HL2000) of the *Spectr-o-Matic* is then switched on and directed toward a small grating (1200 grooves/mm); the resulting 1st order spectrum is visualised on a small plastic plate; this allows to compare the non-linear dispersion of a prism (reds being more compressed than blues) compared to a grating, and to introduce the formulae used in prism and grating optics.
- Then, the spectrometer (Ocean Optics *Red Tide UV*) is switched on and the user records the spectra of a series of sources of light used at home over a window ranging from 350nm to 850nm, using a fibre optic directed toward the sources.
  While the spectra of a conventional tungsten wire bulb and of a halogen lamp merely differ in intensities, the fluorescent lamp which contains traces of mercury shows a fairly different spectrum with the narrow Hg lines in the UV and VIS overlapping with the continuous spectrum emitted by the components used to make the white coating of the lamp. The spectrum of the LED lamp dynamically show the continuous raise and fall of the broad bands emitted by the individual red, green and blue LEDs; when switched to white light, this lamp shows that the light produced mixes together the red + green + blue bands. Finally, the plant-growing lamp, which exhibits a bright violet radiance, shows a good spectral similarity with the fluorescent lamp, with additional broad violet-blue bands created by lanthanide-based components present in the inner coating of the lamp.
  Of course, the solar spectrum can also be recorded, showing the features of the continuous spectrum and its strong intensity.
- The next step consists in producing « atomic light ». This is made possible with a nebuliser and a flame burner.
  The nebuliser is a Plexiglas cylinder closed at both extremities, with a T-shaped inlet at its bottom, produced by 3D-printing, and a straight outlet at its top, directed toward the air inlet of the flame produced by a camping-based burner (B. Néel et al.; Journal of Chemical Education (2014); in press).
  The nebuliser inlet is connected to an external cylinder of pressurised air and to a series of tubes containing solutions of sodium, boron, caesium, potassium, and strontium; these elements show a high emission yield for flame emission spectroscopy and produce highly coloured flames easily identifiable by the naked eye. By venturi effect, the solution is sucked up in the nebuliser and dispersed in a cloud of droplets; the largest droplets fall on the bottom of the nebuliser while the smallest are pushed to the outlet of the nebuliser, where they are further sucked up by the flame burner.
  In the flame, the solution is evaporated and the resulting solid salts are broken into atoms which are excited to higher electronic states, from where they get back to their fundamental state of energy while emitting narrow lines characteristic of the elements under study, which are recorded by the spectrometer.
- In the next step, scholars are made familiar with the natural and artificial food additives used in beverages and fruit squashes. One of the most spectacular and straightforward demonstration is to use mint syrup; depending on the brand used, different food additives can be present in the syrup, *e.g.* in Switzerland, tartrazine (E102; yellow) + Patent Blue V (E131; blue), or safflower seeds (*Carthamus tinctorius*; yellow-orange) + Patent Blue V, or quinoline yellow (E104) + Patent Blue V.
  The spectra of the individual components diluted in deionised water are recorded on the spectrometer, and absorption bands are discussed in connection to the chemical structure of the dyeing molecules. Then, the unknown syrup is analysed after dilution in deionised water and its spectrum is used to identify which food additives are present.
  When very accurate spectra have to be recorded for further discussion, the food additives can be extracted in boiling water containing a long, untreated wool thread which will concentrate the additives (while the high amounts of sugar will remain in water); pigments pre-concentrated in the wool thread are solubilised in a small amount of alcohol and diluted in water prior to spectroscopic analysis.
  Quantitatively speaking, the spectra of individual food additives can be used in combination with the spectrum of the unknown syrup to determine the relative proportions of each of the yellow and blue pigments used in the original brand.

3. CONCLUSION

- The Spectr-o-Matic is a thrilling, yet simple and easy-to-use kit that helps scholars understand the basic principles of the nature of continuous and discrete light, the interactions between light and molecular species, and the use of UV-VIS spectroscopy to characterise qualitatively and quantitatively light-absorbing species in solution.

KEYWORDS – TECHNIQUES – APPLICATIONS

- **Keywords**: Educational UV-VIS spectroscopy
- **Techniques**: Prism and grating diffraction, UV-VIS spectroscopy, flame emission, absorbance
- **Applications**: Everyday light sources, food additives

AUTHORS

- Dr Didier Perret, David Gérard
  Chimiscope, the edutainment chemistry platform of the University of Geneva
  30, quai Ernest-Ansermet
  CH-1211 Geneva 4
  Switzerland