COLORIMETER - digital

Cat: CH1003-001 (9V battery or 12V.AC/DC plug-pak)

DESCRIPTION: The IEC Digital **COLORIMETER** is microprocessor controlled and designed for the classroom or laboratory. For simplicity of use and to avoid loss of parts, 4 coloured LED light sources covering red, yellow, green and blue bands of the spectrum are used and separate colour filters are avoided.. LED selection is manual so the student is involved in some decision making, but all functions of zero calibration, range changing and the controlling of LEDs are performed by the microprocessor.

If the inbuilt 9V battery is flat, the display shows 'bAt' and, as on many IEC designs, a normal 240/12V.AC or DC. plug pak can be used. If no button has been pressed for a period of 10 minutes, the instrument turns itself off to conserve battery power.

The set of Colorimeter parts is fitted into soft foam compartments. The set contains:

- 1x Colorimeter instrument with accuracy within +/- 2%.
- 1x Two piece tubular shroud to eliminate ambient light.
- 6x Small square standard cuvettes (plastic)
- 3x Standard glass test tubes 15-16mm diameter
- 1x 9V type 216 transistor battery
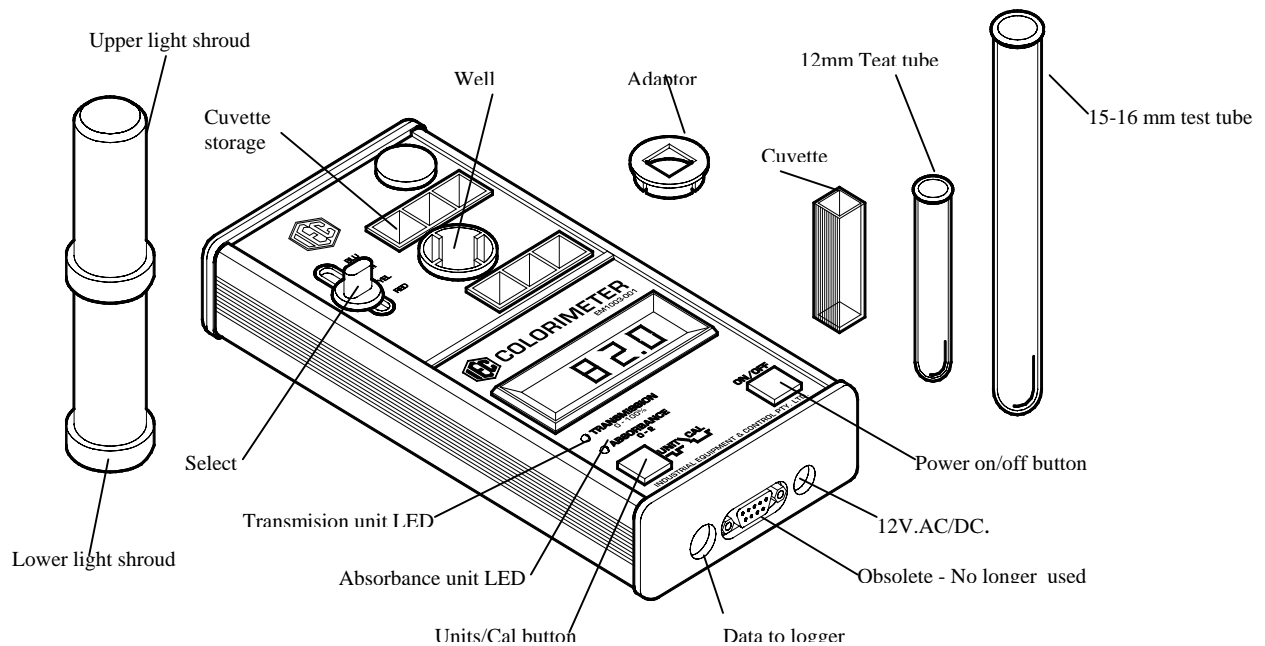- 1x Instruction sheet including several experiments

CH1003-001 colorimeter kit

Physical size: 285x210x63mm LxWxH (outer pack)   Weight: 0.7 kg

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The illustration below shows the general arrangement of the IEC Colorimeter.

The front panel provides a large LCD digital display and two press buttons. Right hand button is power ON/OFF and the left hand button is for changing the desired unit from 'Transmission' to 'Absorbance' and a longer press performs the zero and 100% 'Calibration' of Transmission and 0 to 2.3 of Absorbance. A mini LED indicates which Unit is selected.

The socket that takes the sample is moulded as part of the top panel to prevent any ingress of liquid inside the instrument. If a test tube breaks and the solution is lost, it can be drained out of the socket and the system rinsed with water without any liquid entering the instrument.

The compact size makes it easy to handle both in the laboratory or out in the field. Because many samples are of a solvent nature, it is important that glass containers can be used for the samples. The IEC Calorimeter can take the standard small square plastic cuvette, a mini 10mm diameter glass test tube, a standard 12mm diameter glass test tube or a standard 15-16mm glass test tube.

For convenience, the instrument has receptacles to carry up to 6 small square cuvettes so they need not be placed unstable on the bench. The cuvettes would probably be used as:

- Reference distilled water sample
- Sample solution of known concentration #1
- Sample solution of known concentration #2
- One or more solutions of unknown concentration

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6 1 - 6 5   M c C l u r e   S t .   T h o r n b u r y .   3 0 7 1   M e l b o u r n e .   A u s t r a l i a
T e l :   6 1   (0) 3   9 4 9 7   2 5 5 5   F a x :   6 1   (0) 3   9 4 9 7   2 1 6 6
c h 1 0 0 3 - 0 0 1 . d o c   3 0 - M a y - 0 6

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BASIC PROCEDURE TO DETERMINE CONCENTRATIONS:

A cuvette or test tube of distilled water is prepared to be used as the 100% transmission or zero absorption sample. In addition, two **known concentrations** of the solution should already be prepared in bottles.

Either one of the known concentrations or a sample of the solution at any mid-range concentration is now to be used to determine which light source should be used for the measurement. The first step before measuring concentrations is to find which wavelength of light source provides the least transmission or most absorption through the solution.

- Slide the selector switch to select the first light source (blue) and insert the distilled water sample. Press the UNIT button momentarily to select the 'Transmission' unit.
- Insert the distilled water sample into the well. Cover the sample with the light shroud. Press the UNIT button but this time hold depressed for a second to request CALIBRATION. The display will show 'CAL' and the display will then show 100% transmission for the distilled water sample.
- Remove the distilled water and insert the sample solution. Use the light shroud. Note the % Transmission.
- Select the next light source wavelength (green) and repeat the last two steps.
- When all 4 light sources have been checked, choose the light source that gave the lowest transmission reading. This is the light source to use for this solution. It should be noticed that the light with the lowest transmission or highest absorption is the closest complementary colour to the solution colour.

At this time the correct light source has been determined. Now, the absorption of two **known concentrations** must be measured.

Measurement of Concentration:

Leaving the light source selected to be the light wavelength that gives lowest transmission, now select Absorbance and insert the distilled water sample into the well. Press the CAL button for a second to re-calibrate to 0A (zero Absorbance).

- Remove the distilled water sample and insert the first known concentration. Use the light shroud. Note the reading.
- Remove the first sample and insert the second known concentration sample. Use the light shroud. Note the reading.
- Remove the second known sample and finally insert the unknown sample. Use the light shroud. Note the reading.
- Plot the Absorbance reading against concentration units for the two known samples.
- Draw a straight line between these points. This graph is true for the solution being tested. Keep or file the graph for any future concentration tests using this particular solution.
- From the graph, find the concentration for the unknown sample.

PRECAUTIONS:

The light shrouds:

The instrument is very sensitive to changes in transmitted light. It also is sensitive to ambient light entering the sample. **Always use the light shroud when taking measurements**. The closed tube is the normal shroud for cuvettes and small test tubes. The open tube is used for both supporting the diameter of the long glass test tubes and for extending the closed shroud beyond the long test tubes.

Various sample tubes:

The instrument can accept the following sample tubes:

The small square cuvettes: The round to square adaptor is used in the mouth of the well when using cuvettes.

- They are very convenient sample tubes but be careful to place them so the light passes through the flat smooth sides (not through the ribbed sides). They are accurate and flat so using various cuvettes does not change the passage of the light through the well. If glass test tubes are used, there is a lens effect through the glass that can seriously spoil readings. See below.
- The cuvettes are made from clear plastic so, if solvent solutions are used, the cuvettes will probably dissolve. Always use glass test tubes for solvent solutions.
- The cuvettes are very unstable when placed on the bench and are easily knocked over. Always store the active cuvettes in the storage receptacles provided in the instrument.

Glass test tubes:

- For 10mm diameter mini test tubes, they can fit inside a clean cuvette. The short shroud can be used.
- For 12mm diameter test tubes, they can fit in the square adaptor used for cuvettes. The short shroud can be used.
- For 15-16mm test tubes, the round to square adaptor must be removed and stored on the storage pin. The open shroud is fitted to the well and the tube inserted. This open shroud will help to support the test tube vertical and will prevent it from wobbling in the well. The closed shroud is then applied to the top of the open shroud.

The round shape of the glass test tubes causes a 'lens effect' to the light through the sample. Also the glass is not of even thickness, so rotating the test tube will make serious errors in readings. To obtain good readings using glass test tubes, follow these rules:

- Always use the same test tube for the various solutions including the distilled water reference.
- When the test tube is first used as the distilled water reference, rotate it to find a fairly even area of glass thickness. If very bad, change to another test tube. When found, use a wax pencil or felt pen to mark the glass near the well or near the shroud to be sure to always use that tube in exactly the same position each time. In the professional fields, matched sets of precision tubes can be purchase but they are very expensive.

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T e l :   6 1   (0) 3   9 4 9 7   2 5 5 5   F a x :   6 1   (0) 3   9 4 9 7   2 1 6 6
c h 1 0 0 3 - 0 0 1 . d o c   3 0 - M a y - 0 6

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- Always rinse the test tube with distilled water before filling with another solution.
- Always wash up when finished and keep the tubes spotlessly clean and dry.

Zero absorption reference:

If the solution is water based, used distilled water as the zero reference. If the solution is solvent based, use the base solvent as the zero reference sample instead of water.

Care of the instrument:

- Always keep the instrument clean and dry.
- When not in use, always keep the cuvettes and test tubes clean and dry.
- If a spillage should occur, wipe it away immediately. The panel design prevents small spillage from running into the instrument but to keep spillage small do not use sample sizes any larger than necessary to fill the cuvettes or test tubes beyond the height of the light path.
- The well is sealed internally. If liquid should enter the well or the storage wells for cuvettes, turn the instrument off and carefully flush the fluid from the well or storage wells with clean water. Wipe the cavities dry internally.

The IEC Digital Colorimeter comes in a kit pack with all parts held securely in strong urethane foam. Included are 3 test tubes, 6 cuvettes, light shield and adaptor for long test tubes and 9V battery,

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c h 1 0 0 3 - 0 0 1 . d o c   3 0 - M a y - 0 6

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THE THEORY OF CONCENTRATION MEASUREMENT:

Beer's Law:

Beer's Law states that light absorbed by a solution depends on:

- The absorbing ability of the solute
- The distance travelled by the light
- The concentration of the solution

Thus: Absorbance (A or AU) = k (constant) x C (concentration)

Thus it can be seen that Absorbance is proportional to Concentration of a solution.

Relationship between Absorbance (A or AU) and Transmission (T):

Absorbance is $\log (1 / T) = \log_{10} (100 / \%T) = 2 - \log_{10} \%T$ (log is to base 10)

Absorbance = $2 -$ the $\log_{10}$ of Transmission in percent.

The unit is for Absorbance is 'A' or 'AU' (Absorbance Units).

Therefore:

If Transmission is 0%,   Absorbance is infinity

If Transmission is 1%,   Absorbance is 2A

If Transmission is 10%,   Absorbance is 1A

If Transmission is 100%,   Absorbance is zero

NOTE::   Beer's Law holds true between the limits of about 20% to 80% transmission. Within these limits, only two known concentrations are required to plot the straight line. Outside these limits, the graph of Absorbance to Concentration is no longer a straight line, so several known concentration examples will need to be plotted to determine the shape of the graph of best fit.

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TECHNICAL INFORMATION:

The unit runs from a single 9V dry cell which is accessible from a battery holder in the end of the instrument.   When the battery is becoming flat, the display shows 'bAt'.

The source wavelengths: Blue: 470nm,   Green: 525nm,   Yellow: 591nm,   Red: 625nm.

The instrument can run also from a normal 240/12V.AC/DC Plug Pak as used on many of IECs products.   The sockets in the end of the instrument are for:

- 240/12V.AC/DC Plug Pak for use if internal battery is flat.
- 8 pin mini DIN connector for 0-4.1V or 0-5V signal directly to a data logger. The Y axis is to be scaled **0-5V = 0-100%** when **Transmission** is selected, or **0-5V = 0-2.3A** when **Absorbance** is selected. The X axis it to be scaled in Concentration units.
- 2x 4mm sockets for analogue data out to a logger for when 8 pin mini-DIN plug is not available.

SOCKET INFORMATION FOR CONNECTIONS:

Logger data: 'LOGGER' socket, mini-DIN, pins 3 (sig) & 4 (common, neg) or use 4mm sockets.

Plug Pak: 240V.AC / 12V.AC/DC. Socket diameters: centre pin 2.5mm. outside 5mm

Socket layout:
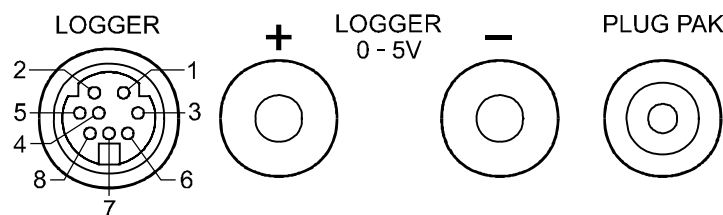
LOGGING: A data logger is often designed to recognise the sensor connected to its input. In the case of the IEC Colorimeter, a logger will have no recognition of our instrument and it will probably default to Voltage logging.   This is quite acceptable and the maximum voltage accepted by the Data Logger usually represents 100% of the vertical Y axis. Remember however that in the case of a Colorimeter, the X axis should not be relevant to time. It should be calibrated in Concentration units you wish to use, perhaps Moles or % concentration etc..

Using your Logger's software, find a graphing option that permits manual calibration of the X axis in fixed units - not time.

 VOLTAGES: Some data loggers accept 0-5V.DC. for full scale from 0-100% of input. Other loggers accept 0-4.096V.DC. as their maximum input voltage. The IEC Colorimeter permits the setting of either output. To check output voltage for logging, power the unit **while holding** the left hand button depressed. The display will show either 5.0 or 4.1 volts.

To change from one to another, press the left hand button while in this mode. When power is turned off, the last output voltage showing will remain in the Colorimeter until altered.

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c h 1 0 0 3 - 0 0 1 . d o c   3 0 - M a y - 0 6

HOW TO MAKE SAMPLE SOLUTIONS:

A **mole** (symbol mol) of a material is an amount equal to 6×10^{23} times the number of its fundamental elements – whether they be atoms, molecules or ions. Therefore 6×10^{23} molecules of $CuSO_4$ (copper sulphate) is 1 mole of the compound. Also 6×10^{23} atoms of helium make one mole of helium. This number is called **Avagadro's number** and it is the number of atoms in 12 grams of carbon$_{12}$. Thus it is the number of atoms or molecules in the weight of any element or compound if the atomic or molecular weight is expressed as grams.

In practical terms this means that the molecular weight of the fundamental part of a substance, either atomic or molecular, expressed in grams is 1 **mole** of that substance.

The unit of solution concentration is mol m^{-3} which is the **number of moles of the chemical in 1 cubic metre of solvent.**

A much more practical unit of solution concentration is the **Molar.** A Molar of any chemical (symbol M) is **the molecular weight of the substance expressed as grams per litre of solvent.** For example, C_2H_5OH (ethanol) has a molecular weight of 46. Thus 4.6 grams of ethanol diluted to become 1000ml of solution will have a concentration of 0.1M. $CuSO_4$ (copper sulphate) has molecular weight of 159.5. Thus 15.9g of the chemical made up to 1000ml of solution has a concentration of 0.1M. Thus 31.8g made up to 1000ml of solution has a concentration of 0.2M and so on..

Easily produced sample solutions can be: Copper Sulphate, Crystal Violet or even Food Colouring solutions.

Using Copper Sulphate: 0.1, 0.2, 0.3 and 0.4 M solutions of copper sulphate will provide a good graphical result. For this blue colour solution, red is the correct colour for the light source (closest complementary colour to blue).

Using Crystal Violet: If 65.3 mg of crystal violet powder is dissolved into 2 litres of water, a concentration of 8×10^{-5} M is formed. If 1 litre of this is added to 1 litre of water, the concentration is halved to be 4×10^{-5} M. If 1 litre of this solution is added to 1 litre of water, the concentration is halved again …. and so on. For this colour solution, the green light source is used.

Using Food Colouring: Take say 1 litre of water and add between 5 and 10 drops of either red, blue or green food colourings. These are available from the Supermarkets. To be sure that the results will follow Beer's law, try the master coloured solution you have made and check that it does not exceed 0.6 absorption. If it is not too high in absorption, call this master solution 100% concentration and dilute to lower concentrations by taking volumes of the master and add correct volumes of water. Make say 80%, 60%, 50%, 40% and 20% solutions as your known references. Keep them stored in sealed and marked bottles for future experiments. To reduce fading, keep them away from direct light during storage.

For red solutions, use green light source, for blue solutions use red or yellow source, for green solutions use the red source and for yellow solutions use blue source.

DILUTING SOLUTIONS:

It is easy to dilute to half strength as described above but it is more tricky to dilute say from 100% to say 70% concentration or from 85% to 25%. There are 2 ways to dilute a solution:

- To add solvent (usually water) to an original volume of original solution concentration to make a new larger volume of final solution concentration.
- To use a particular volume of original solution concentration which will finally make up to a desired final volume of final solution concentration.

1) To add solvent to the original volume of solution to make a larger volume of weaker solution, the formula for the new total volume is:

original volume x original % conc.
**   desired % conc.**

EXAMPLE: To dilute 500ml of 100% solution to 70% solution: 500 x 100/70 = 714ml. So, add 214ml of water to the 500ml of 100% solution to make 714ml total and the concentration of that solution will be 70%.

2) To determine the volume required of an original concentration to make a particular final volume of the final concentration, the formula for the original volume is:

final volume x desired % conc.
**   original % conc.**

EXAMPLE: To dilute a solution of 100% concentration to finally make a volume of 500ml of 70% solution, 500 x 70/100 = 350ml.   So, take 350ml of 100% solution and add 150ml of water to make it up to exactly 500ml volume and the concentration of that solution will be 70%.

SIMPLE AND BRIEF EXAMPLE FOR USING THE INSTRUMENT:

Using cuvettes:

- Press ON/OFF button to power the instrument.
- Place distilled water into one clean cuvette and store in a receptacle provided.
- Prepare at least two solution samples of **known** concentration and store in bottles for future use. Mark the bottles with the known concentration.
- Pour a small sample of each of these known concentration solution in cuvettes, mark them and store them in the receptacles provided.
- Prepare one or more samples of **unknown** concentrations in cuvettes and store them in the receptacles provided.

If the correct light source colour to use is not known, proceed as follows:

- Press UNITS/CAL button to select 'Transmission' in percent.
- Fit the square adaptor into the well, select the first wavelength (blue) and insert the square cuvette with distilled water with the smooth sides in the light path. Press and hold the 'Calibrate' button for one second then release. Meter will calibrate to 100% transmission for that particular illumination wavelength.
- Remove the distilled water cuvette and replace with any sample of the solution. Note the transmission reading in % for that wavelength.
- Using the distilled water cuvette and the same sample, repeat the above for each of the 4x wavelengths (colours) provided and choose the wavelength that provided the LOWEST reading (lowest % transmission or highest absorption). This is the light source you must use for concentration measurements of this colour of sample solution.

Now that the correct light source to use is now known, proceed as follows:

- Select this preferred light source, **select Absorbance** and re-insert the distilled water sample. Press the CAL button for one second to calibrate to zero absorption.
- Using 'X' axis as 0-max concentration units and 'Y' axis as 0-2.3 Absorbance, plot firstly the distilled water reading (zero absorbance and zero concentration) and then the two known concentration sample readings, then join the three points to make a straight line graph relating absorption to concentration. This relationship between absorption and concentration is linear according to Beer's Law over a limited range of concentrations.
- Remove the known coloured reference sample and replace with unknown sample. Note the absorbance reading.   Plot this reading on the graph line to find the corresponding concentration of the solution.

Designed and manufactured in Australia

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