# OIV-MA-AS2-11 Determination of chromatic characteristics according to CIELab

**Type I method**

## 1. Introduction

The colour of a wine is one of the most important visual features available to us, since it provides a considerable amount of highly relevant information.

Colour is a sensation that we perceive visually from the refraction or reflection of light on the surface of objects. Colour is light—as it is strictly related to it—and depending on the type of light (illuminating or luminous stimulus) we see one colour or another. Light is highly variable and so too is colour, to a certain extent.

Wine absorbs a part of the radiations of light that falls and reflects another, which reaches the eyes of the *observer*, making them experience the sensation of colour. For instance, the sensation of very dark red wines is almost entirely due to the fact that incident radiation is absorbed by the wine.

### 1.1. Scope

The purpose of this spectrophotometric method is to define the process of measuring and calculating the *chromatic characteristics* of wines and other beverages derived from *trichromatic components*: X, Y and Z, according to the *Commission Internationale de l'Eclairage* (CIE, 1976), by attempting to imitate real observers with regard to their sensations of colour.

### 1.2. Principle and definitions

The colour of a wine can be described using 3 attributes or specific qualities of visual sensation: tonality, luminosity and chromatism.

*Tonality*—colour itself—is the most characteristic: red, yellow, green or blue. *Luminosity* is the attribute of visual sensation according to which a wine appears to be more or less luminous. However, *chromatism,* or the *level of colouring,* is related to a higher or lower intensity of colour. The combination of these three concepts enables us to define the multiple shades of colour that wines present.

The *chromatic characteristics* of a wine are defined by the *colorimetric* or *chromaticity coordinates* (Fig. 1): *clarity* ($L^*$), *red/green colour component* ($a^*$), and *blue/yellow colour component* ($b^*$); and by its *derived magnitudes*: *chroma* ($C^*$), *tone* ($H^*$) and *chromacity* [($a^*$, $b^*$) or ($C^*$, $H^*$)]. In other words, this CIELab colour or space

system is based on a sequential or continuous Cartesian representation of 3 orthogonal axes: $L^*$, $a^*$ and $b^*$ (Fig. 2 and 3). Coordinate $L^*$ represents clarity ($L^*$ = 0 black and $L^*$ = 100 colourless), $a^*$ green/red colour component ($a^*$>0 red, $a^*$<0 green) and $b^*$ blue/yellow colour component ($b^*$>0 yellow, $b^*$<0 blue).

1.2.1. Clarity

Its symbol is $L^*$ and it is defined according to the following mathematical function:

$$L* = 116(Y/Y_n)^{1/3} - 16 \quad (1)$$

Directly related to the visual sensation of luminosity.

1.2.2. Red/green colour component

Its symbol is $a^*$ and it is defined according to the following mathematical function:

$$a* = 500[(X/X_) - (Y/Y_n)] \quad (I)$$

1.2.3. Yellow/blue colour component

Its symbol is $b^*$ and it is defined according to the following mathematical function:

$$b* = 200 - \left[(Y/Y_n)^{\frac{1}{3}} - (Z/Z_n)^{1/3}\right] \quad (I)$$

1.2.4. Chroma

The chroma symbol is $C^*$ and it is defined according to the following mathematical function:

$$C* = \sqrt{(a*^2 + b*^2)}$$

1.2.5. Tone

The tone symbol is $H^*$, its unit is the sexagesimal degree (°), and it is defined according to the following mathematical function:

$$H* = tg^{-1}(b^*/a^*)$$

1.2.6. Difference of tone between two wines

The symbol is ΔH* and it is defined according to the following mathematical function:

$$\Delta H* = \sqrt{(\Delta E*)^2 - (\Delta L*)^2 - (\Delta C*)^2}$$

**(I) See explanation Annex I**

1.2.7. Overall colorimetric difference between two wines

The symbol is ΔE* and it is defined according to the following mathematical functions:

$$\Delta E* = \sqrt{(\Delta L*)^2 + (\Delta a*)^2 + (\Delta b*)^2} = \sqrt{(\Delta L*)^2 + (\Delta C*)^2 + (\Delta H*)^2}$$

**1.3. Reagents and products**

Distilled water.

1.4. Apparatus and equipment

Customary laboratory apparatus and, in particular, the following:

1.4.1. Spectrophotometer to carry out transmittance measurements at a wavelength of between 300 and 800 nm, with illuminant D65 and observer placed at 10°. Use apparatus with a resolution equal to or higher than 5 nm and, where possible, with scan.

1.4.2. Computer equipment and suitable programme which, when connected to the spectrophotometer, will facilitate calculating colorimetric coordinates ($L^*$, $a^*$ and $b^*$) and their derived magnitudes ($C^*$ and $H^*$).

1.4.3. Glass cuvettes, available in pairs, optical thickness 1, 2 and 10 mm.

1.4.4. Micropipettes for volumes between 0.020 and 2 ml.

1.5. Sampling and sample preparation

Sample taking must particularly respect all concepts of homogeneity and representativity.

If the wine is dull, it must be clarified by centrifugation. For young or sparkling wines, as much carbon dioxide as possible must be eliminated by vacuum stirring or using a sonicator.

1.6. Procedure

- Select the pair of cuvettes for the spectrophotometric reading, ensuring that the upper measurement limit within the linear range of the spectrophotometer is not exceeded. By way of indication, for white and rosé wines it is recommended to use cuvettes with 10 mm of optical thickness, and for red wines, cuvettes with 1 mm optical thickness.

After obtaining and preparing the sample, measure its transmittance from 380 to 780 nm every 5 nm, using distilled water as a reference in a cuvette with the same optical thickness, in order to establish the base line or the white line. Choose illuminant D65 and observer 10°

If the optical thickness of the reading cuvette is under 10 mm, the transmittance must be transformed to 10 mm before calculating: $L^*$, $a^*$, $b^*$, $C^*$ and $H^*$.

Summary:

| |
|---|
| Spectral measurements in transmittance from 780 to 380 nm |
| Interval: 5 nm |
| Cuvettes: use appropriately according to wine intensity: 1 cm (white and rosé wines) and 0.1 cm (red wines) |
| Illuminant D65 |
| Observer reference pattern 10º |

1.7. Calculations

The spectrophotometer must be connected to a computer programme to facilitate the calculation of the colorimetric coordinates ($L^*$, $a^*$ and $b^*$) and their derived magnitudes ($C^*$ and $H^*$), using the appropriate mathematical algorithms.

In the event of a computer programme not being available, see Annex I on how to proceed.

1.8. Expression of results

The colorimetric coordinates of wine will be expressed according to the recommendations in the following table.

| Colorimetric coordinates | Symbol | Unit | Interval | Decimals |
|---|---|---|---|---|
| Clarity | $L^*$ | | 0-100<br>0 black<br>100 colourless | 1 |
| Red/green colour component | $a^*$ | | >0 red<br><0 green | 2 |
| Yellow/blue colour component | $b^*$ | | >0 yellow<br><0 blue | 2 |
| Chroma | $C^*$ | | | 2 |
| Tone | $H^*$ | º | 0-360º | 2 |

1.9. Numerical Example

Figure 4 shows the values of the colorimetric coordinates and the chromaticity diagram of a young red wine for the following values:

X = 12.31; Y = 60.03 and Z = 10.24

L* = 29.2

a* = 55.08

b* = 36.10

C* = 66.00

H* = 33.26°

## 2. Accuracy

The above data were obtained from two interlaboratory tests of 8 samples of wine with blind duplicates of progressive chromatic characteristics, in accordance with the recommendations of the harmonized protocol for collaborative studies, with a view to validating the method of analysis.

Colorimetric coordinate L* (clarity, 0-100)

| Sample Identification | A | B | C | D | E | F | G | H |
|---|---|---|---|---|---|---|---|---|
| Year of interlaboratory test | 2004 | 2002 | 2004 | 2004 | 2004 | 2004 | 2002 | 2004 |
| No. of participating laboratories | 18 | 21 | 18 | 18 | 17 | 18 | 23 | 18 |
| No. of laboratories accepted after aberrant value elimination | 14 | 16 | 16 | 16 | 14 | 17 | 21 | 16 |
| Mean value ($\bar{x}$) | 96.8 | 98.0 | 91.6 | 86.0 | 77.4 | 67.0 | 34.6 | 17.6 |
| Repeatability standard deviation ($s_r$) | 0.2 | 0.1 | 0.2 | 0.8 | 0.2 | 0.9 | 0.1 | 0.2 |
| Relative repeatability standard deviation ($RSD_r$) (%) | 0.2 | 0.1 | 0.3 | 1.0 | 0.3 | 1.3 | 0.2 | 1.2 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Repeatability limit (r) (2.8 x $s_r$) | 0.5 | 0.2 | 0.7 | 2.2 | 0.7 | 2.5 | 0.2 | 0.6 |
| Reproducibility standard deviation ($s_R$) | 0.6 | 0.1 | 1.2 | 2.0 | 0.8 | 4.1 | 1.0 | 1.0 |
| Relative reproducibility standard deviation ($RSD_R$) (%) | 0.6 | 0.1 | 1.3 | 2.3 | 1.0 | 6.1 | 2.9 | 5.6 |
| Reproducibility limit (R) (2.8 x $s_R$) | 1.7 | 0.4 | 3.3 | 5.5 | 2.2 | 11.5 | 2.8 | 2.8 |

Colorimetric coordinate a* (green/red)

| Sample Identification | A | B | C | D | E | F | G | H |
|---|---|---|---|---|---|---|---|---|
| Year of interlaboratory | 2004 | 2002 | 2004 | 2004 | 2004 | 2004 | 2002 | 2004 |
| No. of participating laboratories | 18 | 21 | 18 | 18 | 17 | 18 | 23 | 18 |
| No. of laboratories accepted after aberrant value elimination | 15 | 15 | 14 | 15 | 13 | 16 | 23 | 17 |
| Mean value ($\bar{X}$) | -0.26 | -0.86 | 2.99 | 11.11 | 20.51 | 29.29 | 52.13 | 47.55 |
| Repeatability standard deviation ($s_r$) | 0.17 | 0.01 | 0.04 | 0.22 | 0.25 | 0.26 | 0.10 | 0.53 |
| Relative repeatability standard deviation ($RSD_r$) (%) | 66.3 | 1.4 | 1.3 | 2.0 | 1.2 | 0.9 | 0.2 | 1.1 |
| Repeatability limit (r) (2.8 x $s_r$) | 0.49 | 0.03 | 0.11 | 0.61 | 0.71 | 0.72 | 0.29 | 1.49 |
| Reproducibility standard deviation ($s_R$) | 0.30 | 0.06 | 0.28 | 0.52 | 0.45 | 0.98 | 0.88 | 1.20 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Relative reproducibility standard deviation ($RSD_R$) (%) | 116.0 | 7.5 | 9.4 | 4.7 | 2.2 | 3.4 | 1.7 | 2.5 |
| Reproducibility limit (R) (2.8 x $s_R$) | 0.85 | 0.18 | 0.79 | 1.45 | 1.27 | 2.75 | 2.47 | 3.37 |

Colorimetric coordinate b* (blue/yellow)

| Sample Identification | A | B | C | D | E | F | G | H |
|---|---|---|---|---|---|---|---|---|
| Year of interlaboratory | 2004 | 2002 | 2004 | 2004 | 2004 | 2004 | 2002 | 2004 |
| No. of participating laboratories | 17 | 21 | 17 | 17 | 17 | 18 | 23 | 18 |
| No. of laboratories accepted after aberrant value elimination | 15 | 16 | 13 | 14 | 16 | 18 | 23 | 15 |
| Mean value ($\bar{x}$) | 10.95 | 9.04 | 17.75 | 17.10 | 19.68 | 26.51 | 45.82 | 30.07 |
| Repeatability standard deviation ($s_r$) | 0.25 | 0.03 | 0.08 | 1.08 | 0.76 | 0.65 | 0.15 | 0.36 |
| Relative repeatability standard deviation ($RSD_r$) (%) | 2.3 | 0.4 | 0.4 | 6.3 | 3.8 | 2.5 | 0.3 | 1.2 |
| Repeatability limit (r) (2.8 x $s_r$) | 0.71 | 0.09 | 0.21 | 3.02 | 2.12 | 1.83 | 0.42 | 1.01 |
| Reproducibility standard deviation ($s_R$) | 0.79 | 0.19 | 0.53 | 1.18 | 3.34 | 2.40 | 1.44 | 1.56 |
| Relative reproducibility standard deviation ($RSD_R$) (%) | 7.2 | 2.1 | 3.0 | 6.9 | 16.9 | 9.1 | 3.1 | 5.2 |
| Reproducibility limit (R) (2.8 x $s_R$) | 2.22 | 0.53 | 1.47 | 3.31 | 9.34 | 6.72 | 4.03 | 4.38 |

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Appendix 1

In formal terms, the trichromatic components X, Y, Z of a colour stimulus result from the integration, throughout the visible range of the spectrum, of the functions

obtained by multiplying the relative spectral curve of the colour stimulus by the colorimetric functions of the reference observer. These functions are always obtained by experiment. It is not possible, therefore to calculate the trichromatic components directly by integration. Consequently, the approximate values are determined by replacing these integrals by summations on finished wavelength intervals.

$$X = K \sum_{(\lambda)} T_{(\lambda)} S_{(\lambda)} \overline{X}_{10(\lambda)} \Delta_{(\lambda)}$$

$$Y = K \sum_{(\lambda)} T_{(\lambda)} S_{(\lambda)} \overline{Y}_{10(\lambda)} \Delta_{(\lambda)}$$

$$Z = K \sum_{(\lambda)} T_{(\lambda)} S_{(\lambda)} \overline{Z}_{10(\lambda)} \Delta_{(\lambda)}$$

$$K = 100 / \sum_{(\lambda)} S_{(\lambda)} \overline{Y}_{10(\lambda)} \Delta_{(\lambda)}$$

T (□) is the measurement of the transmittance of the wine measured at the wavelength □ expressed at 1 cm from the optical thickness.

$\Delta_{(\lambda)}$ is the interval between the value of □ at which T (□) is measured

S (□): coefficients that are a function of □ and of the illuminant (Table 1).

$\overline{X}_{10(\lambda)}; \overline{Y}_{10(\lambda)}; \overline{Z}_{10(\lambda)}$: coefficients that are a function of □ and of the observer. (Table 1)

The values of Xn, Yn, and Zn represent the values of the perfect diffuser under an illuminant and a given reference observer. In this case, the illuminant is D65 and the observer is higher than 4 degrees.

$X_n$ = 94.825; $Y_n$ = 100; $Z_n$ = 107.381

This roughly uniform space is derived from the space CIEYxy, in which the trichromatic components X, Y, Z are defined.

The coordinates L*, a* and b* are calculated based on the values of the trichromatic components X, Y, Z, using the following formulae.

$L^* = 116 (Y / Y_n)^{1/3}$ □ 16 where $Y/Yn > 0.008856$

$L^* = 903.3 (Y / Y_n)$ where $Y / Y_n <$ ó = 0.008856

a* = 500 [ f(X / $X_n$) □ f(Y / $Y_n$) □

b* = 200 [f(Y / $Y_n$) □ f(Z / $Z_n$) □

f(X / $X_n$) = (X / $X_n$)$^{1/3}$ where (X / $X_n$) > 0.008856

f(X / $X_n$) = 7.787 (X / $X_n$) + 16 / 166 where (X / $X_n$) < ó = 0.008856

f(Y / $Y_n$) = (Y / $Y_n$)$^{1/3}$ where (Y / $Y_n$) > 0.008856

f(Y / $Y_n$) = 7.787 (Y / $Y_n$) + 16 / 116 where (Y / $Y_n$) < ó = 0.008856

f(Z / $Z_n$) = (Z / $Z_n$)$^{1/3}$ where (Z / $Z_n$) > 0.008856

f(Z / $Z_n$) = 7.787 (Z / $Z_n$) + 16 / 116 where (Z / $Z_n$) < ó = 0.008856

The total colorimetric difference between two colours is given by the CIELAB colour difference

$$\Delta E* = [(\Delta L*)^2 + (\Delta a*)^2 + (\Delta b*)^2])^{1/2}$$

In the CIELAB space it is possible to express not only overall variations in colour, but also in relation to one or more of the parameters L*, a* and b*. This can be used to define new parameters and to relate them to the attributes of the visual sensation.

Clarity, related to luminosity, is directly represented by the value of L*.

Chroma: $C* = (a*^2 + b*^2)^{1/2}$ defines the chromaticness.

The angle of hue: H* = tg$^{-1}$(b*/a*) (expressed in degrees); related to hue.

The difference in hue: $\Delta H* = [(\Delta E*)^2 + (\Delta L*)^2 + (\Delta C*)^2])^{1/2}$

For two unspecified colours, Δ C* represents their difference in chroma; Δ L*, their difference in clarity, and Δ E*, their overall variation in colour. We thus have:

$$\Delta E* = [(\Delta L*)^2 + (\Delta a*)^2 + (\Delta b*)^2]^{1/2} = [(\Delta *L)^2 + (\Delta C*)^2 + (\Delta H*)^2)^{1/2}$$

Table 1.

| **Wavelength (□) nm.** | $S_{(\lambda)}$ | $\bar{X}_{10(\lambda)}$ | $\bar{Y}_{10(\lambda)}$ | $\bar{Z}_{10(\lambda)}$ |
|---|---|---|---|---|
| 380 | 50.0 | 0.0002 | 0.0000 | 0.0007 |

| | | | | |
|---|---|---|---|---|
| 385 | 52.3 | 0.0007 | 0.0001 | 0.0029 |
| 390 | 54.6 | 0.0024 | 0.0003 | 0.0105 |
| 395 | 68.7 | 0.0072 | 0.0008 | 0.0323 |
| 400 | 82.8 | 0.0191 | 0.0020 | 0.0860 |
| 405 | 87.1 | 0.0434 | 0.0045 | 0.1971 |
| 410 | 91.5 | 0.0847 | 0.0088 | 0.3894 |
| 415 | 92.5 | 0.1406 | 0.0145 | 0.6568 |
| 420 | 93.4 | 0.2045 | 0.0214 | 0.9725 |
| 425 | 90.1 | 0.2647 | 0.0295 | 1.2825 |
| 430 | 86.7 | 0.3147 | 0.0387 | 1.5535 |
| 435 | 95.8 | 0.3577 | 0.0496 | 1.7985 |
| 440 | 104.9 | 0.3837 | 0.0621 | 1.9673 |
| 445 | 110.9 | 0.3867 | 0.0747 | 2.0273 |
| 450 | 117.0 | 0.3707 | 0.0895 | 1.9948 |
| 455 | 117.4 | 0.3430 | 0.1063 | 1.9007 |
| 460 | 117.8 | 0.3023 | 0.1282 | 1.7454 |
| 465 | 116.3 | 0.2541 | 0.1528 | 1.5549 |
| 470 | 114.9 | 0.1956 | 0.1852 | 1.3176 |
| 475 | 115.4 | 0.1323 | 0.2199 | 1.0302 |
| 480 | 115.9 | 0.0805 | 0.2536 | 0.7721 |
| 485 | 112.4 | 0.0411 | 0.2977 | 0.5701 |

| | | | | |
|---|---|---|---|---|
| 490 | 108.8 | 0.0162 | 0.3391 | 0.4153 |
| 495 | 109.1 | 0.0051 | 0.3954 | 0.3024 |
| 500 | 109.4 | 0.0038 | 0.4608 | 0.2185 |
| 505 | 108.6 | 0.0154 | 0.5314 | 0.1592 |
| 510 | 107.8 | 0.0375 | 0.6067 | 0.1120 |
| 515 | 106.3 | 0.0714 | 0.6857 | 0.0822 |
| 520 | 104.8 | 0.1177 | 0.7618 | 0.0607 |
| 525 | 106.2 | 0.1730 | 0.8233 | 0.0431 |
| 530 | 107.7 | 0.2365 | 0.8752 | 0.0305 |
| 535 | 106.0 | 0.3042 | 0.9238 | 0.0206 |
| 540 | 104.4 | 0.3768 | 0.9620 | 0.0137 |
| 545 | 104.2 | 0.4516 | 0.9822 | 0.0079 |
| 550 | 104.0 | 0.5298 | 0.9918 | 0.0040 |
| 555 | 102.0 | 0.6161 | 0.9991 | 0.0011 |
| 560 | 100.0 | 0.7052 | 0.9973 | 0.0000 |
| 565 | 98.2 | 0.7938 | 0.9824 | 0.0000 |
| 570 | 96.3 | 0.8787 | 0.9556 | 0.0000 |
| 575 | 96.1 | 0.9512 | 0.9152 | 0.0000 |
| 580 | 95.8 | 1.0142 | 0.8689 | 0.0000 |
| 585 | 92.2 | 1.0743 | 0.8256 | 0.0000 |
| 590 | 88.7 | 1.1185 | 0.7774 | 0.0000 |

| | | | | |
|---|---|---|---|---|
| 595 | 89.3 | 1.1343 | 0.7204 | 0.0000 |
| 600 | 90.0 | 1.1240 | 0.6583 | 0.0000 |
| 605 | 89.8 | 1.0891 | 0.5939 | 0.0000 |
| 610 | 89.6 | 1.0305 | 0.5280 | 0.0000 |
| 615 | 88.6 | 0.9507 | 0.4618 | 0.0000 |
| 620 | 87.7 | 0.8563 | 0.3981 | 0.0000 |
| 625 | 85.5 | 0.7549 | 0.3396 | 0.0000 |
| 630 | 83.3 | 0.6475 | 0.2835 | 0.0000 |
| 635 | 83.5 | 0.5351 | 0.2283 | 0.0000 |
| 640 | 83.7 | 0.4316 | 0.1798 | 0.0000 |
| 645 | 81.9 | 0.3437 | 0.1402 | 0.0000 |
| 650 | 80.0 | 0.2683 | 0.1076 | 0.0000 |
| 655 | 80.1 | 0.2043 | 0.0812 | 0.0000 |
| 660 | 80.2 | 0.1526 | 0.0603 | 0.0000 |
| 665 | 81.2 | 0.1122 | 0.0441 | 0.0000 |
| 670 | 82.3 | 0.0813 | 0.0318 | 0.0000 |
| 675 | 80.3 | 0.0579 | 0.0226 | 0.0000 |
| 680 | 78.3 | 0.0409 | 0.0159 | 0.0000 |
| 685 | 74.0 | 0.0286 | 0.0111 | 0.0000 |
| 690 | 69.7 | 0.0199 | 0.0077 | 0.0000 |
| 695 | 70.7 | 0.0138 | 0.0054 | 0.0000 |

| | | | | |
|---|---|---|---|---|
| 700 | 71.6 | 0.0096 | 0.0037 | 0.0000 |
| 705 | 73.0 | 0.0066 | 0.0026 | 0.0000 |
| 710 | 74.3 | 0.0046 | 0.0018 | 0.0000 |
| 715 | 68.0 | 0.0031 | 0.0012 | 0.0000 |
| 720 | 61.6 | 0.0022 | 0.0008 | 0.0000 |
| 725 | 65.7 | 0.0015 | 0.0006 | 0.0000 |
| 730 | 69.9 | 0.0010 | 0.0004 | 0.0000 |
| 735 | 72.5 | 0.0007 | 0.0003 | 0.0000 |
| 740 | 75.1 | 0.0005 | 0.0002 | 0.0000 |
| 745 | 69.3 | 0.0004 | 0.0001 | 0.0000 |
| 750 | 63.6 | 0.0003 | 0.0001 | 0.0000 |
| 755 | 55.0 | 0.0002 | 0.0001 | 0.0000 |
| 760 | 46.4 | 0.0001 | 0.0000 | 0.0000 |
| 765 | 56.6 | 0.0001 | 0.0000 | 0.0000 |
| 770 | 66.8 | 0.0001 | 0.0000 | 0.0000 |
| 775 | 65.1 | 0.0000 | 0.0000 | 0.0000 |
| 780 | 63.4 | 0.0000 | 0.0000 | 0.0000 |

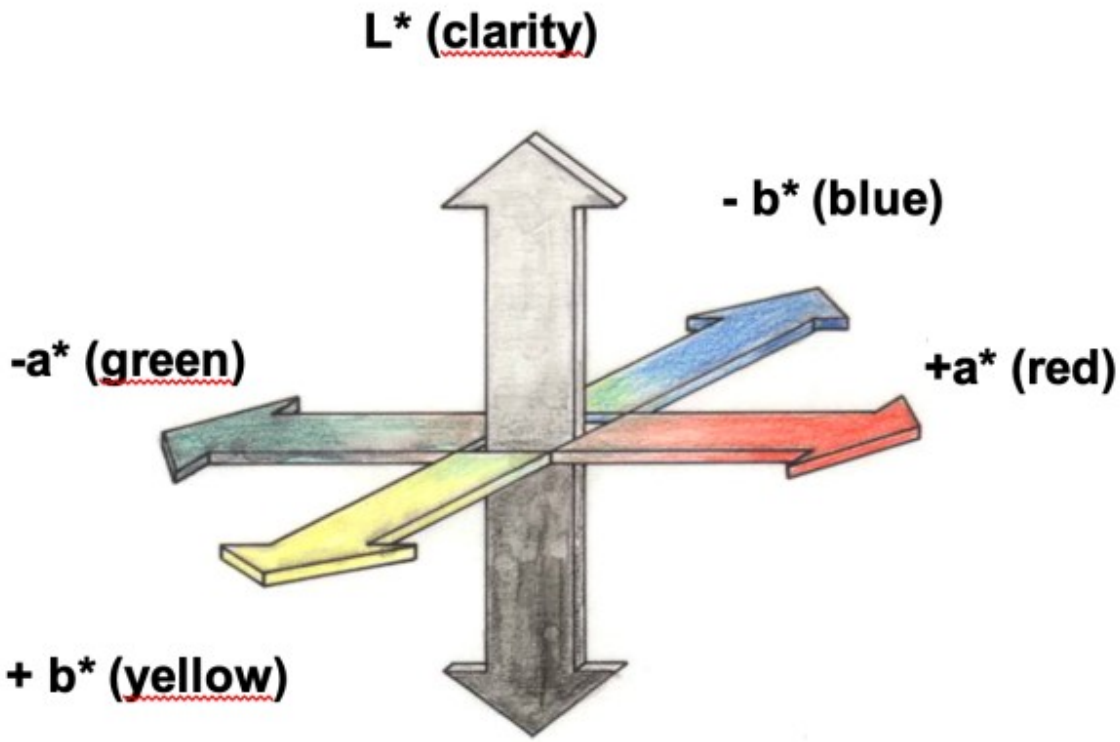



Figure 1. Diagram of colourimetric coordinates according to Commission Internationale de l'Eclairage (CIE, 1976)

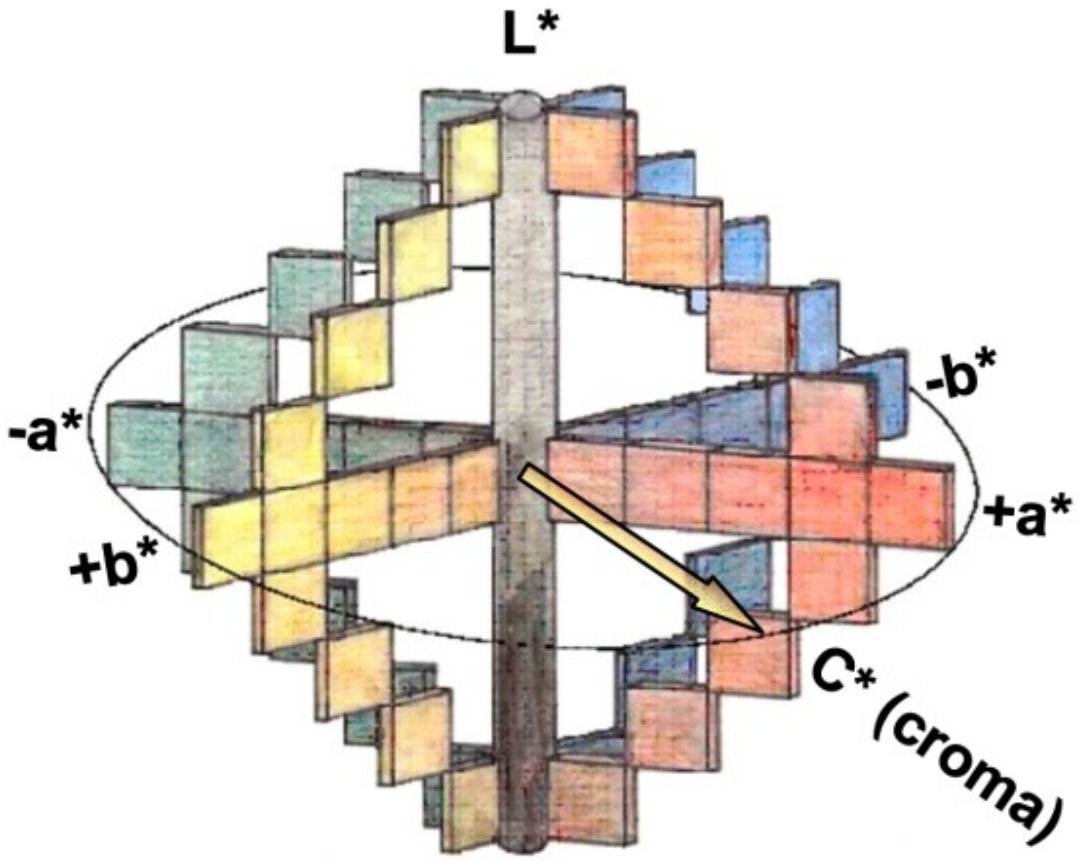



Figure 2. CIELab colourspace, based on a sequential or 3 orthogonal axis continual Cartesian representation L*, a* y b*

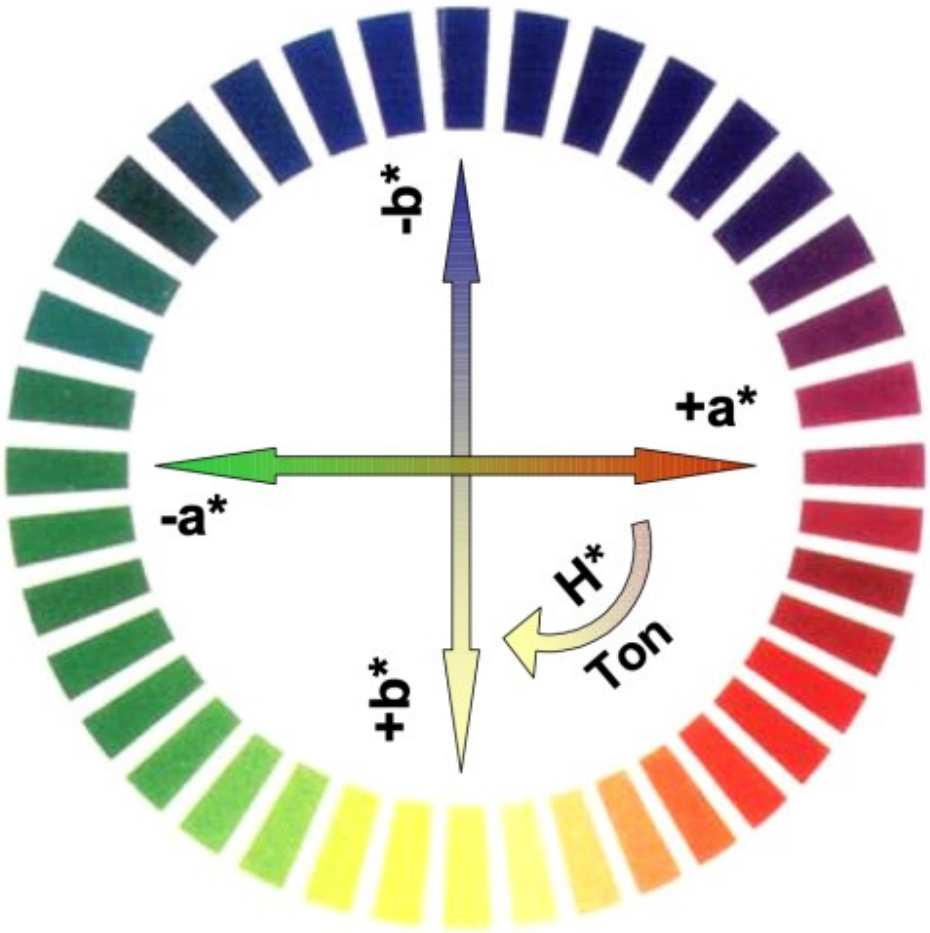



Figure 3. Sequential diagram and/or continuation of a and b colourimetric coordinates and derived magnitude, such as tone (H*)

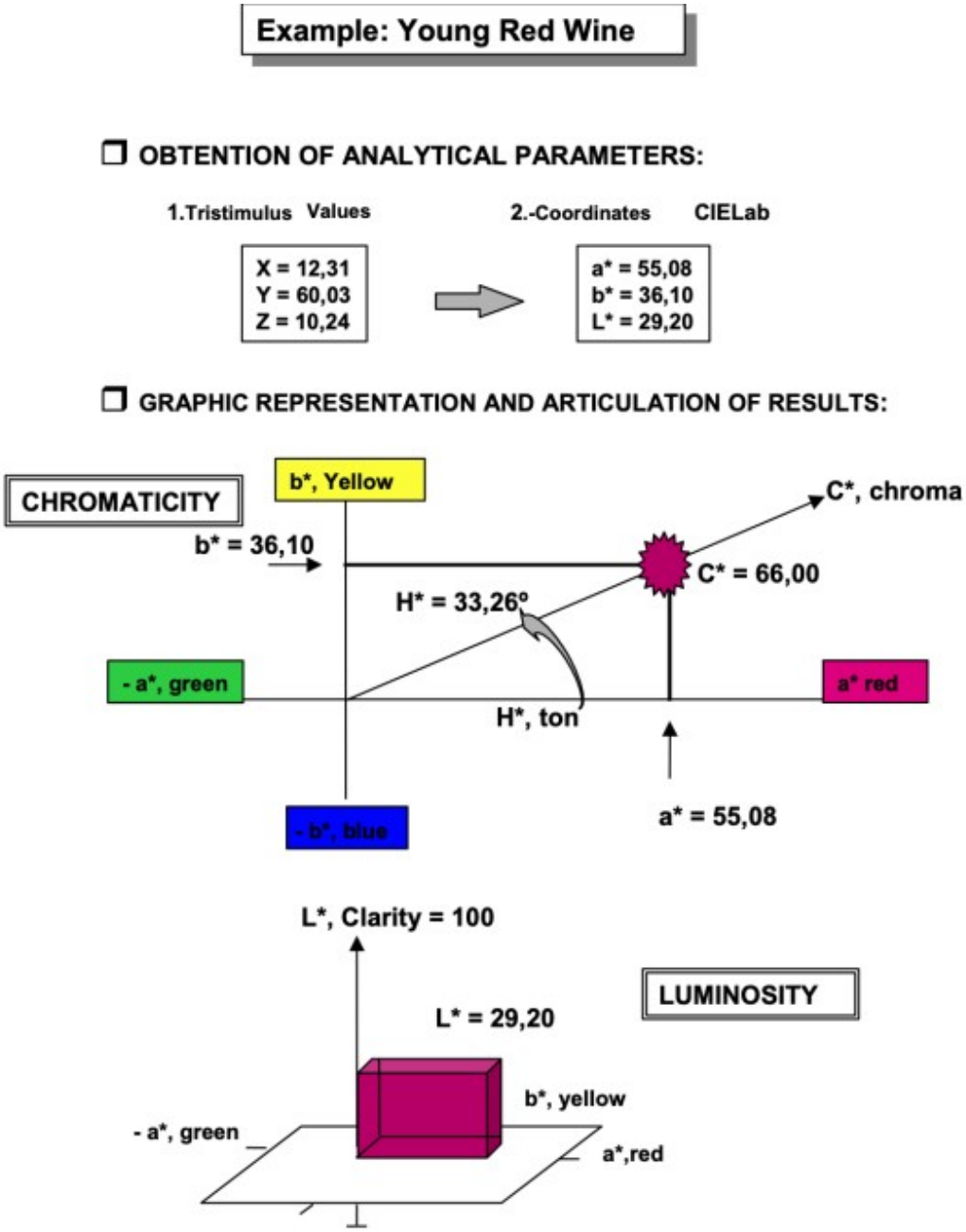



Figure 4. Representation of colour of young red wine used as an example in Chapter 1.8 shown in the CIELab three dimensional diagram.