A Summary of Ultra-Violet Fluorescent Materials Relevant to Conservation

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This summary was produced to assist Museum Victoria's Conservation team to interpret results of ultra-violet (UV) light examination. The table below lists materials with published results of UV light examination from conservation journals and other sources, including personal observations. By no means an exhaustive list, it is reproduced here in the hope that it will be of benefit to other conservators using this examination technique. These results would benefit from further testing and research.

UV light is a form of electromagnetic radiation, along with visible light, infrared, x-rays etc. (see Figure 1, below). UV light radiates at shorter wavelengths than visible light and cannot be seen by the human eye. However, when UV light is absorbed by certain materials, it is reflected back towards the eye as longer wavelength visible radiation, or visible light. This phenomenon is referred to as UV-induced visible fluorescence.

Figure 1: The Electromagnetic Radiation Spectrum. Diagram: Danielle Measday

Observation of this fluorescence can be used by conservators as a non-destructive analytical technique to aid in the examination of objects. The presence of fluorescence may assist with materials identification, detecting insect damage or surface coatings, and uncovering areas of previous restoration. The colours of the observed fluorescence will depend on the material and on the wavelength of UV light used. For example, many adhesives fluoresce under long-wave UV but do not fluoresce at all under short-wave UV. On the other hand, many mineral specimens fluoresce under short-wave UV.

Limitations

Fluorescence is a useful tool for identification, however caution should be taken when drawing conclusions based solely on examination with UV light. It may be easily misinterpreted, or produce misleading results due to age or surface dirt obscuring fluorescing materials underneath. Further testing may be required. UV light can cause damage to collection objects, and while the amount of radiation absorbed by an object during examination will be small, it is recommended that exposure time should be limited.

Safety

Long term exposure to UV radiation can lead to serious and irreversible vision problems, including cataracts, glaucoma and macular degeneration. UV radiation may also increase the risk of skin cancer, and exposure to unprotected skin should be minimised (World Health Organisation 2016). When carrying out examination using UV light, the following minimum personal protective equipment is required:

- UV filtering safety glasses
- Long sleeves (e.g. lab coat)
- Nitrile gloves

Interpreting results

The colours of the observed fluorescence will depend on the material and the wavelength of the UV light that is being used. It is important to use a UV lamp with the appropriate wavelength for the questions at hand. Remember also that as with any examination technique, avoid drawing conclusions from the results of UV-induced visible fluorescence examination alone.

Range	Wavelength	Abbreviations	
Short-wave	100-280nm	SW	UVC
Mid-wave	280-315nm	MW	UVB
Long-wave	315-400nm	LW	UVA

OBJECTS	UV Lamp	Results	Notes	Reference/Source
Ceramics			UV examination is most useful to determine the presence of previous repairs as many adhesives and fills fluoresce. (See Adhesives, Consolidants, Binders, Varnishes & Coatings section).	
Hard-paste porcelain	Short-wave UV	Fluoresces dim pink		Simpson-Grant 2000 (B)
Soft-paste porcelain	Short-wave UV	Fluoresces milky white		Simpson-Grant 2000 (B)
Glass			The colour of fluorescence is not so much characteristic of the type of glass, but rather is indicative of the refining agents, the furnace atmosphere and melting temperature.	Newton & Davison 1989
Borosilicate glass		Does not fluoresce		Simmons 1995, p. 169.
Crystal/lead glass	Short-wave UV	Fluoresces dramatic icy blue	The colour can change to green if larger amounts of lead are present.	Simpson-Grant 2000 (B); Newton & Davison 1989
Soda- Lime glass	Long-wave UV	Fluoresces yellow-green		Simmons 1995, p. 169.
Uranium glass	Long-wave UV	Fluoresces bright yellow/green		Simpson-Grant 2000 (B)
Stone				
Aged marble, limestone and alabaster	Long-wave UV	Patina may exhibit mottled fluorescence		Simpson-Grant 2000 (B)
Freshly cut marble, limestone and alabaster	Not specified	Does not fluoresce significantly		Simpson-Grant 2000 (B)
Ivory and Bone				
New ivory and bone	Long-wave UV	Fluoresces bright white		Simpson-Grant 2000 (B)
Old ivory and bone	Long-wave UV	Fluoresces a subdued, mottled yellow		Simpson-Grant 2000 (B)
Metals			Generally metals do not	

			fluoresce, however some coatings applied to the surface may fluoresce. See Adhesives, Consolidants, Binders, Varnishes & Coatings section	
Plastics			Optical brighteners (OBs) introduced into plastics in 1950s	Mustalish 2000, p.135
Wood			Some coatings applied to the surface may fluoresce. See Adhesives, Consolidants, Binders, Varnishes & Coatings section	
Old wood	Long-wave UV	Patina may fluoresce in mottled tones		Simpson-Grant 2000 (B)
Sumac	Long-wave UV	Strong fluorescence (Colour not specified)		Simpson-Grant 2000 (B)
Textiles				
Textiles treated with optical brighteners (OB's)	Long-wave UV	Fluoresce brightly	OBs used in silks and wool from 1840s; in polyester, polyacrylonitrile, viscose rayons, cellulose acetate and nylon from 1960s. Used in laundry detergents from 1830s, textiles washed in detergents with OB's may also fluoresce.	Simpson-Grant 2000 (B); Mustalish 2000, pp.134-135.
Wool	Long-wave UV	Fluoresces blue-white	Fluorescence occurs when keratin begins to decompose or due to treatments, which disrupt disulphide bonds, e.g. oxidizing agents.	Collins et al. 1988, pp. 349–51

ADHESIVES, CONSOLIDANTS, BINDERS, VARNISHES & COATINGS	UV Lamp	Results	Notes	Reference/Source
Beeswax	Short-wave UV	Fluoresces bright pale orange		Pemberton & Kowalski pers. comm. 6 September 2016
	Long-wave UV	Fluoresces bright pink/orange		Pemberton & Kowalski pers. comm. 6 September 2016
Carnauba	Long-wave UV	Fluoresces yellow-brown	Thin wax coatings on furniture are generally not visible with hand held UV lamps.	Rivers & Umney 2013, p. 610
Cellulose	Long-wave UV	Fluoresces bright white		Rivers & Umney 2013, p. 610
Cellulose acetate (UHU)	Long-wave UV	Milky white fluorescence		Simpson-Grant 2000 (B)
Cellulose Nitrate	Long-wave UV	Fluoresces greenish yellow		Simpson-Grant 2000 (B)
Copal	Short-wave UV	Fluoresces matte, deep orange – dark yellow		Pemberton & Kowalski pers. comm. 6 September 2016
	Long-wave UV	Fluoresces bright, light orange		Pemberton & Kowalski pers. comm. 6 September 2016
Dammar	Short-wave UV	Fluoresces dull yellow green		Pemberton & Kowalski pers. comm. 6 September 2016
	Long-wave UV	Fluoresces variable colours, green/yellow to green/ white		Pemberton & Kowalski pers. comm. 6 September 2016

		Fluoresces greenish white		Rivers & Umney 2013, p. 610
Dammar and Wax	Short-wave UV	Fluoresces very dull orange		Pemberton & Kowalski pers. comm. 6 September 2016
	Long-wave UV	Fluoresces slight, dull orange		Pemberton & Kowalski pers. comm. 6 September 2016
Dextrin	Long-wave UV	Fluoresces blue-white		Jirat-Wasiutynski 1986, p.24
Egg white	Short-wave UV	Fluoresces pale yellow		Pemberton & Kowalski pers. comm. 6 September 2016
	Long-wave UV	Fluoresces variable colours dull pink/orange to bright light yellow		Pemberton & Kowalski pers. comm. 6 September 2016
Epoxy adhesives	Long-wave UV	Fluoresces bright yellowish white		Simpson-Grant 2000 (B)
Gum Arabic	Short-wave UV	Absorbs UV		Pemberton & Kowalski pers. comm. 6 September 2016
	Long-wave UV	Absorbs UV		Pemberton & Kowalski pers. comm. 6 September 2016
Hide glue	Long-wave UV	Fluoresces bright white		Rivers & Umney 2013, p. 610
Laropal K80 (Ketone resin N)	Short-wave UV	Fluoresces purple		Pemberton & Kowalski pers. comm. 6 September 2016
	Long-wave UV	Fluoresces purple		Pemberton & Kowalski pers. comm. 6 September 2016
Linseed oil	Short-wave UV	Fluoresces deep yellow		Pemberton & Kowalski pers. comm. 6 September 2016
	Long-wave UV	Fluoresces orange		Pemberton & Kowalski pers. comm. 6 September 2016
Mastic	Short-wave UV	Fluoresces dull yellow/green		Pemberton & Kowalski pers. comm. 6 September 2016
	Long-wave UV	Fluoresces variable colours, green/yellow to green/ white		Pemberton & Kowalski pers. comm. 6 September 2016
		Fluoresces greenish white		Rivers & Umney 2013, p. 610
Mowilith 50 (Poly Vinyl Acetate)	Short-wave UV	Fluoresces dull light orange		Pemberton & Kowalski pers. comm. 6 September 2016
	Long-wave UV	Fluoresces slight dull yellow		Pemberton & Kowalski pers. comm. 6 September 2016
Natural resins	Long-wave UV	Fluoresces green, yellowish or milky grey		Simpson-Grant 2000 (B)
Old varnish	Not specified	Fluorescence appears milky but transparent	Under UV light a painting with a smooth coat of old varnish looks milky but fairly transparent. Interference such as attempts to remove the varnish, local retouching & repairs can be clearly seen as darker patches.	Hours 1976, p.45
Oriental Lacquer	Long-wave UV	Varies from no fluorescence to		Rivers & Umney 2013, p. 610

		muted orange to bright orange.		
Paraffin wax	Long-wave UV	Fluoresces blue	Thin wax coatings on furniture are generally not visible with hand held UV lamps.	Rivers and Umney 2013, p. 610
Paraloid B72	Not specified	No fluorescence		Simpson-Grant 2000 (B); Pemberton & Kowalski pers. comm. 6 September 2016
Poly vinyl acetate	Long-wave UV	Blueish milky fluorescence		Simpson-Grant 2000 (B)
Regalrez (hydrocarbon resin)	Short-wave UV	Fluoresces dull yellow		Pemberton & Kowalski pers. comm. 6 September 2016
	Long-wave UV	Fluoresces pale orange/yellow	Similar to Dammar	Pemberton & Kowalski pers. comm. 6 September 2016
Shellac	Short-wave UV	Fluoresces dull orange		Pemberton & Kowalski pers. comm. 6 September 2016.
	Long-wave UV	Fluoresces bright orange	Shellac that has had extensive sun exposure may exhibit yellow-green fluorescence	Simpson-Grant 2000 (B); Rivers & Umney 2013, p. 610; Pemberton & Kowalski pers. comm. 6 September 2016
Some waxes	Long-wave UV	Fluoresces bright white		Simpson-Grant 2000 (B)
Stand oil	Short-wave UV	Fluoresces orange – slightly grey		Pemberton & Kowalski pers. comm. 6 September 2016
	Long-wave UV	Fluoresces orange		Pemberton & Kowalski pers. comm. 6 September 2016
Synthetic resins	Long-wave UV	Vary from no fluorescence to blue-white or lavender. Some aged synthetic resins may exhibit a greenish-white fluorescence.	Synthetic resins can become more fluorescent over time, making it difficult to distinguish them from natural resins.	Rivers & Umney 2013, p. 388. 610; Pemberton & Kowalski pers. comm. 6 September 2016
Tempera	Short-wave UV	Fluoresces pale yellow	Type of tempera not classified in available prepared sample	Pemberton & Kowalski pers. comm. 6 September 2016
	Long-wave UV	Fluoresces bright pale orange	Type of tempera not classified in available prepared sample	Pemberton & Kowalski pers. comm. 6 September 2016

PIGMENTS, INKS & DYES	UV Lamp	Results	Notes	Reference/Source
Red				
Alizarin	Short-wave UV	Dull orange colour change	Oil binder	Pemberton & Kowalski pers. comm. 6 September 2016
	Long-wave UV	Dull orange colour change	Oil binder	Pemberton & Kowalski pers. comm. 6 September 2016
	Not specified	Fluoresces pale violet		Museum of Fine of Boston n.d.
Alizarin Lake (Synthetic)	Not specified	No fluorescence		Fitzhugh 1997, p.124
Cadmium red	Not specified	Fluoresces red		Stuart 2007, p.77
		No fluorescence	Oil binder	Pemberton & Kowalski pers. comm. 6 September 2016

Carmine	Not specified	Fluoresces vivid pink	True for carmine from both cochineal and kermes beetles.	Feller 1986, p.255, 273.
Cinnabar, pure	Not specified	Fluoresces dark red		Eastman Kodak Company 1987
Cinnabar substitute (lithol red)	Not specified	Fluoresces cinnabar red		Eastman Kodak Company 1987
Cinnabar substitute (Permanent red)	Not specified	Fluoresces carmine		Eastman Kodak Company 1987
Crimson lake	Short-wave UV	Fluoresces pale orange Dull orange colour change	Oil binder	Pemberton & Kowalski pers. comm. 6 September 2016
	Long-wave UV	Fluoresces pale orange Dull orange colour change	Oil binder	Pemberton & Kowalski pers. comm. 6 September 2016
Dragon's blood	Short-wave UV	Fluoresces slight, pale orange		Pemberton & Kowalski pers. comm. 6 September 2016
	Long-wave UV	Fluoresces slight, pale orange		Pemberton & Kowalski pers. comm. 6 September 2016
Eosin	Not specified	Not specified	Fades rapidly in sunlight	Museum of Fine of Boston n.d.
		Fluoresces bright orange		Chapman 2000.
Indian red	Short-wave UV	Dull orange colour change	Oil binder	Pemberton & Kowalski pers. comm. 6 September 2016
	Long-wave UV	Orange colour change	Oil binder	Pemberton & Kowalski pers. comm. 6 September 2016
Lac Lake	Not specified	No fluorescence		Fitzhugh 1997, p.124
Madder	Not specified	Fluoresces fiery yellow red		Gettens & Stout 1966, p.126
		Fluoresces dull orange	Madder Carmine will also fluoresce orange (Feller p.274)	Fitzhugh 1997, p.124
	Short-wave UV	Fluoresces bright yellow-orange	Oil binder	Pemberton & Kowalski pers. comm. 6 September 2016
	Long-wave UV	Fluoresces bright yellow-orange	Oil binder	Pemberton & Kowalski pers. comm. 6 September 2016
		Fluoresces bright yellow-orange		Museum of Fine of Boston n.d.
Red ochre	Not specified	No fluorescence		Stuart 2007, p.77
Red lead	Not specified	Fluoresces dark red		Stuart 2007, p.77
	Long-wave UV	Absorbs		Fiske & Stiber Morenus 2004, p.26
Red lead pure	Not specified	Fluoresces dark red		Eastman Kodak Company 1987
Red lead substitute (helio red)	Not specified	Fluoresces reddish-brown		Eastman Kodak Company 1987
Red lead substitute (lac red)	Not specified	Fluoresces orange-red		Eastman Kodak Company 1987
Safflower red	Long-wave UV	Fluoresces orange		Fiske & Stiber Morenus 2004, p.31
Vermillion	Short-wave UV	Orange colour change	Oil binder	Pemberton & Kowalski pers. comm. 6 September 2016
	Long-wave UV	Absorbs, appears dark red brown		Fiske & Stiber Morenus 2004, p.26, 31
		Orange colour change	Oil binder	Pemberton & Kowalski pers. comm. 6 September 2016

	Not specified	Fluoresces red		Stuart 2007, p.77
Orange				
Cadmium orange	Short-wave UV	No fluorescence	Oil binder	Pemberton & Kowalski pers. comm. 6 September 2016
	Long-wave UV	No fluorescence	Oil binder	Pemberton & Kowalski pers. comm. 6 September 2016
Yellow				
Cadmium yellow	Not specified	Fluoresces light red		Stuart 2007, p.77
		No fluorescence	Oil binder	Pemberton & Kowalski pers. comm. 6 September 2016
Cadmium yellow - Light	Short-wave UV	Orange colour change	Liquitex Acrylic	Pemberton & Kowalski pers. comm. 6 September 2016
	Long-wave UV	Orange colour change	Liquitex Acrylic	Pemberton & Kowalski pers. comm. 6 September 2016
Cadmium yellow - Pale	Short-wave UV	Fluoresces dull orange/yellow	Oil binder	Pemberton & Kowalski pers. comm. 6 September 2016
		Dark green colour change	Liquitex Acrylic	Pemberton & Kowalski pers. comm. 6 September 2016
	Long-wave UV	Fluoresces dull orange/yellow	Oil binder	Pemberton & Kowalski pers. comm. 6 September 2016
		Dark green colour change	Liquitex Acrylic	Pemberton & Kowalski pers. comm. 6 September 2016
Chrome yellow	Not specified	Fluoresces red		Stuart 2007, p.77
Gamboge	Not specified	Fluoresces olive green		Wilson 2014
Hansa yellow light	Short-wave UV	Lime green colour change	Liquitex Acrylic	Pemberton & Kowalski pers. comm. 6 September 2016
	Long-wave UV	Lime green colour change	Liquitex Acrylic	Pemberton & Kowalski pers. comm. 6 September 2016
Indian Yellow	Short-wave UV	Fluoresces dull orange	Liquitex Acrylic	Pemberton & Kowalski pers. comm. 6 September 2016
	Long-wave UV	Fluoresces bright yellow, sometimes orange-yellow		Feller 1986, pp.32-33; Pemberton & Kowalski pers. comm. 6 September 2016
Naples yellow	Short-wave UV	Dull, slight orange colour change	Oil binder	Pemberton & Kowalski pers. comm. 6 September 2016
	Long-wave UV	Dull, slight orange colour change	Oil binder	Pemberton & Kowalski pers. comm. 6 September 2016
	Not specified	Fluoresces light red		Stuart 2007, p.77
Nickel titanate yellow	Short-wave UV	Dull yellow colour change	Oil binder	Pemberton & Kowalski pers. comm. 6 September 2016
	Long-wave UV	Dull yellow colour change	Oil binder	Pemberton & Kowalski pers. comm. 6 September 2016
Orpiment	Not specified	Fluoresces light yellow		Stuart 2007, p.77
Zinc yellow	Not specified	Fluoresces bright red		Stuart 2007, p.77
	Short-wave UV	Green colour change	Oil binder	Pemberton & Kowalski pers. comm. 6 September 2016
	Long-wave UV	Green colour change	Oil binder	Pemberton & Kowalski pers. comm. 6 September

				2016
Green				
Chromium oxide	Long-wave UV	Absorbs UV light, appearing dark	Windsor & Newton Watercolour	Pemberton & Kowalski pers. comm. 6 September 2016
Cobalt Green	Short-wave UV	Bright green/yellow colour change	Oil binder	Pemberton & Kowalski pers. comm. 6 September 2016
	Long-wave UV	Bright green/yellow colour change	Oil binder	Pemberton & Kowalski pers. comm. 6 September 2016
Emerald Green (copper aceto-arsenite)	Not specified	Absorbs UV light, appearing very dark	This is true whether the colour is bright green or discoloured tan, or whether layer is thin or thick.	Zieske 2002, p.93
Green earth (Terre Verte)	Not specified	Fluoresces bright blue		Stuart 2007, p.77
	Short-wave UV	Lighter green colour change	Oil binder	Pemberton & Kowalski pers. comm. 6 September 2016
	Long-wave UV	Yellow colour change	Oil binder	Pemberton & Kowalski pers. comm. 6 September 2016
Phthalocyanine green	Not specified	No fluorescence		Stuart 2007, p.77
Prussian green	Short-wave UV	Lighter green colour change	Oil binder	Pemberton & Kowalski pers. comm. 6 September 2016
	Long-wave UV	No fluorescence	Oil binder	Pemberton & Kowalski pers. comm. 6 September 2016
Verdigris	Not specified	No fluorescence		Stuart 2007, p.77
Viridian	Not specified	Fluoresces bright red		Stuart 2007, p.77
Blue				
Antwerp blue	Short-wave UV	Green colour change	Oil binder	Pemberton & Kowalski pers. comm. 6 September 2016
	Long-wave UV	Dull, green colour change	Oil binder	Pemberton & Kowalski pers. comm. 6 September 2016
Azurite	Not specified	Fluoresces dark blue		Stuart 2007, p.77
Cerulean blue	Not specified	Fluoresces lavender blue		Stuart 2007, p.77
	Short-wave UV	Dull aqua colour change	Oil binder	Pemberton & Kowalski pers. comm. 6 September 2016
	Long-wave UV	Bright aqua colour change	Oil binder	Pemberton & Kowalski pers. comm. 6 September 2016
Cobalt blue	Not specified	Fluoresces red		Stuart 2007, p.77
	Short-wave UV	Slight green colour change		Pemberton & Kowalski pers. comm. 6 September 2016
Dayflower	Long-wave UV	Fluoresces warm, light to medium grey or blue-grey	Can be difficult to differentiate from Indigo.	Fiske & Stiber Morenus 2004, p.31
Egyptian blue	Not specified	Fluoresces purple		Stuart 2007, p.77
Indigo	Not specified	Fluoresces dark purple		Stuart 2007, p.77
	Long-wave UV	Fluoresces light to medium blue-grey	Can be difficult to differentiate from Dayflower.	Fiske & Stiber Morenus 2004, p.31
Phthalocyanine blue	Not specified	No fluorescence		Stuart 2007, p.77

Prussian blue	Not specified	No fluorescence		Stuart 2007, p.77
	Long-wave UV	Fluoresces dark to medium blue	Brighter blue than dayflower and indigo.	Fiske & Stiber Morenus 2004, p.31
Smalt	Not specified	Fluoresces light purple		Stuart 2007, p.77
Ultramarine blue, pure	Not specified	Dark blue-violet		Eastman Kodak Company 1987
Ultramarine blue, deep	Short-wave UV	Slight green colour change	Oil binder	Pemberton & Kowalski pers. comm. 6 September 2016
Victoria Blue	Not specified	Fluoresces dark blue-violet	Substitute for pure ultramarine.	Eastman Kodak Company 1987
Purple				
Cobalt violet	Short-wave UV	Fluoresces dull pale purple	Oil binder	Pemberton & Kowalski pers. comm. 6 September 2016
	Long-wave UV	Fluoresces pale purple	Oil binder	Pemberton & Kowalski pers. comm. 6 September 2016
Brown				
Bistre ink	Not specified	Ink lines can fluoresce	Fluorescence more likely in un-aged inks.	Baker 1983, p.161
Iron gall ink	Not specified	Absorbs UV light with no fluorescence		Stuart 2007, p.77
	Long-wave UV	Appears black		Jirat-Wasiutynski 1986, p.23; Pemberton & Kowalski pers. comm. 6 September 2016
	Not specified	Fluorescent halo around aged ink lines recto and verso	No fluorescence seen in un-aged sample or light-aged sample. Ink lines themselves don't fluoresce.	Baker 1983, p.161
Black				
Carbon	Not specified	Absorbs, appears black	A Chinese ink stick (also carbon-based) was found to fluoresce under ultraviolet in an oven-aged sample.	Baker 1983, p.161;
Lamp Black	Short-wave UV	Bright green colour change	Oil binder	Pemberton & Kowalski pers. comm. 6 September 2016
	Long-wave UV	Green colour change	Oil binder	Pemberton & Kowalski pers. comm. 6 September 2016
White				
Calcium Carbonate/Chalk	Long-wave UV	Fluoresces medium purple		Jirat-Wasiutynski 1986, p.23
	Not specified	Fluoresces dark yellow		Stuart 2007, p.77
Chalk, ground	Not specified	Fluoresces red to brown		Eastman Kodak Company 1987
Chalk, precipitated	Not specified	Fluoresces black		Eastman Kodak Company 1987
Chalk, natural	Not specified	Fluoresces dark yellow		Eastman Kodak Company 1987
Chalk, siliceous	Not specified	Fluoresces red-violet		Eastman Kodak Company 1987
Gypsum	Not specified	Fluoresces violet		Stuart 2007, p.77
Lead white	Short-wave UV	Dull, pale orange colour change	Binder type not identified in sample tested	Pemberton & Kowalski pers. comm. 6 September 2016

	Long-wave UV	Fluoresces reddish-purple		Jirat-Wasiutynski 1986, p.23
		Fluoresces bright pale orange	Binder type not identified in sample tested	Pemberton & Kowalski pers. comm. 6 September 2016
	Not specified	Fluoresces brown-pink		Stuart 2007, p.77
Leaded zinc white	Long-wave UV	Fluoresces deep yellow orange with slight greenish tint		Jirat-Wasiutynski 1986, p.23
Lithopone	Not specified	Fluoresces orange-yellow		Stuart 2007, p.77
Titanium dioxide	Short-wave UV	Purple/grey colour change	Windsor & Newton Watercolour	Pemberton & Kowalski pers. comm. 6 September 2016
	Short-wave UV	Intense purple colour change	Liquitex Acrylic	Pemberton & Kowalski pers. comm. 6 September 2016
	Long-wave UV	Fluoresces deep purple		Jirat-Wasiutynski 1986, p.23
	Long-wave UV	Purple colour change	Windsor & Newton Watercolour and Liquitex Acrylic	Pemberton & Kowalski pers. comm. 6 September 2016
	Not specified	Mixtures with zinc oxide fluoresce green-yellow		Museum of Fine of Boston n.d.
Titanium (unbleached)	Short-wave UV	Deep purple colour change	Liquitex Acrylic	Pemberton & Kowalski pers. comm. 6 September 2016
	Long-wave UV	Deep purple colour change	Liquitex Acrylic	Pemberton & Kowalski pers. comm. 6 September 2016
Zinc white	Short-wave UV	Fluoresces dull creamy yellow	Oil binder	Pemberton & Kowalski pers. comm. 6 September 2016
	Long-wave UV	Fluoresces bright creamy yellow	Oil binder	Pemberton & Kowalski pers. comm. 6 September 2016
		Fluoresces yellow green		Jirat-Wasiutynski 1986, p.23
	Not specified	Fluoresces yellow		Museum of Fine of Boston n.d.

PAPER, PARCHMENT & PHOTOS	**UV Lamp**	**Results**	**Notes**	**Reference/Source**
Bio deterioration of paper	Not specified	Fluoresces Grey	Used to observe damage to paper caused by bacteria or fungi that may not visible to the naked eye.	Stuart 2007, p.77
Foxing	Not specified	Fluoresces (colour not specified)	UV fluorescence is detected in the early stage of foxing.	Choi 2007, p.142
Optical Brighteners (OB) in photographs	Long-wave UV	Fluoresces bluish white.	OB's may be washed out in water. Used in raw paper stock, emulsions, baryta, processing chemicals & surface coatings from the 1950's. A bright appearance can also be attributed to other factors incl. gelatin (which has a natural fluorescence) and baryta coatings.	Messier et al. 2005, p.2
Optical Brighteners		Fluoresces bright white	Common use in paper from	Mustalish 2000, p.133;

in Paper			1945.	Leclerc & Flieder 1992, p.257.
Paper	Long-wave UV	Fluoresces (colour not specified)	Fluorescence of old paper changes dramatically upon washing	Jirat-Wasiutynski 1986, p.24; Cohn 1982
Parchment	Not specified	May fluoresce bright yellow or purple or no fluorescence depending on state of degradation	If parchment is water damaged or degraded it will not fluoresce.	Melzer, Pers. Comm. 15th April 2016.
Bleach				
Sodium borohydride	Long-wave UV	Fluoresces bright white		Jirat-Wasiutynski 1986, p.24.

NATURAL HISTORY	UV Lamp	Results	Notes	Reference/Source
Bird Pigments		UV fluorescence is a stable attribute of some feather pigments, and a light-sensitive attribute in others.	Feathers whose pigments are not directly fluorescent may still undergo appearance changes under an UV light source as a consequence of light aging. Fluorescence is demonstrated to be an early marker of chemical change, and can be used to detect such change before it is day-light visible or can be measured.	Pearlstein et al, 2014
Porphyrins (brown)	Long-wave UV	Fluoresces purple/magenta.	Light sensitive & often not detectable in museum specimens due to light damage.	Hill 2010
Psittacofulvins (red & yellow)	Long-wave UV	Fluoresces yellow, orange or green.	Unique to Psittaciformes. May be combined with blue structural colouration to produce secondary colours.	Lagorio et al. 2015; Hill 2010
Spheniscin (yellow)	Long-wave UV	Fluoresces blue	Unique to Sphenisciformes.	Lagorio et al 2015
Invertebrate Colouration			Ethanol in which UVF specimens are stored may gradually become fluorescent itself	Welsh et al 2012
Beta-carboline	Long-wave UV	Fluoresce blue-green	Scorpions & Spiders, including fossilised specimens	Lagorio et al. 2015
Green Fluorescent Protein (GFP)	Long-wave UV	Fluoresces green	Marine Invertebrates especially *Aequorea Victoria* (Crystal Jelly),Corals.	Gaffin et al. 2014; The Smithsonian Walter Reed Biosystematics Unit n.d.; Lagorio et al. 2015
Guanine	Long-wave UV	Fluoresces Red, Orange or Green	Fish	Lagorio et al. 2015
Pterins	Long-wave UV	Fluoresces blue	Moths and Butterflies, fly and beetle larvae, millipedes.	Lagorio et al. 2015; Welsh et al 2012.
Schiff Bases	Long-wave UV	Fluoresces blue	Bees	Lagorio et al. 2015
Mineral Specimens	All ranges	Many colours	UVF is too inconsistent to be a helpful identification tool. Gemstones which fluoresce: ruby, kunzite, diamond and opal.	Wilkins 1999; King 2015; Henkel 1988.

PESTS & PESTICIDES	UV Lamp	Results	Notes	Reference/Source
Mercuric Chloride (corrosive sublimate) -pesticide	Long-wave UV	Fluoresces cream, yellow, peach, orange or red.	Mercuric chloride Hg (II) breaks down over time to mercurous chloride Hg (I). Hg (I) is often a fluorescent under UV light.	Purewal & Colston 2014.
Mould			UV fluorescence gradually increases and decreases depending on life cycle of fungi.	Florian 1997
Urine		Cat urine fluoresces orange with a bright yellow halo.		Pemberton Pers. Comm. 15th April 2016

References:

1. Baker, CA 1983, 'A comparison of drawing inks using ultraviolet and infrared light examination techniques', *Application of science in examination of works of art: proceedings of the seminar, September 7-9*, Boston, pp.159-163.
2. Chapman, J 2000, *Glebe Stamps*, viewed 15 April 2016, <http://www.glebecoins.net/kgv/The_KGV_1d_Red/the_kgv_1d_red.htm>.
3. Choi, S 2007, 'Foxing on paper: A literature review', in *Journal of the American Institute of Conservation,* vol. 46 (2), pp. 137-152.
4. Collins S, Davidson S, Greaves PH, Healy, M, and Lewis, DM 1988, 'The natural fluorescence of wool', *Journal of the Society of Dye Chemists*, vol. 104, pp. 348-352.
5. Eastman Kodak Company 1987, *Ultraviolet and Fluorescence Photography*, Publication No. M-27, Eastman Kodak Ltd, Rochester, New York.
6. Feller, R (ed.) 1986, *Artist's Pigments: A Handbook of Their History and Characteristics*, Volume 1, National Gallery of Art, Washington.
7. Fiske, B and Stiber Morenus, L 2004, 'Ultraviolet and Infrared Examination of Japanese Woodblock Prints: Identifying Reds and Blues', *The Book and Paper Group Annual*, 23, pp.21-32.
8. Fitzhugh, E (ed.) 1997, *Artists Pigments: A Handbook of Their History and Characteristics*, vol. 3, National Gallery of Art, Washington.
9. Gaffin, DD, Bumm, LA, Taylor, MS, Popokina, NV and Mann, S 2012, 'Scorpion fluorescence and reaction to light,' *Animal Behaviour*, vol. 83, pp. 429-436.
10. Gettens, R and Stout, G 2007, *Painting Materials: A Short Encyclopaedia*, Dover Publications, New York.
11. Henkel, G 1988, 'The Henkel Glossary of Fluorescent Minerals', *Journal of the Fluorescent Mineral Society*, vol. 15.
12. Hill, G 2010, *Bird Colouration,* National Geographic, Washington D.C.
13. Hours, M 1976, *Conservation and Scientific Analysis of Painting*, Van Nostrand Reinhold Company, New York.
14. Jirat-Wasiutynski, T (ed.) 1986, 'Visual Examination', *Paper Conservation Catalogue*, Book and Paper Group of the AIC, Washington.
15. King, H 2015, *Fluorescent minerals*, viewed 21 December 15, <http://geology.com/articles/fluorescent-minerals/>.
16. Lagorio, GM, Cordon, GB and Iriel, A 2015, 'Reviewing the relevance of fluorescence in Biological systems', *Photochemical and Photobiological Sciences,* vol.14, pp. 1538-1559.
17. Leclerc, F and Flieder, F 1992, 'Influence of optical brighteners on paper permanence', *Manchester Conference Papers*, The Institute of Paper Conservation, UK.

18. Messier, P, Baas, V, Tafilowski, D, Varga, L 2005, 'Optical brightening agents in photographic paper', *Journal of the American Institute of Conservation*, vol. 44 (1), pp. 1-12.
19. Museum of Fine Arts, Boston, *Cameo Materials Database*, viewed 5 January 2016, <http://cameo.mfa.org/wiki/Madder>.
20. Mustalish, R A 2000, 'Optical brighteners: history and technology', *Tradition and Innovation, Advances in Conservation*, IIC Melbourne Congress, pp. 133-136.
21. Newton, R and Davison, S 1989, *Conservation of Glass*, Butterworth-Heinemann Ltd, Oxford, p. 192.
22. Pearlstein, E, Hughes, M, Mazurek, J, McGraw, K, Pesme, C, Garcia-Garibay, M 2014, 'Correlations between photochemical damage and UV fluorescence of feathers', *Preprints of ICOM-CC 17th Triennial Conference,* Melbourne.
23. Purewal, VJ and Colston BJ 2014, 'Novel detection and removal of hazardous biocide residues historically applied to Herbaria', Poster presented at Society for the Preservation of Natural History Collections Annual meeting, National Museum of Wales, Cardiff.

24. Rivers, S and Umney, N 2013, *Conservation of Furniture*, Routledge, New York, pp. 388 and 610.
25. Simmons, J 1995, 'Storage of Fluid Preserved Collections', in Rose, CL, Hawks, C and Genoways, HH (eds.) *Storage of Natural History collection: A Preventive Conservation Approach,* SPNCH, New York.
26. Simpson-Grant, M. 2000a, 'The Use of Ultraviolet Induced Visible-Fluorescence in the Examination of Museum Objects, Part I',*Conserve-O-Gram* 1/09, viewed 15 April 16, < https://www.nps.gov/museum/publications/conserveogram/01-09.pdf>.
27. Simpson-Grant, M. 2000b, 'The Use of Ultraviolet Induced Visible-Fluorescence in the Examination of Museum Objects, Part 2',*Conserve-O-Gram* 1/10, viewed 15 April 16, <https://www.nps.gov/museum/publications/conserveogram/01-10.pdf>.
28. The Smithsonian Walter Reed Biosystematics Unit, n.d., *Fluorescence in Scorpions,* accessed 21 December 15, <http://www.wrbu.org/scorpions/sc_uv.html>.
29. Stuart, B 2007, *Analytical Techniques in Materials Conservation*, Wiley, Chichester.
30. Welsh, VL, Van Hooijdonk, E, Intrater, N, and Vigneron, J 2012, 'Fluorescence in insects', *Proc. SPIE, Nat. Light: Light in Nat, IV.*
31. Wilkins, A 1999, 'Ultra violet light and its use with Fluorescent minerals', *The Fluorescent mineral society,* viewed 21 December 15, <https://www.uvsystems.com/articles/uvlightandfluorescentminerals.pdf>.
32. Wilson, L 2014, *To see the world in a grain of sand: a closer look at the 'Melbourne Blakes',* viewed 19 January 16 <www.ngv.vic.gov.au/.../to-see-a-world-in-a-grain-of-sand-a-closer-look->.
33. World Health Organisation 2016, 'Ultraviolet radiation', viewed 2 December 16, <http://www.who.int/uv/en/>.
34. Zieske, F 2002, 'Paul Cezanne's Watercolours: His Choice of Pigments and Papers', *The Broad Spectrum*, Archetype Publications, London.

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