Micro-fading report

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Object:	Suffragette Scroll, signed by Emmeline Pankhurst and Emmeline Pethick-Lawrence
Maker:	?
Accession No:	[redacted]
Materials and media	Paper, screen printing (?) inks, writing ink
Collection:	[redacted]
Year of production	May 1912
Exhibition:	MoAD
Test Date:	6-11-17
Operator:	Bruce Ford
Requested by:	[redacted]

Summary

The least lightfast elements are the inks of very faded appearance in the signatures (9 & 10) which responded at a rate equivalent to approximately BW1 (CIE_{00}) under the test conditions (Endnotes 1 & 2). This is towards the least stable end of the range of lightfastness (BW1 or worse to BW3) for colourants described in the CIE standard for museum lighting as having “high responsivity to light” for museum purposes (CIE 2004) and equivalent to 0.1 – 0.2 Mlux h/JND where one year’s display is about 0.15 - 0.2 Mlux h depending on light intensity and hours of opening.

The paper around the signatures is brown stained, which appears likely to be discolouration of a consolidant or varnish perhaps applied in a (futile in principle) effort to protect them from further light damage.

The Pankhurst signature tested negative for Fe using a bathophenantholine test, which if positive would be indicative (but not proof) of an iron gall ink component. This may have been because a varnish prevented Fe ion transfer to the test strip, or because the ink does not contain Fe. Several inks tested at the same time, which had superficially similar spectra, are likely to be blue-tinted IGIs, which while susceptible to permanent fading if the blue component were light sensitive, would be unlikely to fade out completely (Ford 2014).

In this case, however, the response at the red (700nm) end is uncharacteristic of IGIs, which undergo their greatest spectral change in this region (Fig 17). Given their already faded appearance and any positive evidence that they contain IGI, they have to be assumed to be both highly light sensitive and susceptible to complete fading.

Many of the printer’s inks are also light-sensitive, several well within the BW2-3 range (1-3 Mlux h/JND). The pink (7) and red-brown (6), red (12) and possibly mauve (1) printer’s inks probably contain alizarin or if not another anthraquinone dye (Figs 17 & 18).

Whilst the colour change for paper (11) was measured in order to assess the effect of its spectral change on transparent colourants, it is not directly relevant to exposure limits because both photochemical and thermal processes contribute to yellowing and bleaching (Endnote 3).

According to the National Museum of Australia’s exposure guidelines, and based on the response and importance of the signatures, the certificate would only be considered suitable for display at 50 lux for 2-3 months/decade or if it were a very significant item, a replica might be considered (Endnote 4).

Figure 1 Test positions

	CIE76			CIE2000							
Colour	BW Range	BW Equivalent	ΔE76	BW Range	BW Equivalent	ΔE2000	ΔL*	Δa*	Δb*	ΔC	Δh
BW1			12.4			4.5	3.8	-4.4	11.0	-10.5	8.8
BW2			7.4			2.6	2.3	-2.0	6.7	-6.4	3.9
BW3			2.6			0.6	0.4	-1.1	2.3	-2.5	0.5
BW4			1.1				-0.2	1.0	0.6	-0.7	-1.7
1 light mauve	BW4-BW3	3.5	1.9	BW3-BW2	2.6	1.5	1.7	-0.3	-0.8	-0.8	-1.5
2 blue violet	BW4	3.8	1.5	BW3	2.8	0.9	0.5	0.1	-1.4	1.3	0.4
3 green	BW4-BW3	3.6	1.7	BW3-BW2	2.7	1.3	1.3	1.0	0.5	0.3	-1.9
4 olive	BW3	3.0	2.7	BW3-BW2	2.4	1.8	1.6	1.7	1.3	1.1	-2.8
5 dark brown	>BW4	>BW4	0.3	>BW3	>BW3	0.2	0.0	-0.1	-0.3	-0.3	0.0
6 red-brown	BW4-BW3	3.6	1.7	BW3	2.8	1.0	0.8	-0.9	-1.3	-1.5	-0.5
7 pink	BW3	3.0	2.8	BW3-BW2	2.7	1.2	-0.4	-1.5	-2.2	-2.6	-0.9
8 cyan	BW4-BW3	3.3	2.1	BW3-BW2	2.6	1.5	0.7	-0.2	-2.0	-1.9	3.4
9 writing ink a	BW3	2.9	3.1	BW2	2.1	2.4	2.6	0.2	1.7	1.7	-0.7
10 wrting ink b	BW3-BW2	2.5	5.2	<BW1	<BW1	4.7	4.8	-0.7	2.3	1.3	12.6
11 paper	BW3	3.0	2.5	BW3-BW2	2.6	1.4	0.6	-0.2	-2.4	-2.4	-0.4
12 red overprint	>BW4	>BW4	1.1	BW3	3.0	0.7	0.0	-0.3	-1.0	-1.0	-1.2

Table 1. Colour change summary. See last page for CIELAB diagram and Endnote 2 for a discussion of CIE76 vs CIE2000 results.

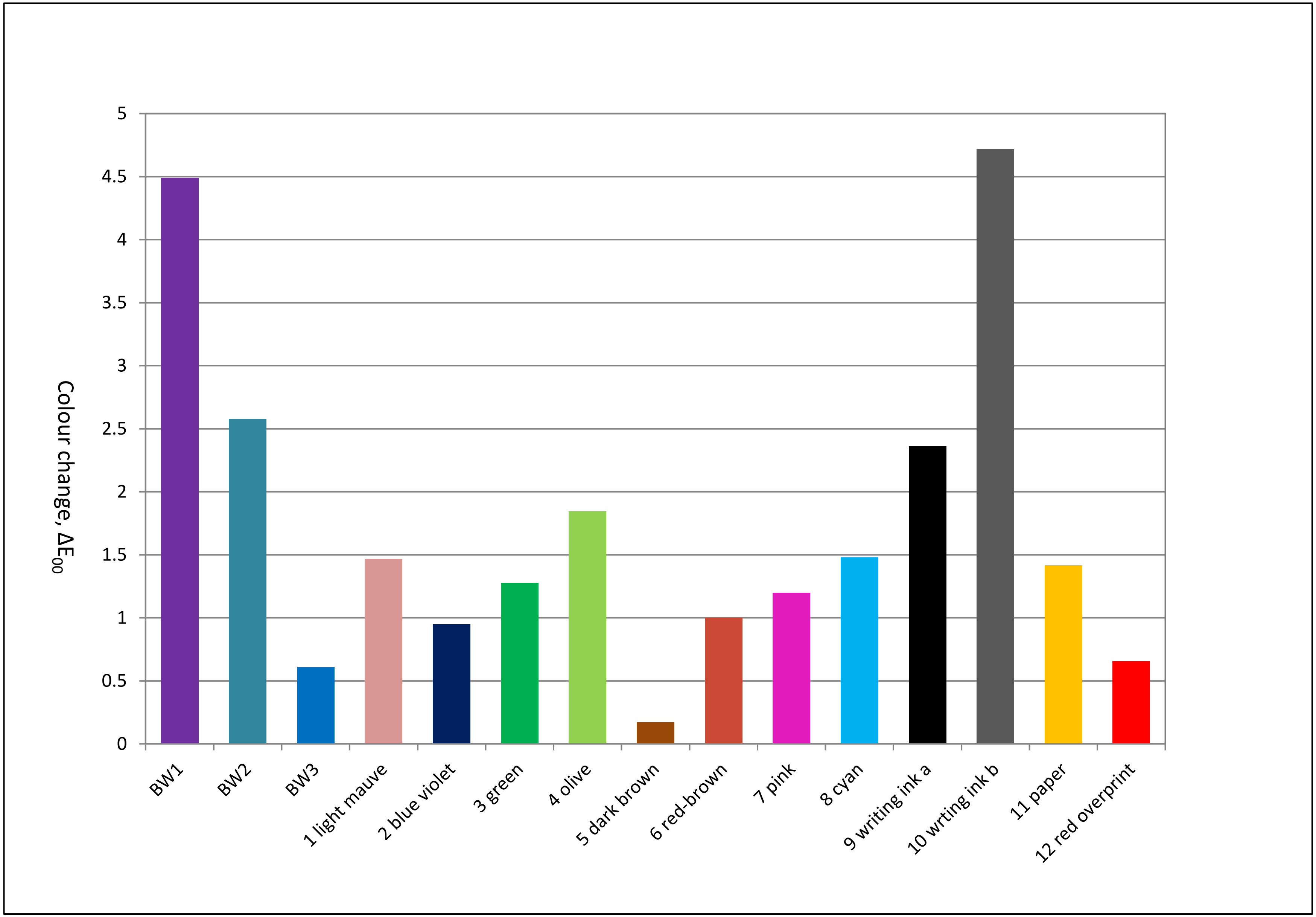


Figure 2. Relative colour change rates , CIE2000

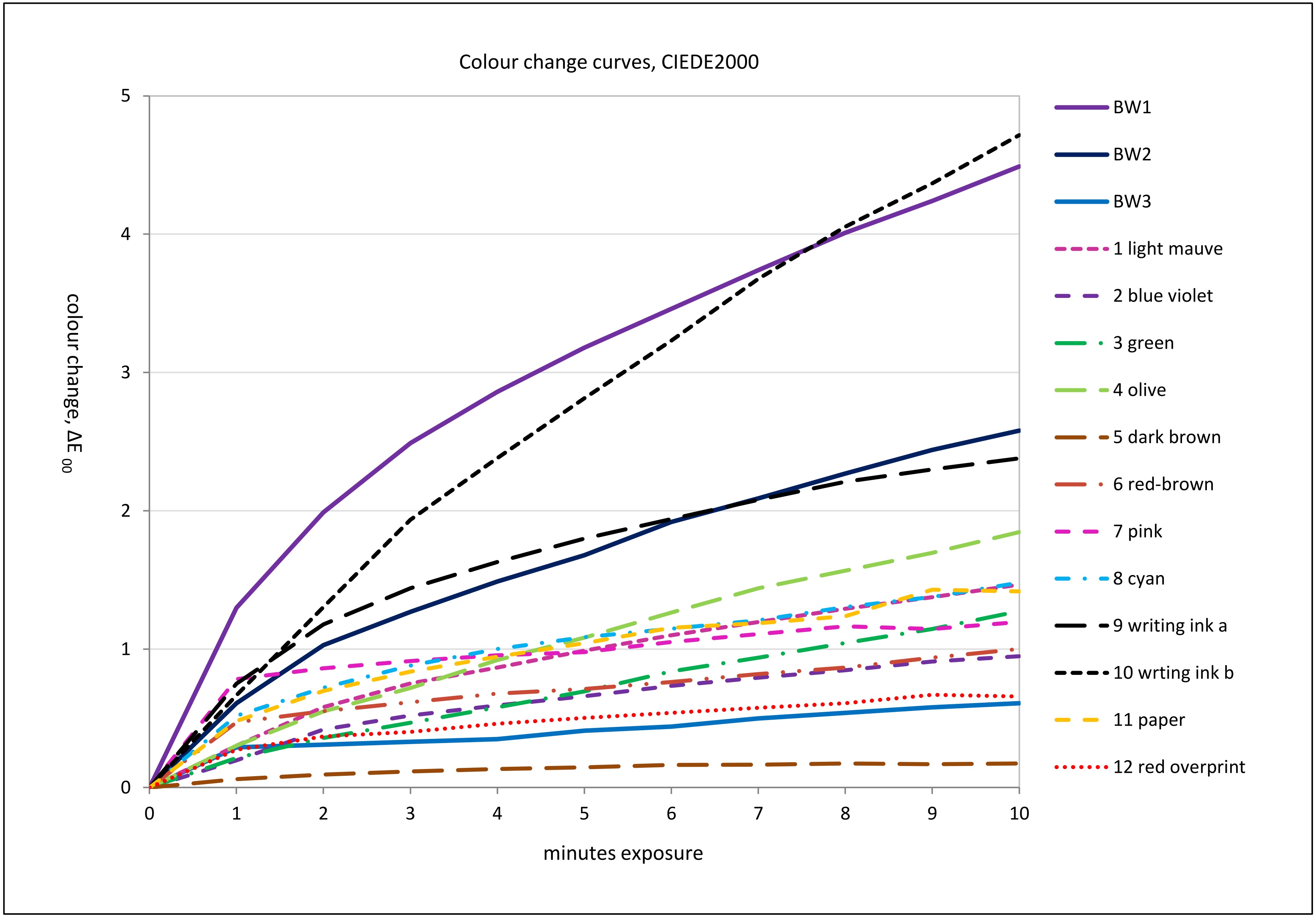
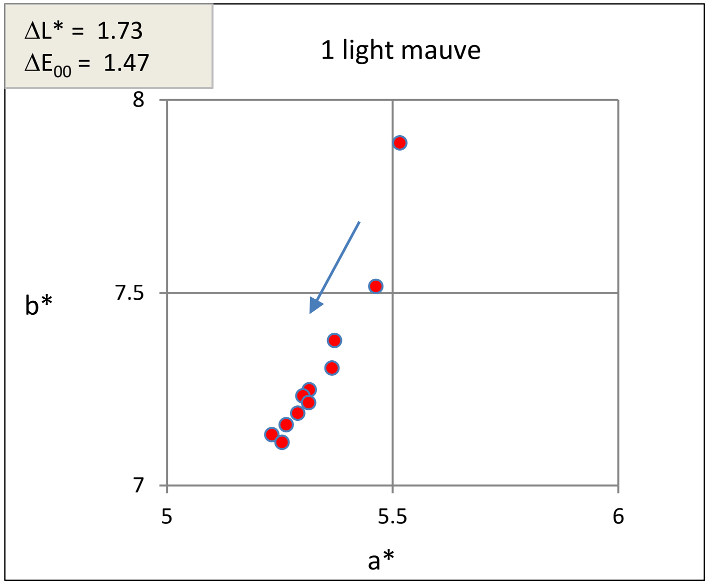
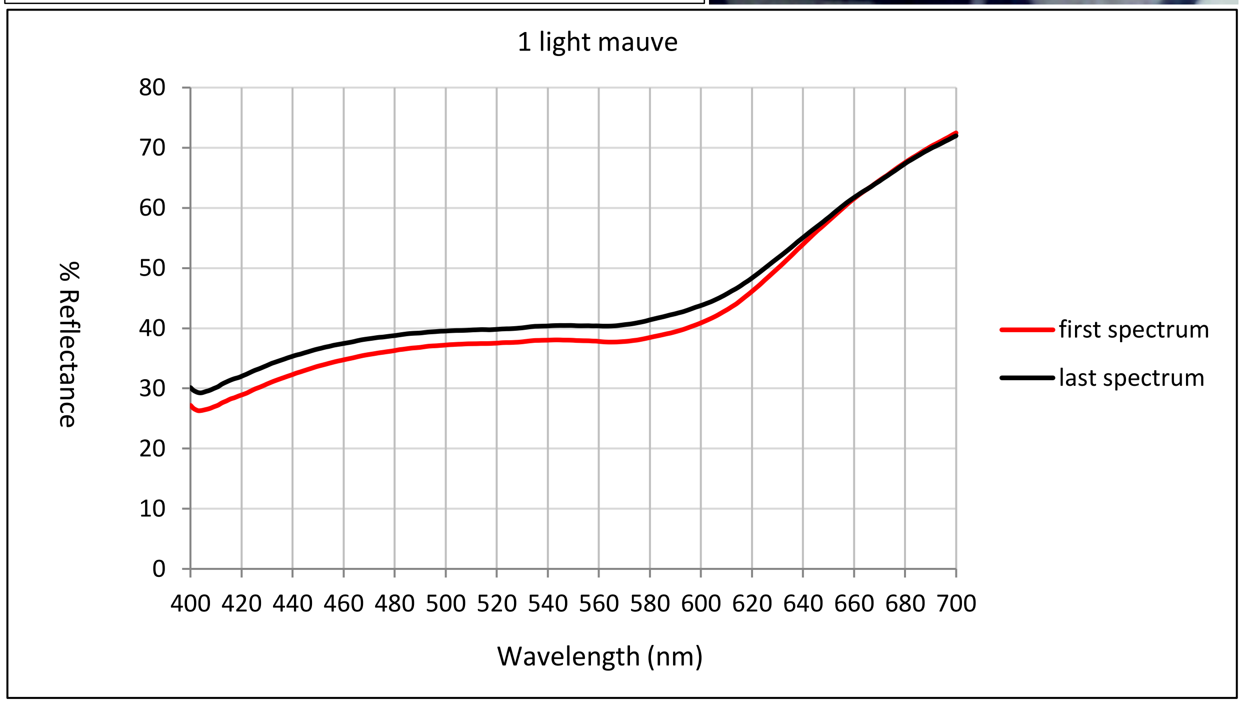


Figure 3. Colour change curves, CIE2000

Figure 4. Light mauve(1): lighter, chroma loss.





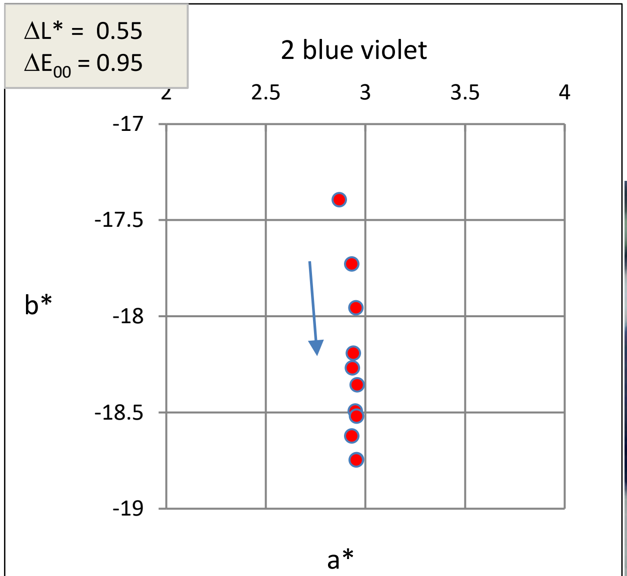


Figure 5. Blue violet (2): lighter, apparent chroma increase (bluer) but probably a decrease in yellow of the paper through transparent dyes. Most of the apparent response is probably due to paper bleaching.

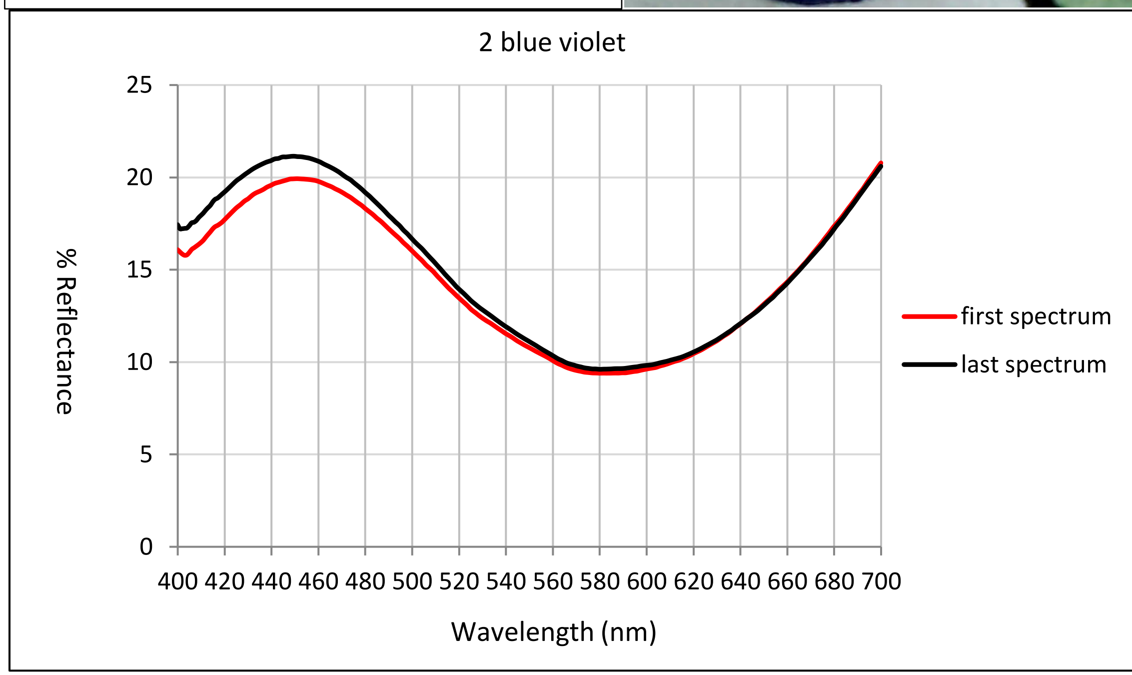
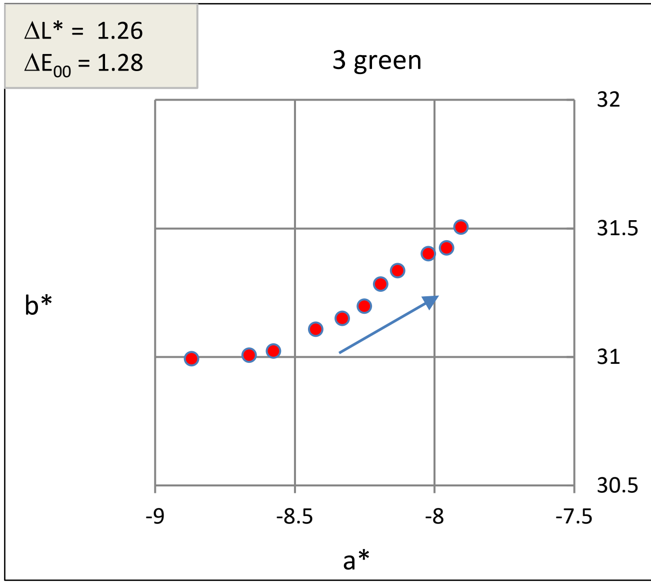
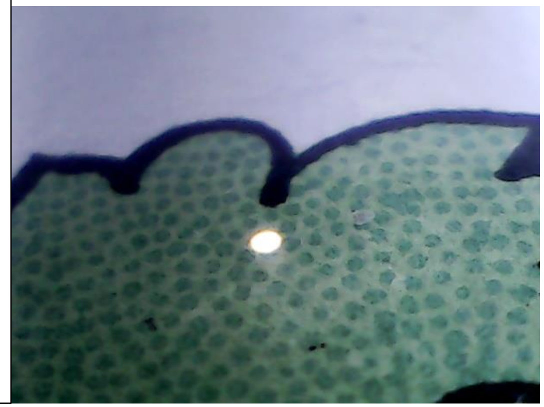
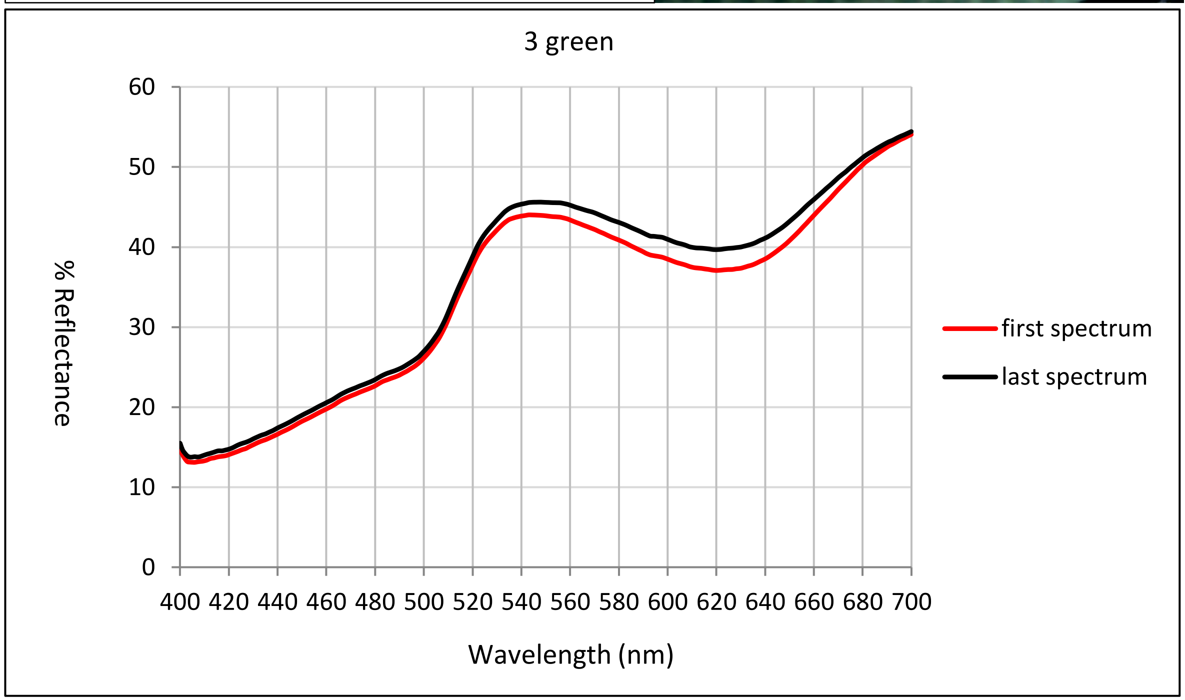


Figure 6. Green (3): lighter, chroma loss.







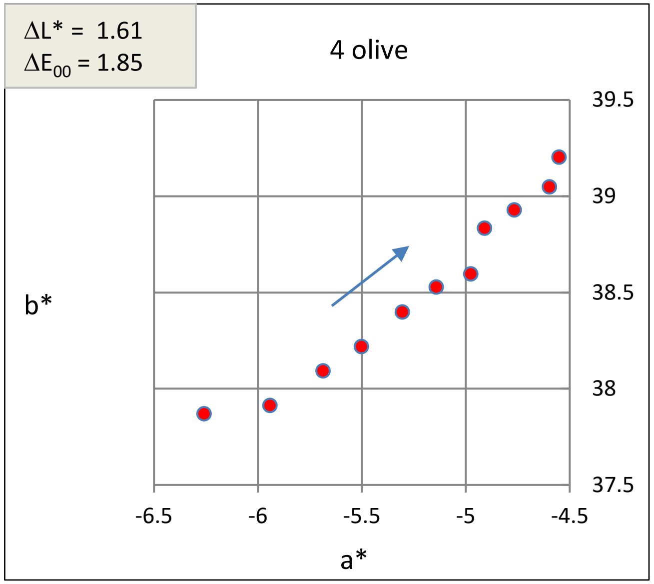
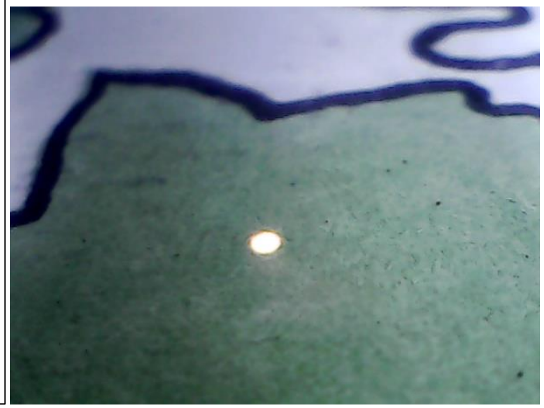
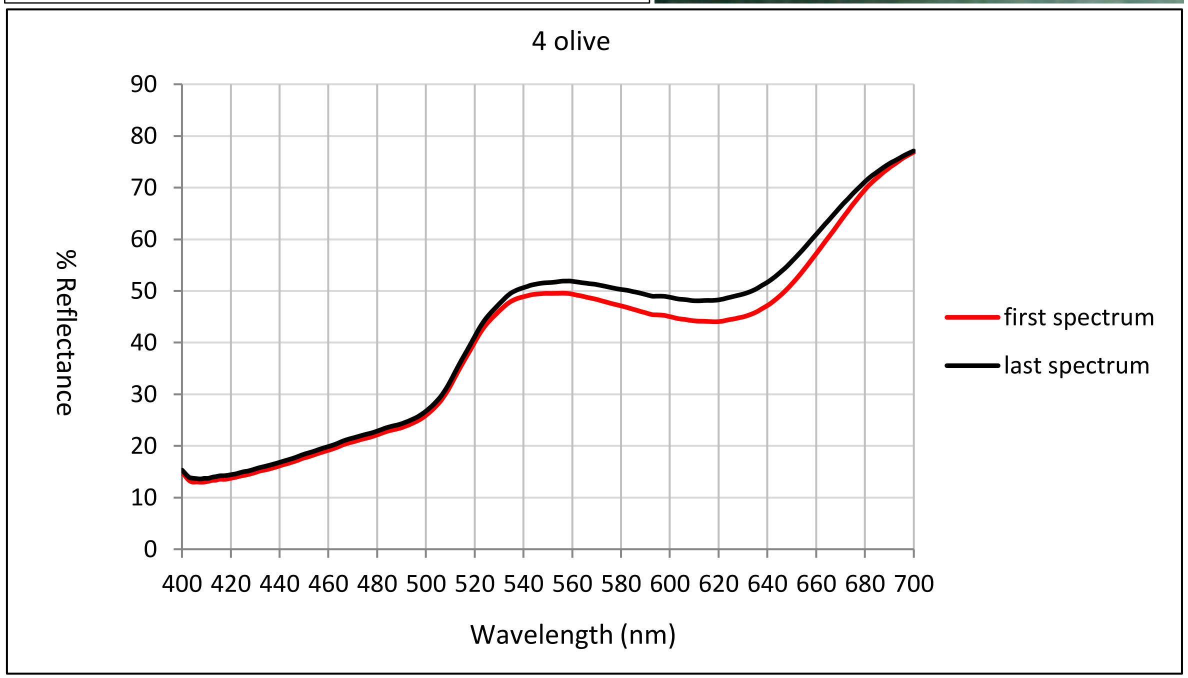


Figure 7. Olive green (4): lighter, chroma loss.





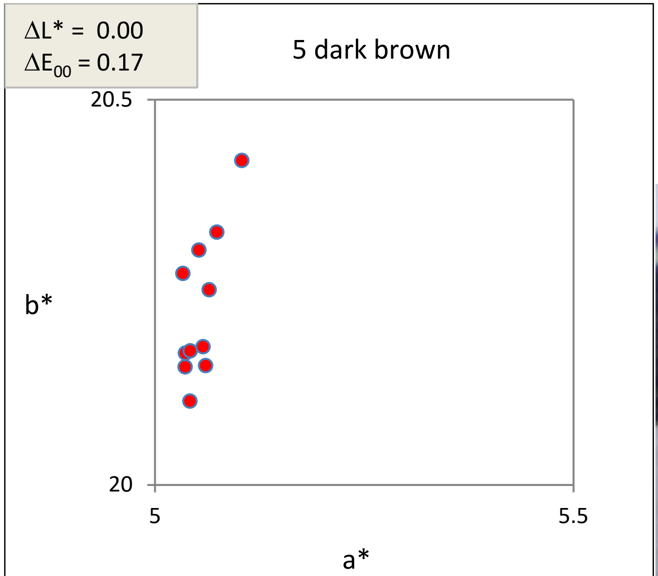
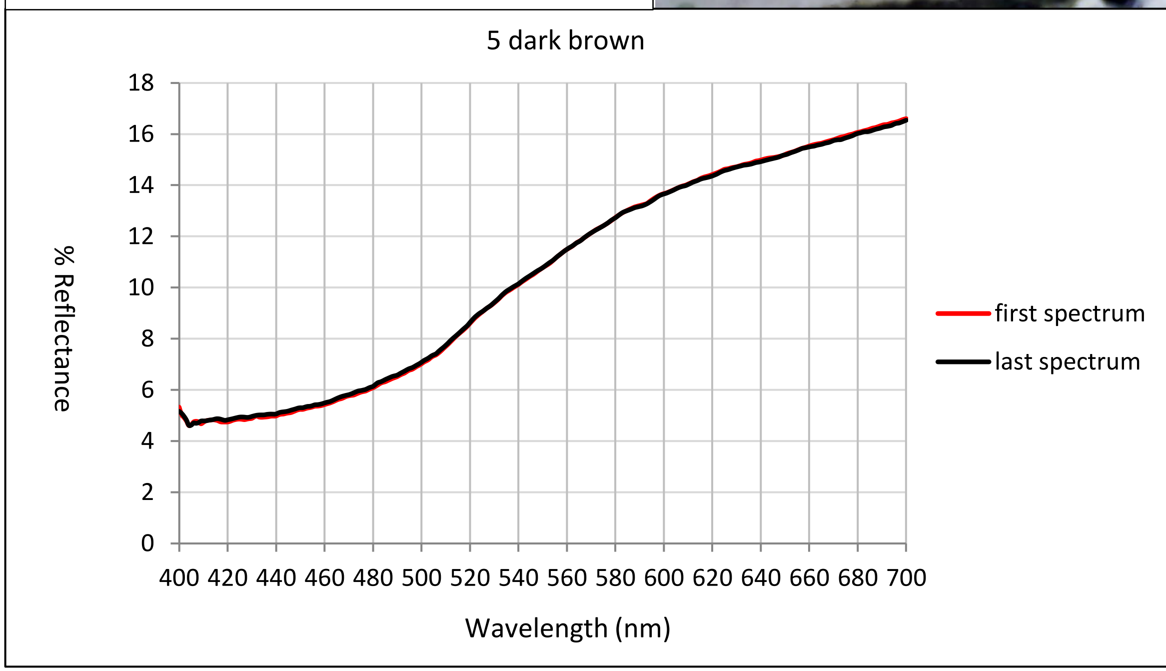


Figure 8. Dark brown (5): little response.



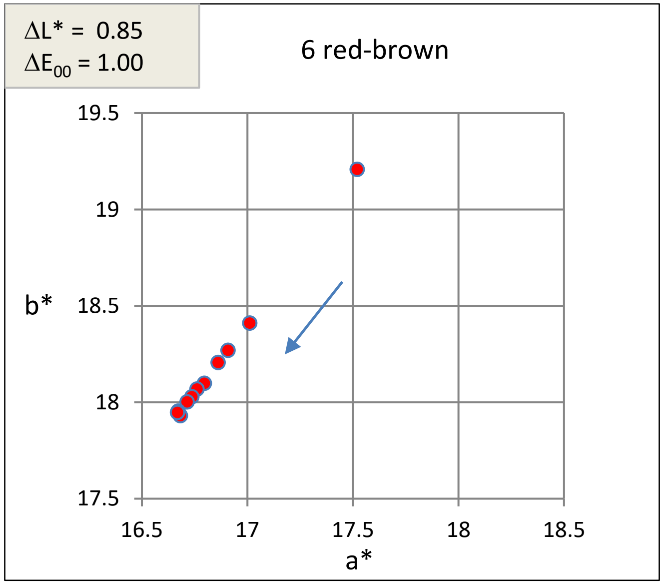
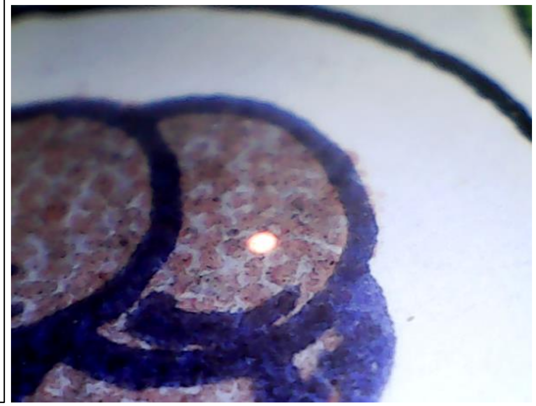
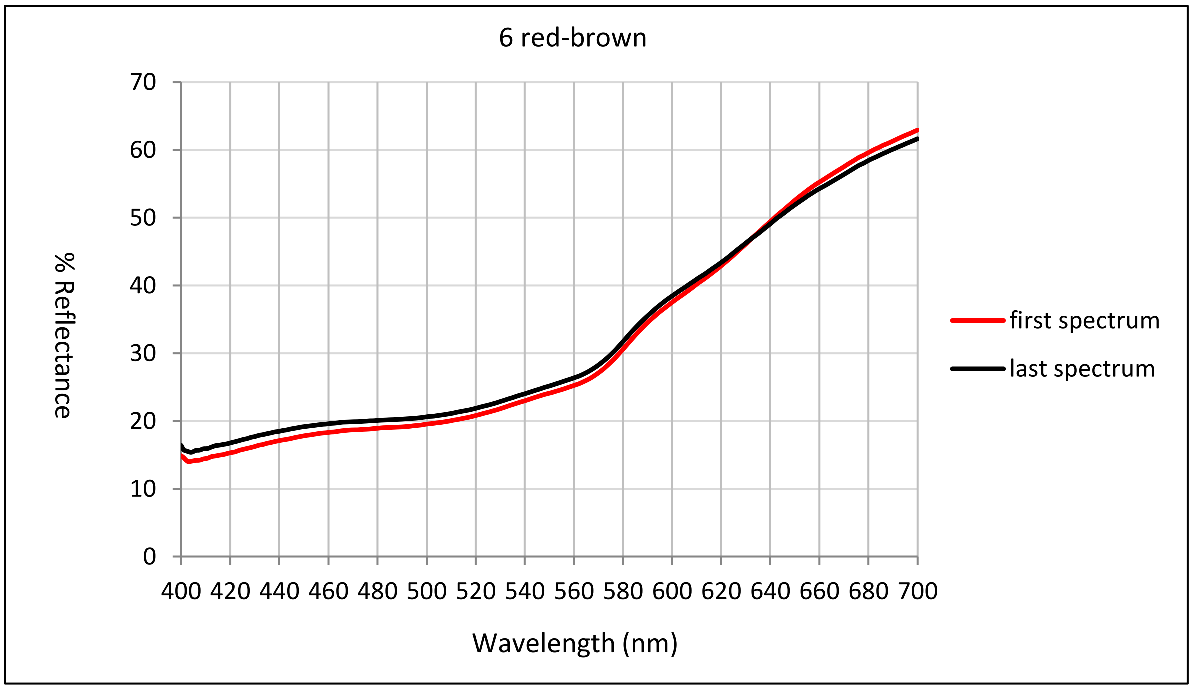


Figure 9. Red-brown (6): lighter, chroma loss. Anthraquinone, possibly cochineal, probably not madder on spectral grounds.





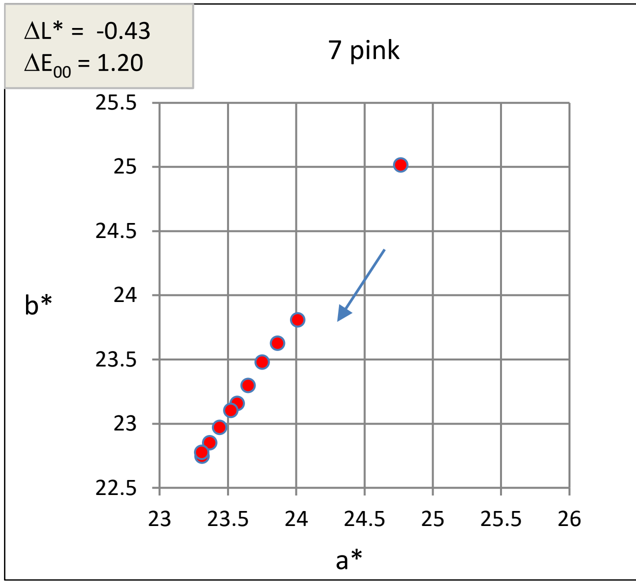
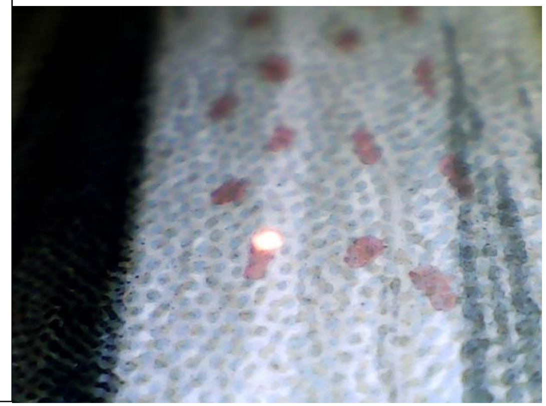
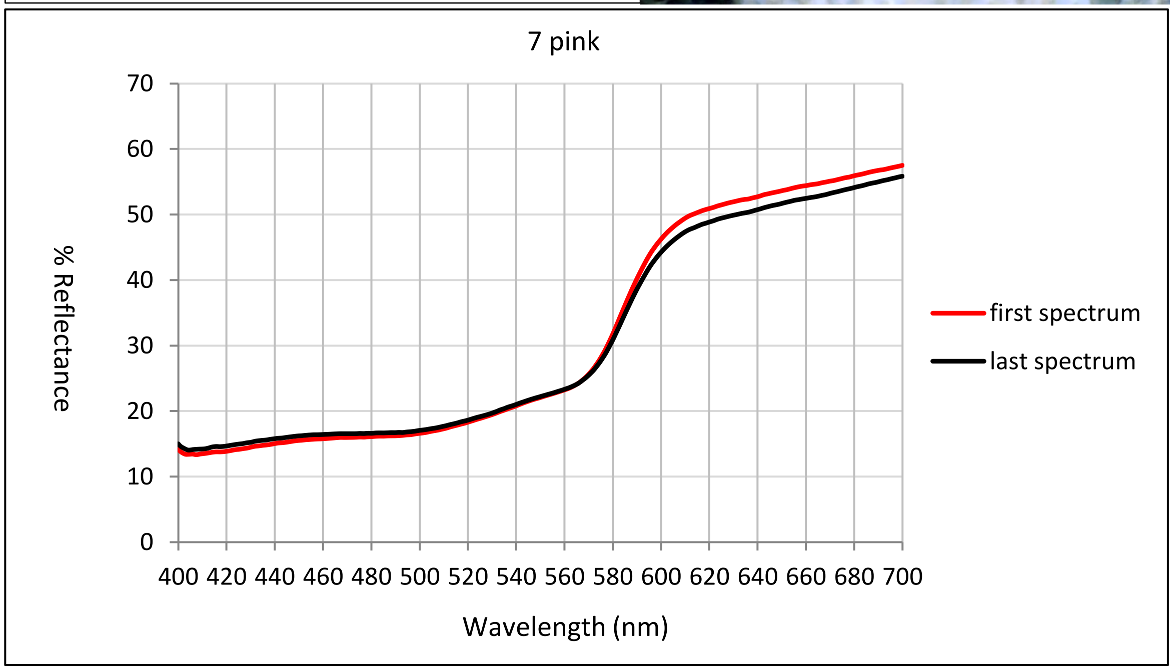


Figure 10. Pink (7): slightly darker, chroma loss. Anthraquinone, probably alizarin (Fig.18).





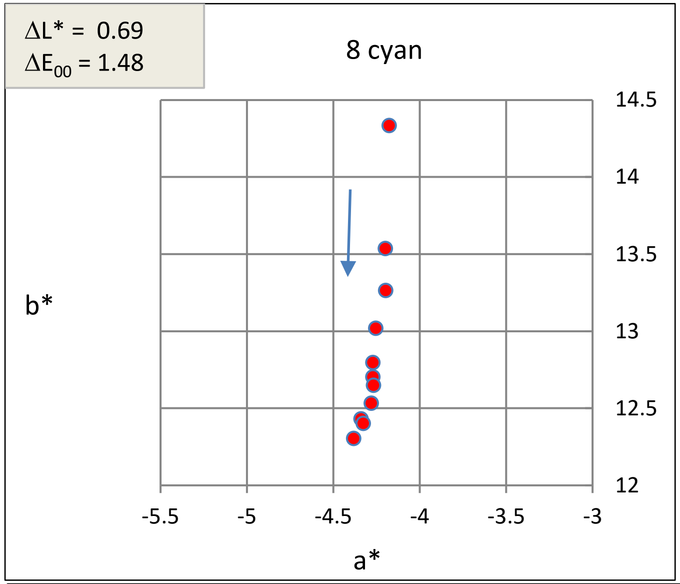
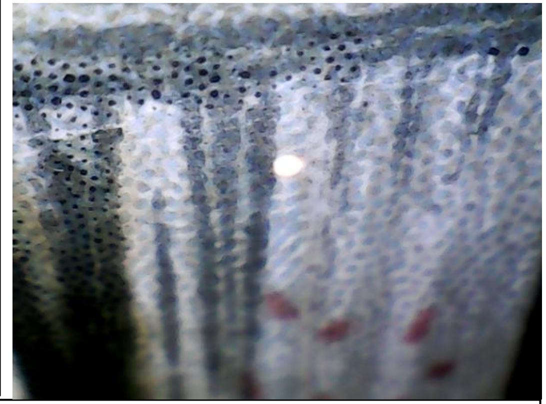
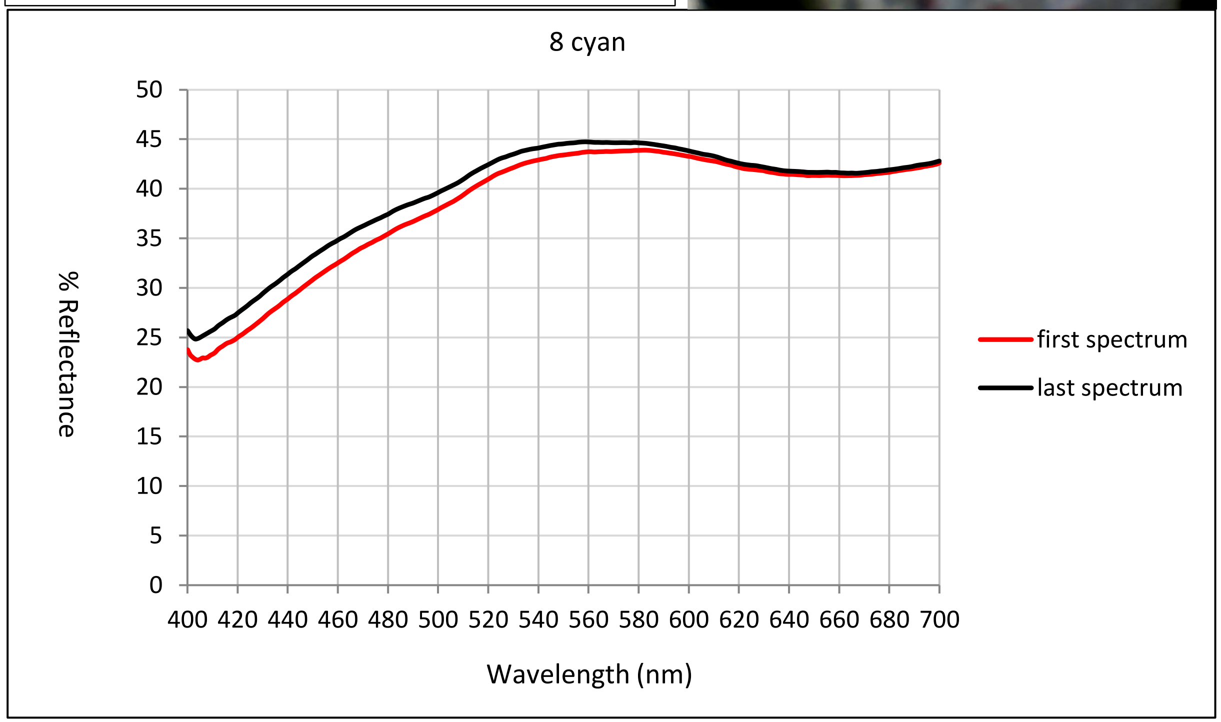


Figure 11. Cyan (8): lighter, chroma loss





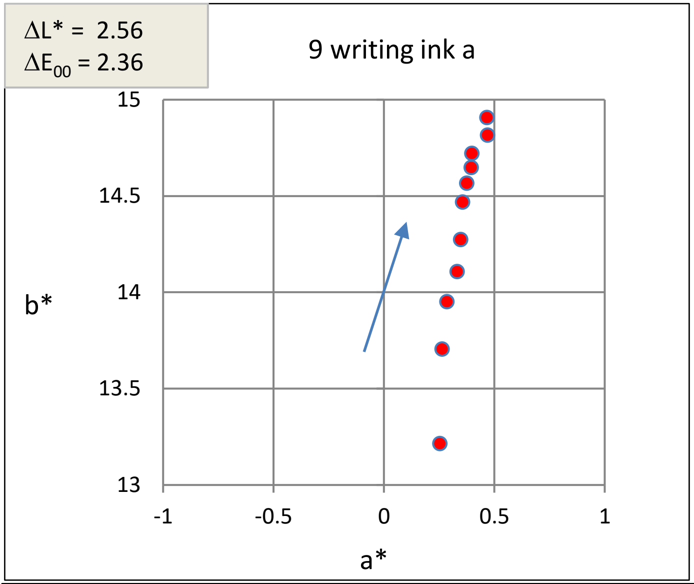
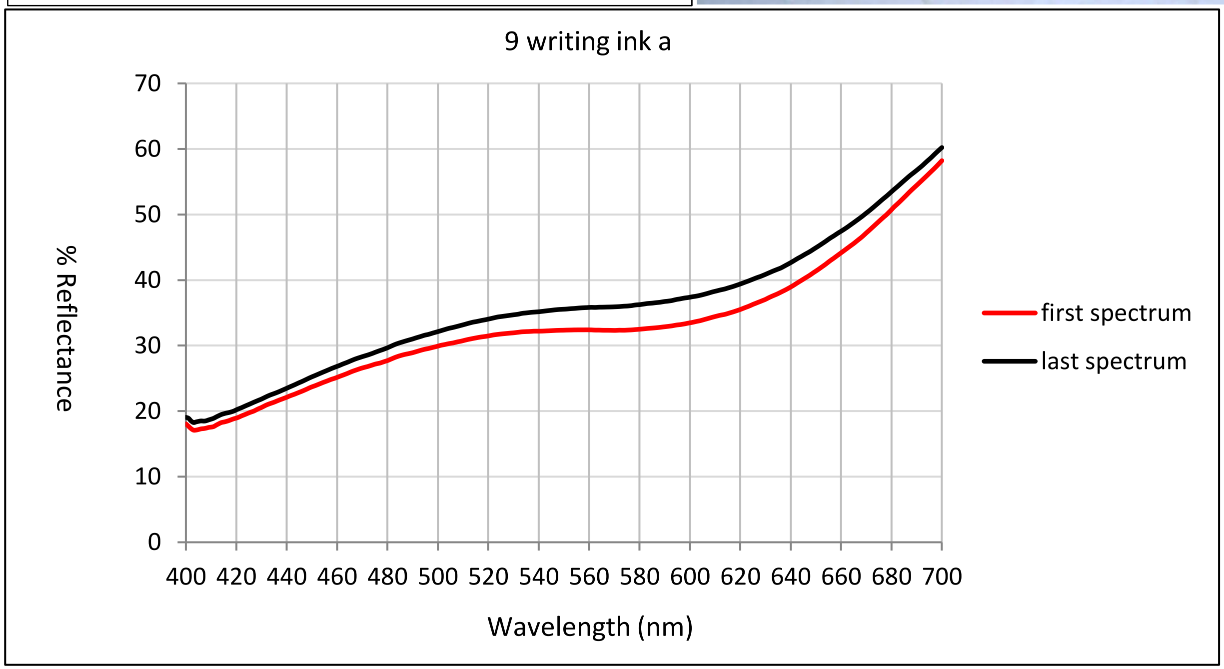


Figure 12. Writing ink (a) Pethick-Lawrence signature (9): lighter, chroma increase (yellower). Almost certainly not an iron-gall ink unless it also contains an additional purplish colourant.



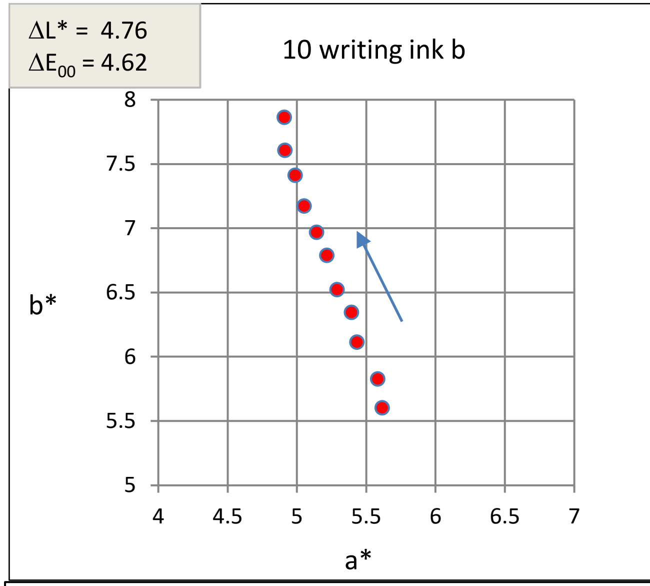
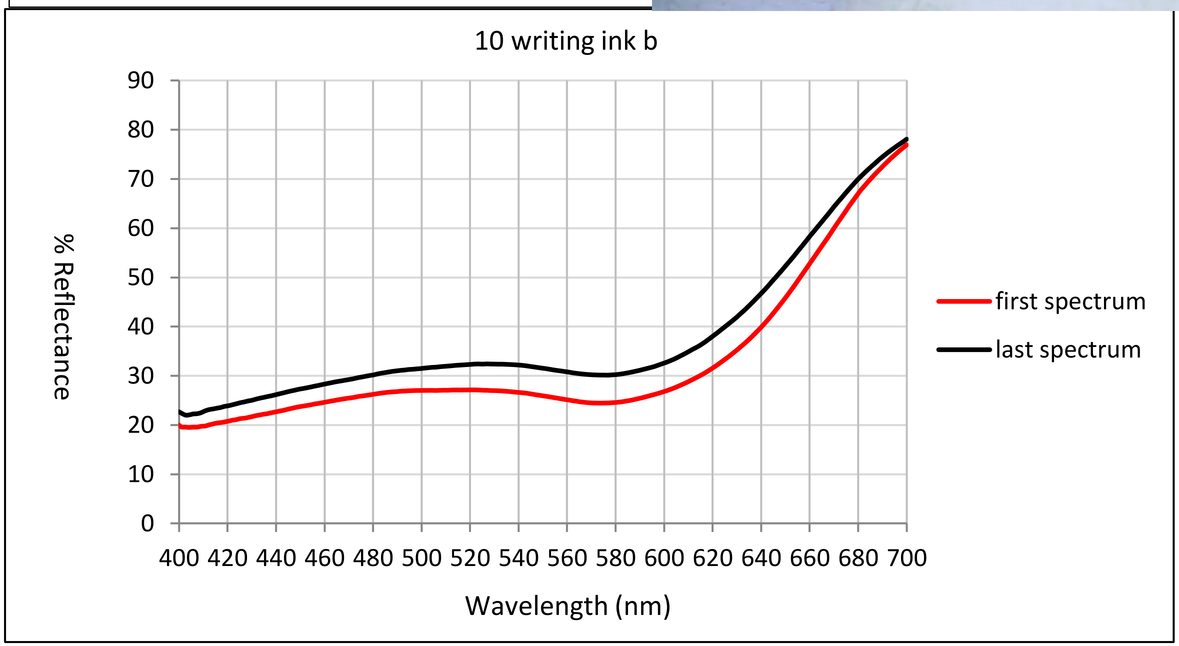


Figure 13. Writing ink (b) Emmeline Pankhurst (10): lighter, less purple-grey. As for the other writing ink (9), but in this instance it appears to be purpler.



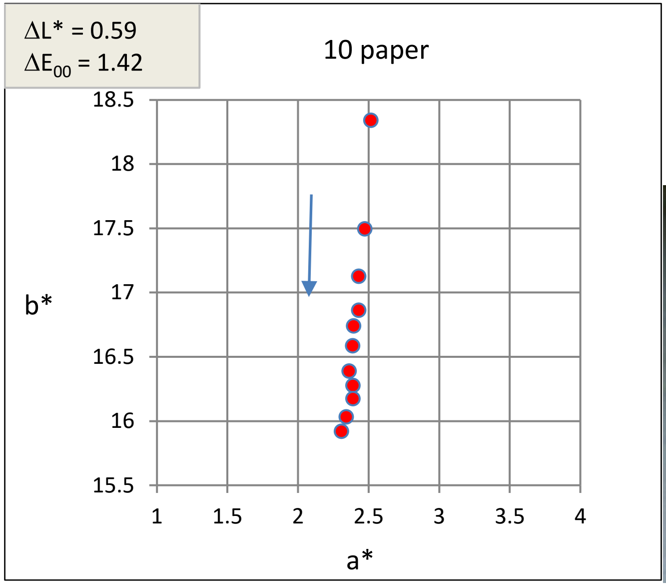
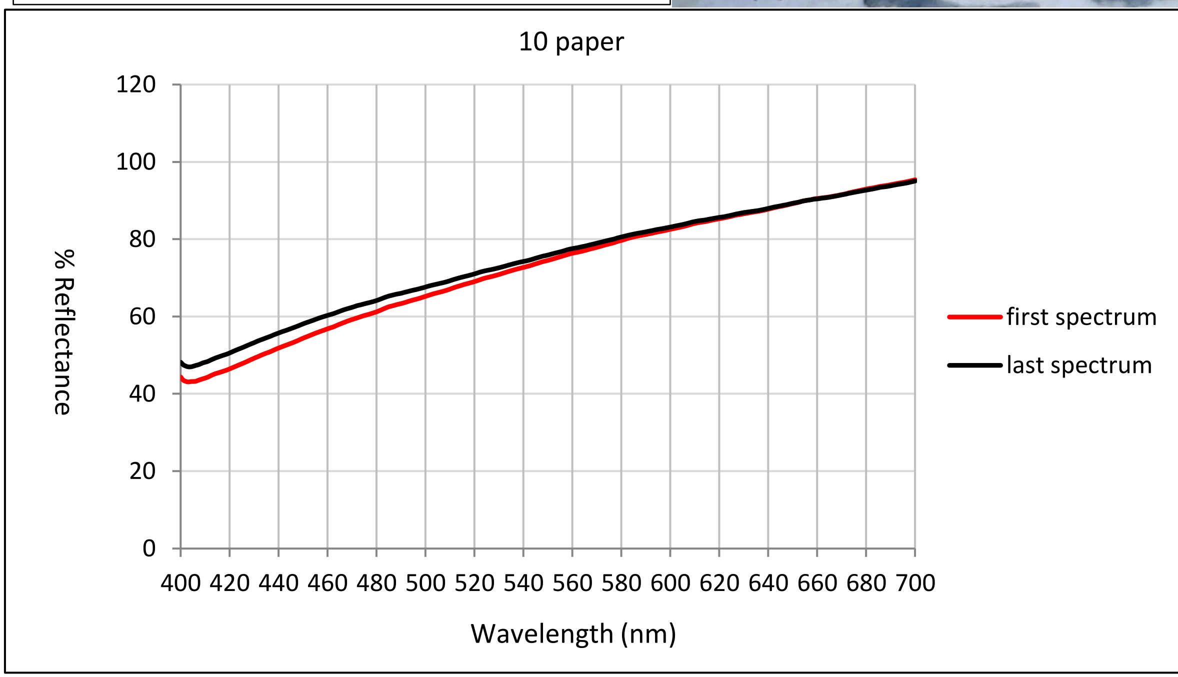


Figure 14. Paper (10): lighter, chroma loss (less yellowed).



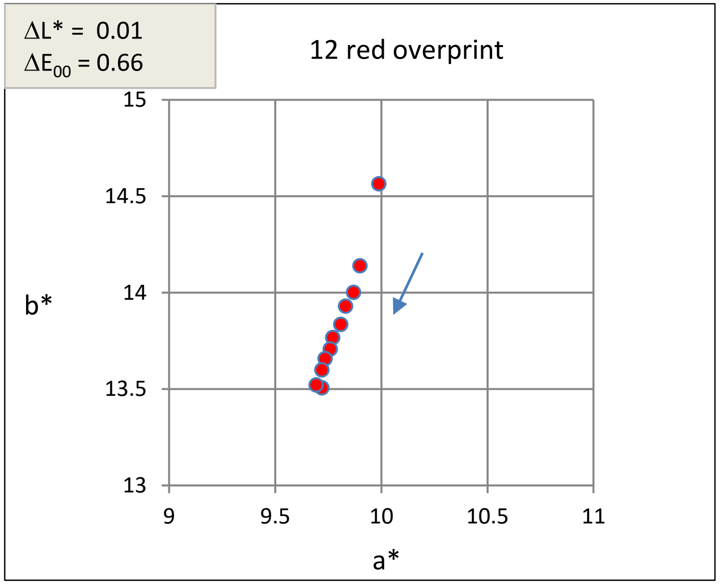
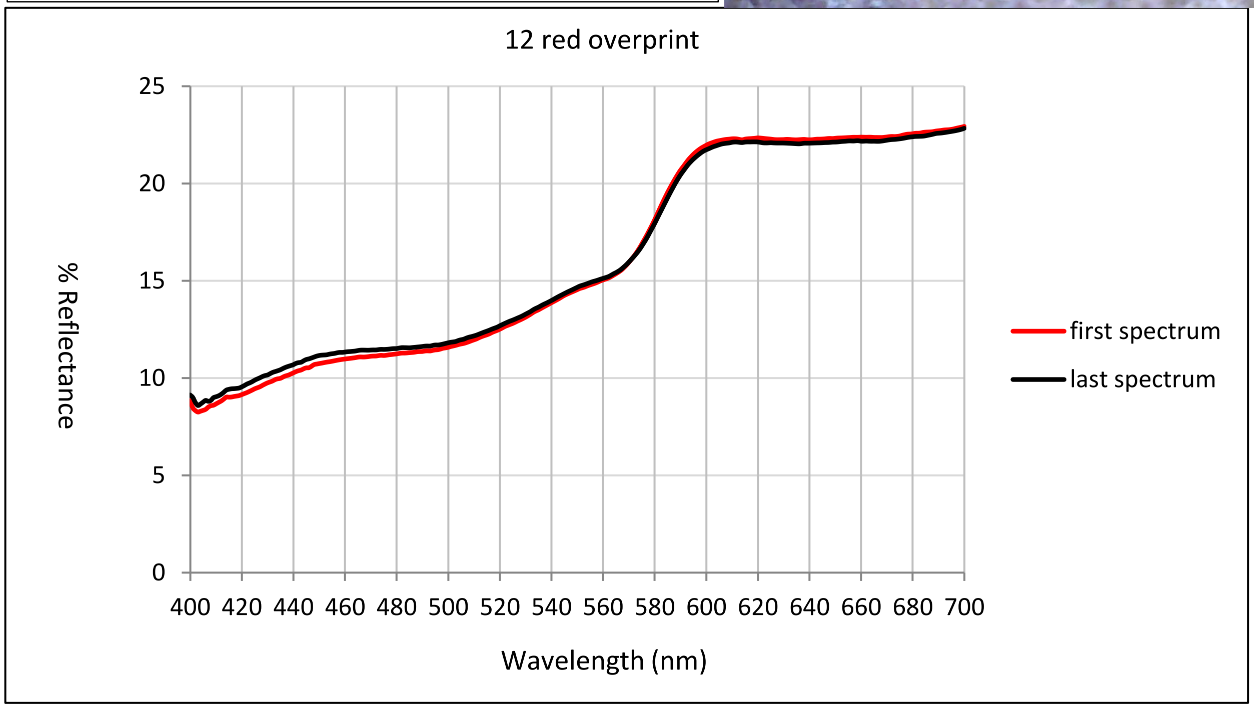


Figure 15. Red overprint (12): chroma loss, no change in lightness.



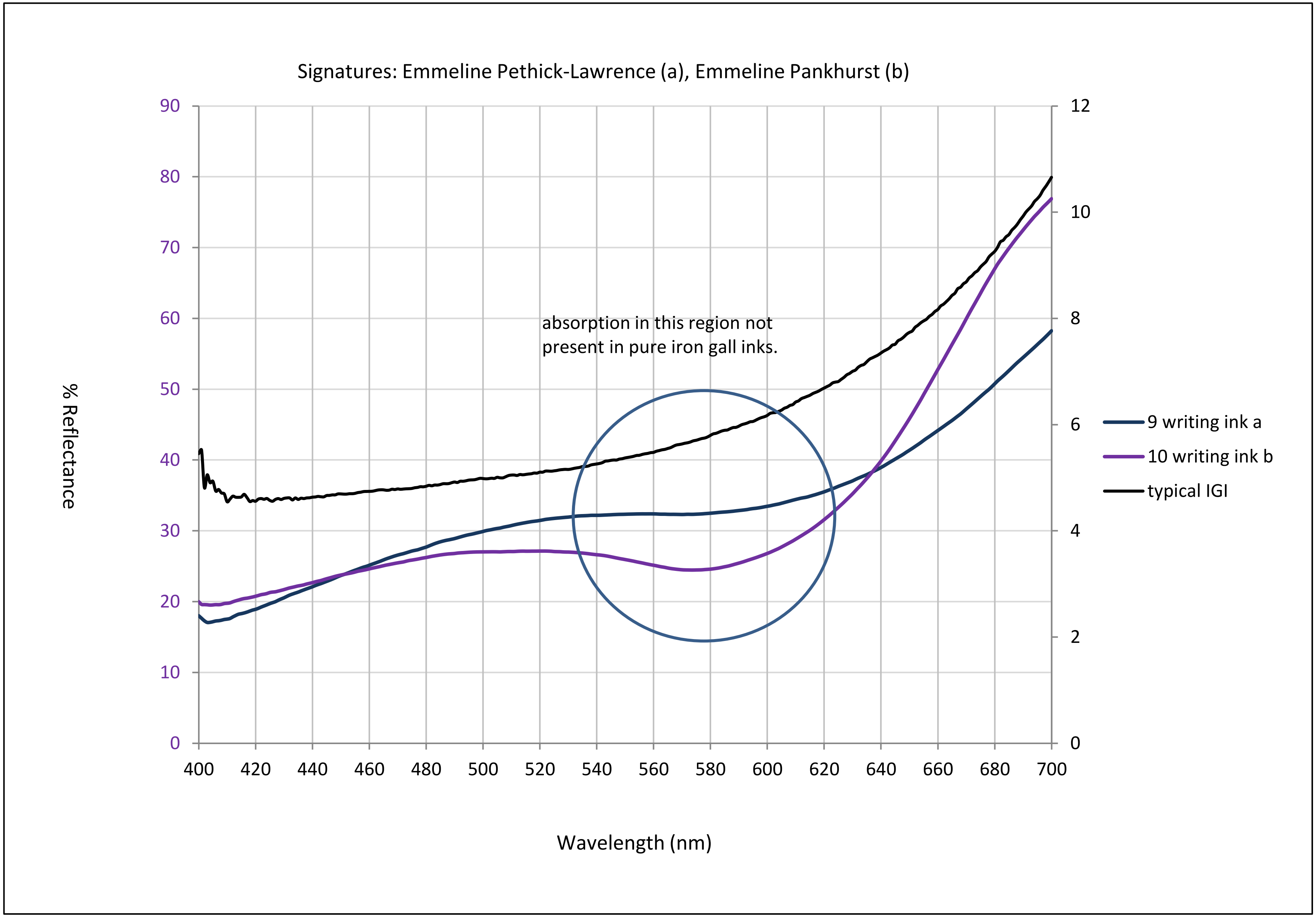


Figure 16. Spectral comparison of inks.

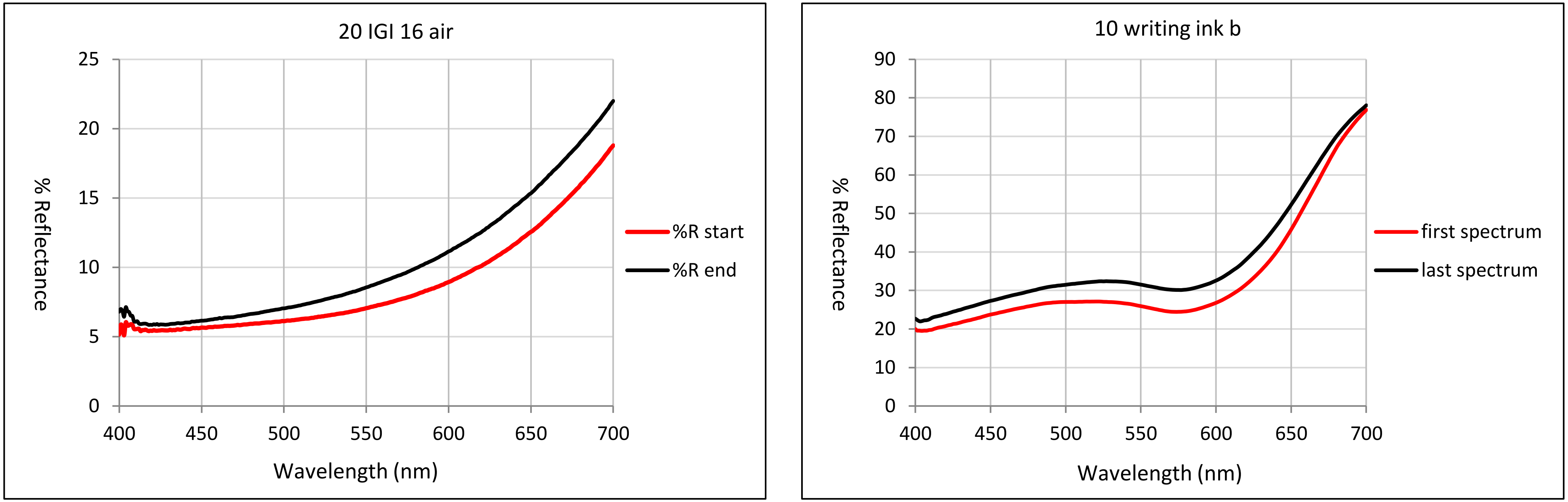


Figure 17. Spectral change during IGI microfading (left) c.f. the Pankhurst signature (right). Note the negligible reflectance change for the latter at 700nm compared to the former. Either the Pankhurst ink does not contain IGI or if it does, a fugitive purple dye additive is driving its fading. Either way the fading will likely be permanent, unlike IGIs which undergo a reversible photoreduction and after accelerated exposure can be observed reverting to their original colour (Ford 2014), below.

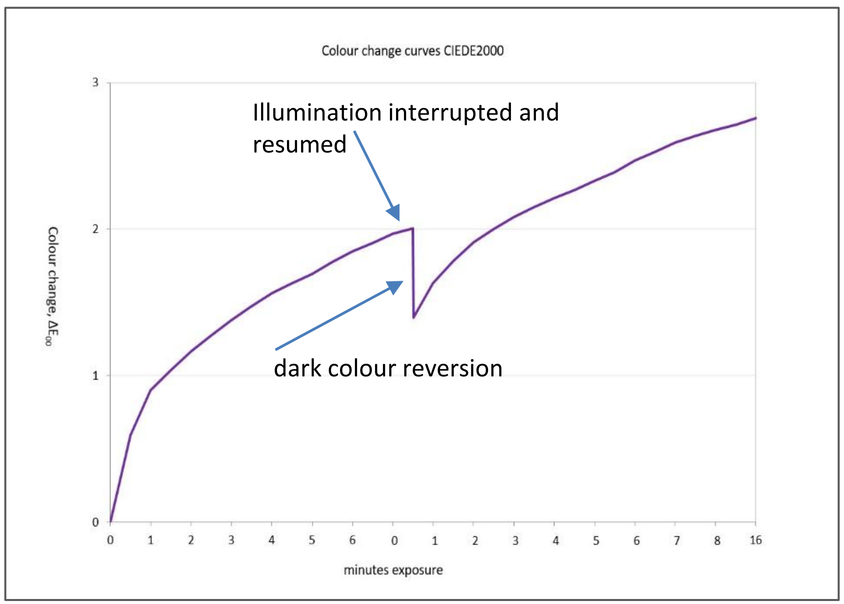


Figure 18. The same red dye, an anthraquinone (Figure 18), seems to have been used throughout the document.

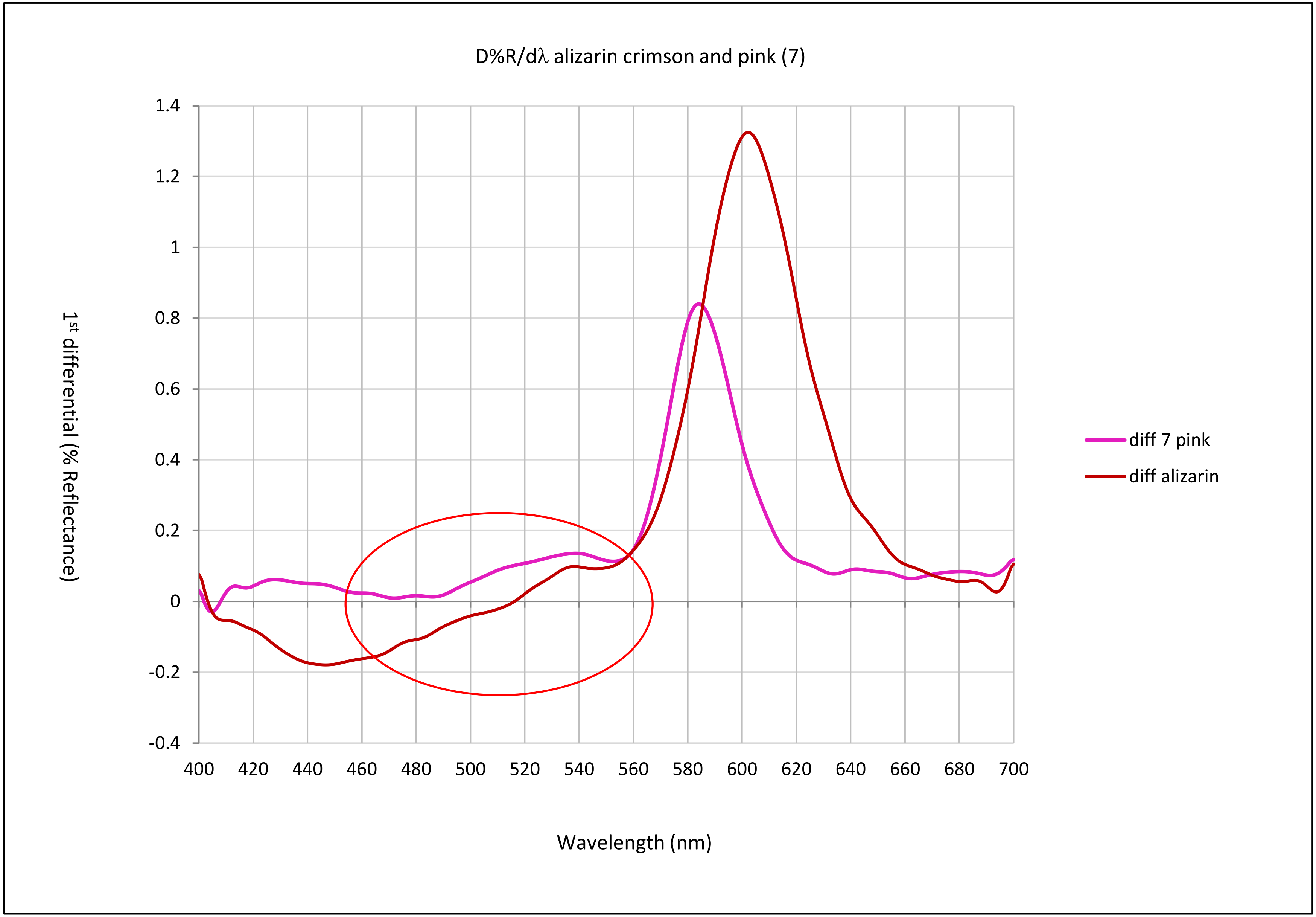


Figure 19. Alizarin is a close match for the red dye based on the position of secondary absorption "bumps" (circled) characteristic of anthraquinones. Alizarin was a common synthetic dye in use at the time.

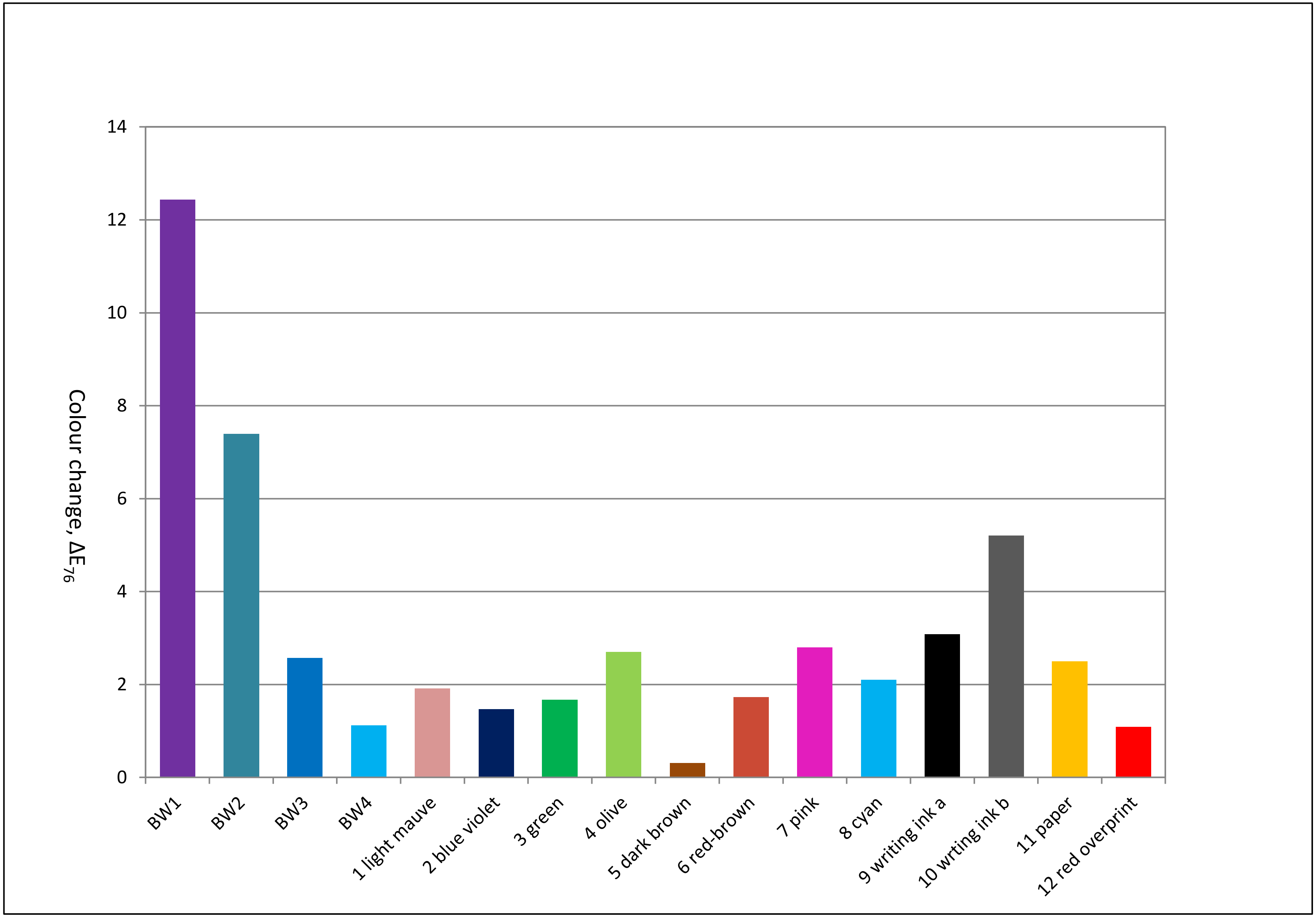


Figure 20. Relative colour change rates , CIE76

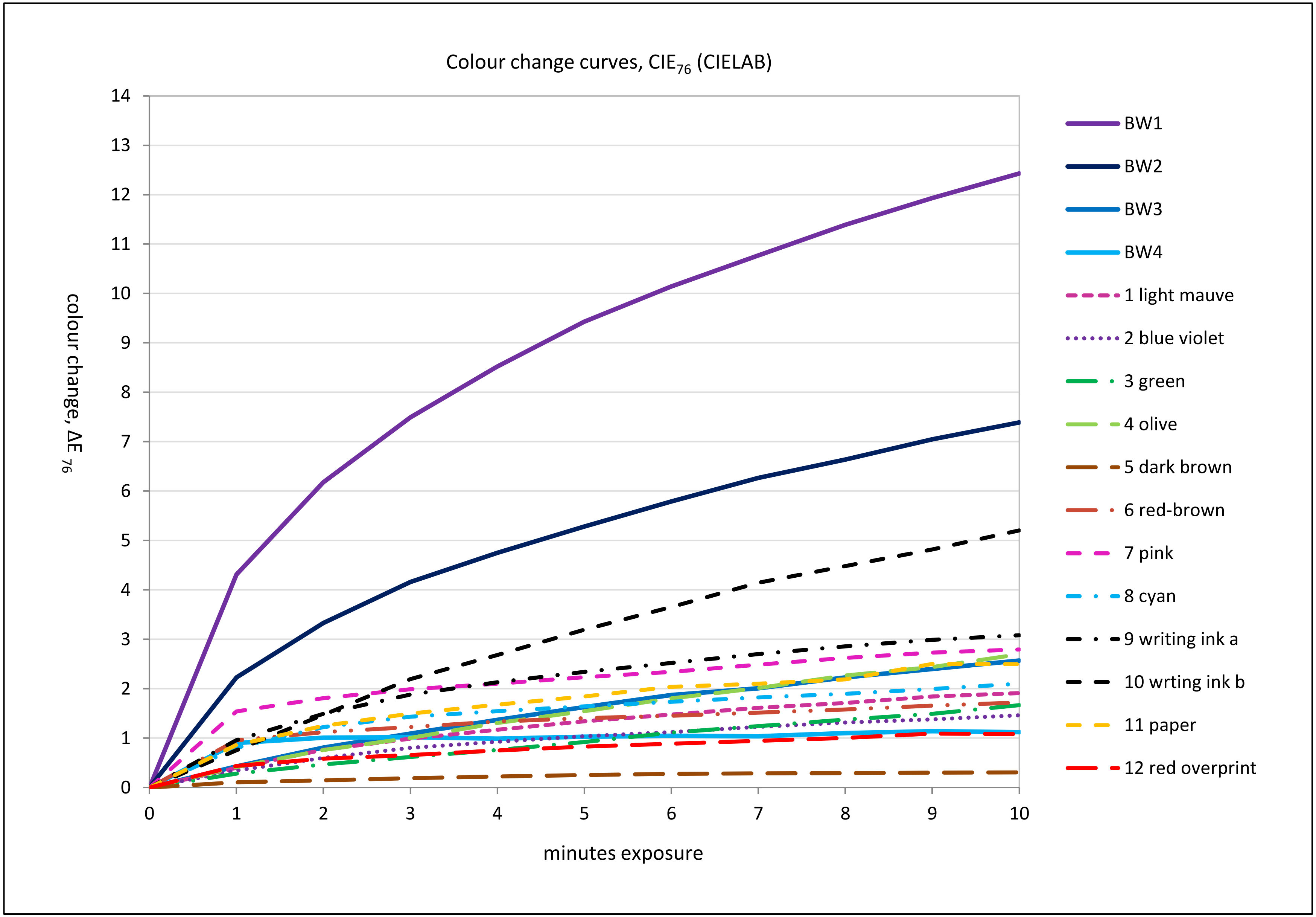


Figure 21. Colour change curves, CIE76

Notes & References

Endnote 1

Microfade testing is an accelerated test method and there are uncertainties surrounding the correlation between what is observed at very high intensities and what is likely to occur on display and during subsequent storage (Whitmore et al 2000). It is a semi-quantitative risk assessment tool rather than necessarily predictive. The results in this case apply only to UV-free light.

Endnote 2

For the purposes of this report colour change (ΔE) has been calculated using the CIE's 2000 (CIEDE2000) colour difference formula which replaced the earlier and much simpler 1976 (CIE76 or CIELAB) equation. Relative fading rates using the latter calculation are also provided in Table 1 and Figures 20 & 21. While much of the accelerated and ambient fading instrumental data in the conservation literature has mostly been calculated using CIELAB, CIEDE2000 is likely to be more accurate (CIE 2001). The ability of an "average observer" to notice differences between blues was exaggerated by a factor of about two in CIELAB, and in CIEDE2000 the ISO Blue Wools (BWs) fade approximately twice as slowly as in CIELAB. This affects the relative fading rates of the ISO Blue Wools (BWs) used as internal standards and other colourants not affected by the revision to the same degree. There are many other colour difference equations all of which will give different results, for example CMC, S-CIELAB, and a proposed I* (I-star) metric for photographs (McCormick-Goodhart 2007).

Michalski's estimates of how much exposure (megalux hours, Mlux h) will result in a just noticeable fade or difference (JNF or JND) for each of the BWs (CIE 2004) are themselves approximations with a maximum error of ± 1 BW step (Michalski 2010). Therefore absolute predictions of the response of a colourant to a particular exposure (mlx-h) are possibly uncertain to a similar extent. The most recent (unpublished) research by the CCI and GCI indicates that for BWs 2-5 Michalski's estimates are reasonable, but the lightfastness of BW1 is overestimated by as much as a factor of two or three.

Endnote 3

Microfading cannot predict the post-exposure colour of undyed and unpigmented fibres and paper because only the immediate photochemical response is measured and not the effect of concurrent and subsequent thermal (oxidative) yellowing reactions (Feller 1994). Light exposure accelerates subsequent yellowing via a mechanism involving residual photochemical reaction products. Thermal (dark) discolouration depends heavily on temperature, chemical processing of fibres, pH, exogenous and endogenous pollutants, prior conservation treatments and so on. To further complicate matters, ultraviolet directly yellows, rather than bleaches, groundwood paper and most natural fibres like wool. For example the rapid discolouration of newspaper in sunlight is the result of UV (<400nm) yellowing outpacing visible (>400nm) light bleaching.

Endnote 4

The NMA assumptions (Ford BL & N Smith 2009) are based on those of the V&A Museum (Ashley-Smith et al 2002): that is works should last for at least 500 years in a coloured form; a Just Noticeable Difference (JND) = 1.6ΔE and 10 JNDs signal the effective end of coloured life for an object. This may often be a conservative estimate because approximately 30ΔE represents complete fading, but for low chroma colours it seems reasonable. The absolute fading rates of the BWs are taken from CIE157 (2004), see Endnote 2. CIE157 recommends colourants less lightfast than BW3 be exposed only half as much as the V&A's 2 years/decade at 50lux recommendation.

The NMA further makes a judgement based on a significance test as to whether the object/collection is likely to be in strong demand for exhibition in the future (i.e. at higher risk of fading over time) and adjusts recommended exposures accordingly. Objects judged likely to be more in demand are treated more conservatively than objects which may rarely if ever displayed again (Ford BL & N Smith 2009) .

References

Ashley-Smith, J, Derbyshire, A & B Pretzel 2002, The continuing development of a practical lighting policy for works of art on paper and other object types at the Victoria and Albert Museum, *Preprints of the 13th triennial meeting of the ICOM Committee for Conservation in Rio de Janeiro*, vol.1, pp. 3-8.

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Feller, RL. 1994. *Accelerated ageing: photochemical and thermal aspects*. Research in Conservation No. 4, GCI. http://www.getty.edu/conservation/publications_resources/pdf_publications/accelerated_aging.html

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Ford, B. 2014. The accelerated light fading of iron gall inks in air, hypoxia and near-anoxia. In: ICOM-CC 17th Triennial Conference, Melbourne, 2014: paper 0604

Refs ctd.
Michalski, S., Canadian Conservation Institute (CCI), personal communication, 10th October 2010.

McCormick-Goodhart, M. 2007. *An introduction to the I* Metric*. Aardenburg Imaging and Archives.

Whitmore, PM, Bailie, C & S Connors 2000, Micro-fading to predict the result of exhibition: progress and prospects, in *Tradition and Innovation: Advances in Conservation*, ed. A. Roy and P. Smith, pp. 200-205. London: IIC.

The Canadian Conservation Institute website has an excellent general introduction to light and museum collections: http://www.cci-icc.gc.ca/resources-ressources/agentsofdeterioration-agentsdedeterioration/chap08-eng.aspx

For a complete list of references to microfading and its applications see http://www.microfading.com/resources.html

Blue Wool categories	1	**2**	3	4	**5**	6	7	**8**	Over 8	
Mlx h[a] for noticeable fade[b] UV present[c]	0.22	**0.6**	1.5	3.5	**8**	20	50	**120**		
Probable Mlx h[a] for noticeable fade[b] if no UV[d]	0.3	**1**	3	10	**30**	100	300	**1000**		

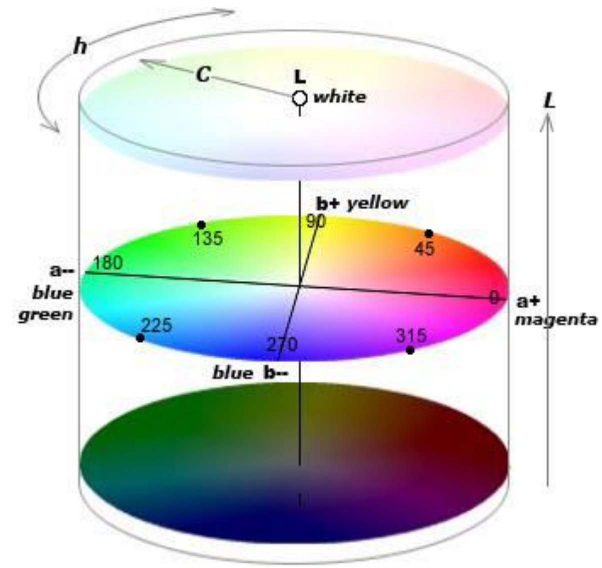
Explanatory notes to table:
The "Blue Wool categories" are the international standard (ISO) categories for specifying sensitivity to light, based on 8 blue dyes on wool, used as reference samples in most lightfastness tests.
a. Mlx h is the unit of light exposure, or dose. Megalux hours. It is light intensity (lux) multiplied by exposure time (hours)
b. A noticeable fade is defined here as Grey Scale 4 (GS4) , the step used in most lightfastness tests as noticeable. It is approximately equal to a colour difference of 1.6 CIELAB units. There are approximately thirty such steps in the transition from a bright colour to almost white.
c. UV rich refers to a spectrum similar to daylight through glass. This is the spectrum generally used for the lightfastness data used to derive this table. The exposures here are the best fit to data that varies about one Blue Wool step.
d. Exposures estimated for UV blocked light source are derived from a study on 400 dyes and the blue wool standards themselves. As such, it is only probable, and probably only for organic colorants. These estimates show minor benefit of UV filtration for low sensitivity colorants, but large improvements for high sensitivity colorants. For conservative estimates, use the UV rich scale.
f. "No sensitivity" to light does not mean guaranteed colour life. Many colorants in this group are sensitive to pollution. Many organic media will chalk or yellow or both if any UV is present.
g. The particular paint medium makes only small differences to fading rate, it is the colorant that matters in fading, not whether it is oil, or tempera, or watercolour, or acrylic. Media does, however, make large differences to rate of discoloration from pollutants such as ozone and hydrogen sulphide.

Michalski's BWFS estimates from *Running A Museum, a practical handbook* ICOM 2004.
http://portal.unesco.org/culture/en/ev.php-URL_ID=36646&URL_DO=DO_TOPIC&URL_SECTION=201.html More recent estimates of BW1 put it at about 0.1 Mlux h/JND (UV-free), far less lightfast than Michalski's estimate (Druzik 2016).

Instrument Settings

Luminous flux (mlm)	~600
Spot lux (megalux)	~ 6-8
Spot diameter (mm)	0.4
Colour difference equations	ΔE_{76} & ΔE_{00}

Simplified L*a*b* colour space



L* a* b* and L C h are different ways of describing the same shift in CIELAB space

L* = Lightness
a* = red-green axis
b* = yellow-blue axis

C = vividness (chroma)
h = hue angle anticlockwise from red (0)