

# Metamerism in Colour Mixtures Containing Cadmium Red and Pigment Red 254

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**Abstract:** In modern times, cadmium compounds were significant for producing a bright red pigment for artists', and conservators' inpainting palettes. In contemporary practice, to avoid toxicity, many synthetic organic compounds have been proposed to replace cadmium red. One particular pigment suggested as a replacement is PR 254, which has lightfastness and colour properties that closely match cadmium red. This project further explored the differences in colours produced when these two pigments are used in complimentary colour mixing with acrylic paint when mixed with other commonly used pigments such as phthalo blue and phthalo green, cerulean blue, cobalt green, ultramarine blue, burnt sienna and bone black. A set of neutral tones were mixed with these pigments using cadmium red. An attempt was made to reproduce these exact tones by eye, using the PR 254 to create the mixture. L\*a\*b\* values and spectral reflectance curves of the neutrals were measured and compared. ΔE values and the presence of metamers were noted. Also, comparisons were made between pure corrected tints and two cadmium red hue products. Understanding the differences in mixing properties between historic and contemporary red pigments helps conservators and contemporary artists to understand the scientific difference between the colours mixed from these two different red pigments.

## Experimental

**Materials:** - Golden and Tri Art artist's acrylic paints with these colours  
 • CP cadmium red middle, pyrrole red and cadmium red middle (hue)

### Experimental Method:

- commercial artists paints examined by p-XRF and XRD (Fig. 2 and 3)
- mixtures compared to cadmium red middle hue paints (Figure 4)
- mixtures were then mixed to neutral tones with other pigments
- pairs of samples were compared visually, by the L\*a\*b\* colour system, and through spectrophotometry (Figure 5 and 6).

**Sample Preparation:** All paint colour comparisons were completed using the same technique (Figure 1)

Black stripes to ensure sample opacity

Outer sample: mixture with cadmium pigments

Inner sample: mixture with pyrrole red matched by eye to cadmium sample

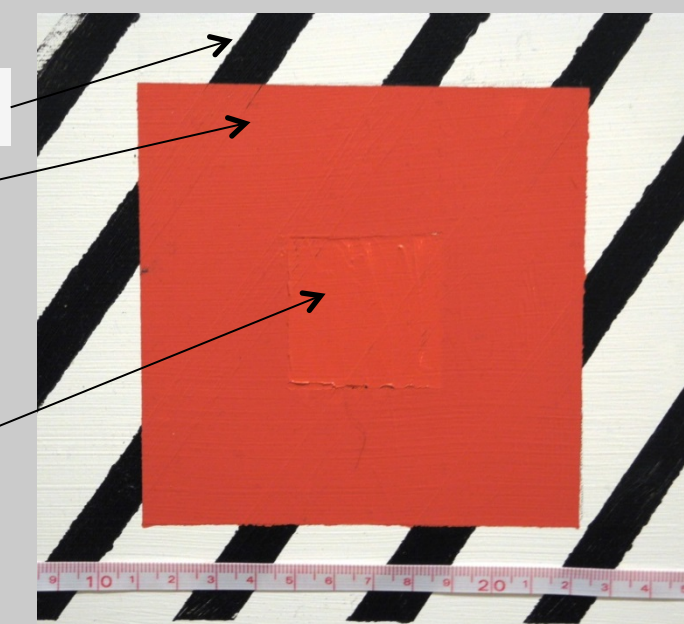


Figure 1: Sample Preparation Technique

## Results and Conclusion

### Results

- CP Cadmium Red pigment for artists varies in elemental composition from manufacturer to manufacturer (Figure 2)
- The bluish shade α phase PR 254 pigment is used in artists acrylic paints; in oil paint the phase difference is indeterminate due to a barium sulfate additive (Figure 3)
- PR 254 is too orange to match cadmium red well in masstone, but too purplish in tints to match cadmium red tints
- PR 254 across manufacturers can be matched reasonably well to cadmium reds in tints, but only with the addition of yellow oxide and either ultramarine blue or magenta
- These mixtures are superior in colour performance to cadmium red middle hue products on the market today (Figure 5)
- Mixtures made with this pigment do not perform in the same way as mixtures made with cadmium red, both in spectral reflectance (Figure 4) and difference in L\*a\*b\* values (Figure 6)
- According to ASTM D 4086 92 A, no samples were highly metameric, but some did display multiple spectral crossovers

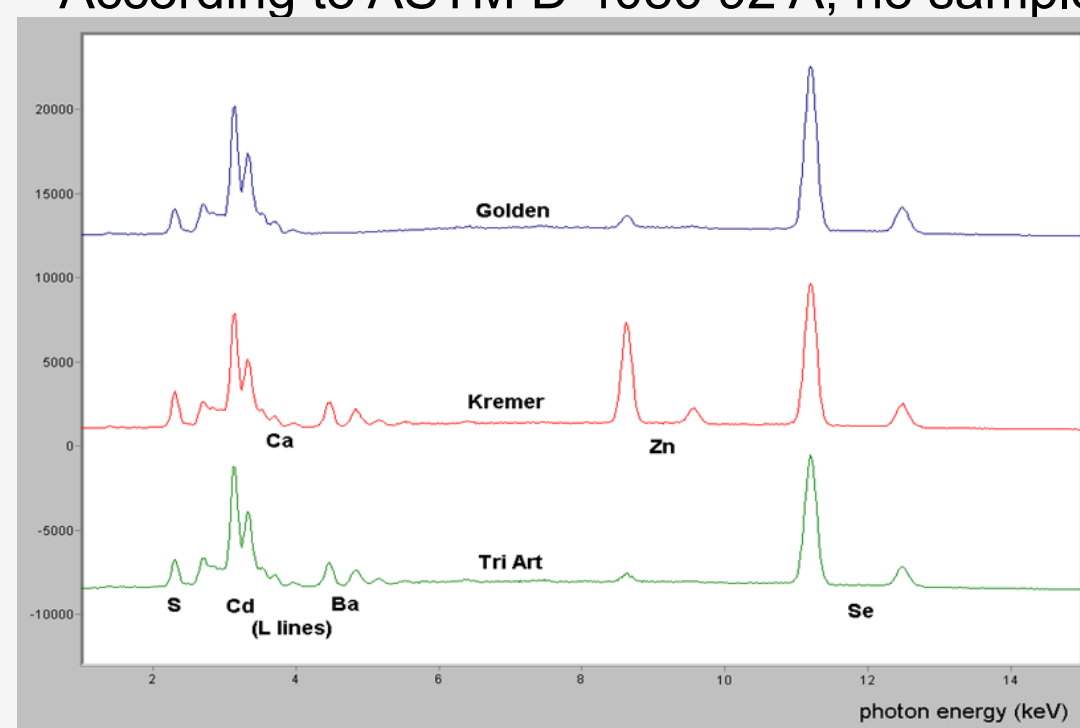


Figure 2. XRF Spectra of Three Cadmium Red Medium Pigments, Showing Varying Elemental Composition

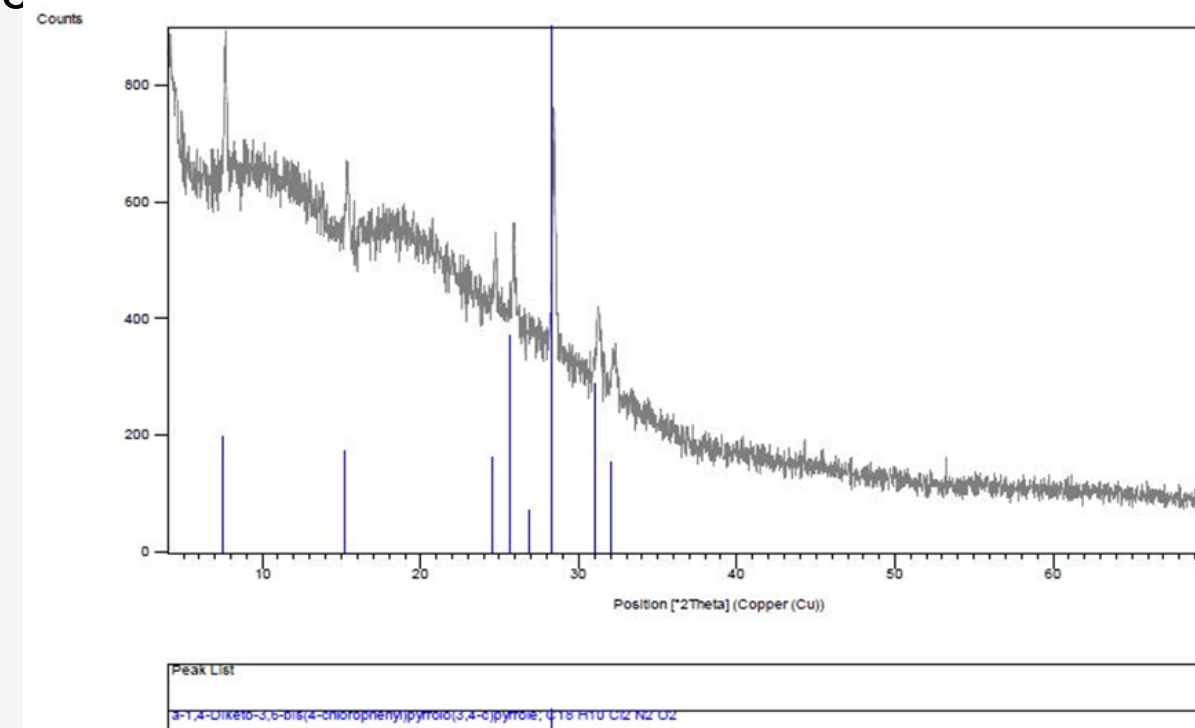


Figure 3. XRD of Alpha crystallization PR 254 Compared to Artist's Acrylic PR 254 Paint

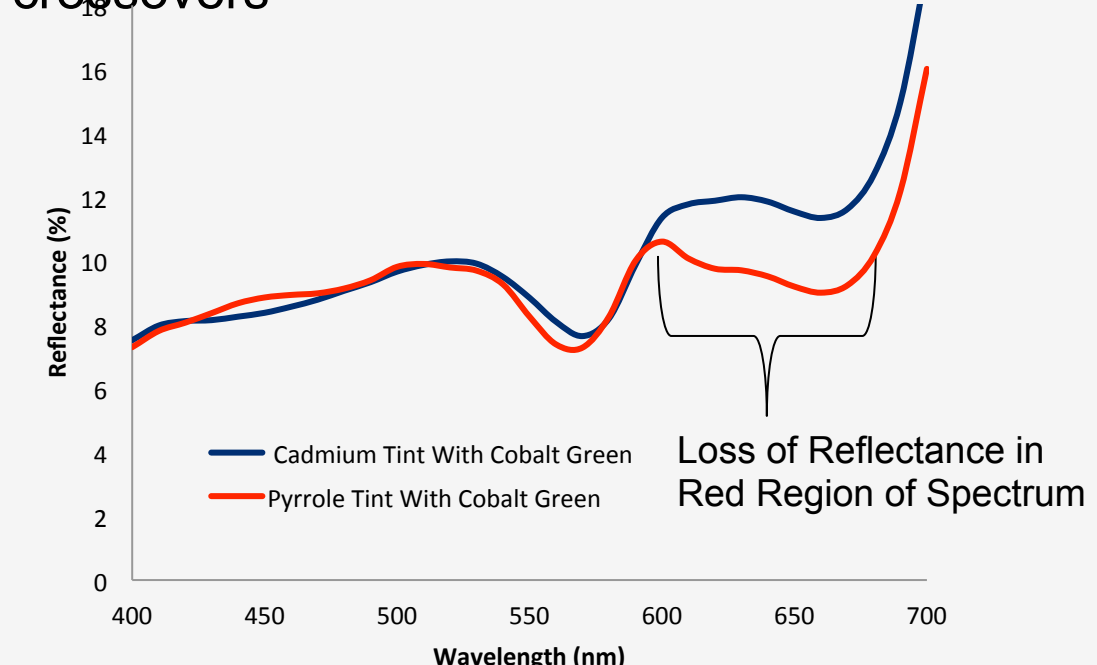


Figure 4. Comparison of Reflectance of a Golden Paint Pyrrole Mixture Prepared with Cobalt Green versus Identical Cadmium Mixture, showing Loss of Reflectance in the Red Region of the Spectrum

Mixture	ΔE76 Compared to Cadmium Tint	ΔE2000	ΔL*	Δa*	Δb*
Golden Cadmium Red Hue	14.44	4.87	-0.1	-14.4	0.52
Tri Art Cadmium Red Hue	10.59	4.45	0.48	-5.53	-9.02
Golden Final Corrected Pyrrole Mixture (Pyrrole, yellow oxide and Magenta)	2.21	0.93	-0.69	-1.90	-0.90
Tri Art Final Corrected (Pyrrole, yellow oxide and ultramarine blue)	2.04	1.60	-1.68	-0.96	-0.65

Figure 5. Comparison of L\*a\*b\* values of Pyrrole Mixtures Verses Cadmium Red Hues

Mixture	ΔE76 Compared to Cadmium Sample	ΔE2000	ΔL*	Δa*	Δb*
Tri Art Cobalt Green	3.40	3.05	-1.71	-2.00	-2.15
Golden Cobalt Green	2.94	3.09	-0.90	-1.84	-2.11

Figure 6. Delta E Values for Pyrrole/Cobalt Green Neutrals Compared to Cadmium Mixtures

### Conclusions

PR 254 does have colourimetric properties that make it appealing to be a replacement for cadmium red medium. Although the two pigments can be matched well in masstone with a correcting pigment, in a tint this is more difficult. Mixtures with two other pigments and PR 254 can give tints where the delta E values are near or at tolerance for colour difference in the L\*a\*b\* system. The same can not be said for cadmium red middle hue products based on naphthol red. When a closer analysis is made of the tint and mixtures made with it, the PR 254 mixtures are, even when corrected, bluer than cadmium mixtures, with a loss of spectral reflectance in the red region. This means that for exact matching to cadmium, PR 254 could not replace cadmium. For a cadmium red medium hue, however, these mixtures are better than the current cadmium red medium hues available.

## Paint Samples

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