Teacher and Technician Sheet

In this practical students will:

- Create egg tempera paints and oil paints from different types of minerals.
- Evaluate the different paints, looking at various aspects, including:
  - what colours different minerals make;
  - how easy the different types of paint are to use;
  - and which paints give the highest quality finish on different surfaces.

Introduction:

(The topic could start with a group discussion during which teachers introduce the following ideas, especially the words in bold.)

The science of paint was once the domain of artists who developed and made their own paints, but as time went on it became a manufacturing industry with clear criteria for each paint type. It did not become chemistry until the 19^{th} century. Before 1800 artists used natural **minerals** as **pigments** and **lake pigments** from natural dyes and some manufactured minerals.

Yet each era in art history has had its own science story. One thing that is clear the practice of making paint is very old and still works to the same principles. One book, *Il Libro dell' Arte*, set out the principles of paint and paint materials making. It was written in the 15^{th} century by the artist Cennino d'Andrea Cennini and continued in use for many years.

From the **Palaeolithic** Period to **Early Romantic Art** many of the paints were made using the same materials in the same way using natural **minerals** as **pigments** such as:

- Green = **malachite** (basic copper(II) carbonate $CuCO_3.Cu(OH)_2$), a mineral found in many parts of the world where copper veins have been altered by **weathering** and contact with rain. It was used for eye-paint in Predynastic Egypt and as paint on tombs.
- Red-brown = **haematite** (iron(III) oxide Fe_2O_3), a mineral found in many parts of the world. Ochre is clay that is coloured by varying amounts of haematite, from 20% to 70%. Red ochre contains unhydrated haematite; yellow ochre contains hydrated hematite (Fe_2O_3 H_2O). The principal use of ochre is for tinting with a permanent colour and has been used from Palaeolithic times.
- Black = **charcoal** (carbon C), an element obtained when organic materials are burnt;
- White = **calcite, limestone, chalk and marble,** (calcium(II) carbonate $CaCO_3$). Calcite is a mineral that makes up limestone and chalk. Limestone and chalk are **sedimentary** rocks found in many parts of the world. Chalk is a fine grained form of limestone. Marble is a **metamorphic** rock formed from limestone that has been in contact with an **igneous** intrusion. This heat changes the **crystalline** structure to form large crystal grains making it very hard. All forms are found in painting as

white pigments and for other purposes. Calcite was used as a white pigment. Chalk was used with animal glue to form a ground coat (white surface for painting on) and as an **extender**. Marble was ground up and used in fresco painting. Marble is also a popular material for sculptures.

Each **pigment** is mixed with a **binder** such as egg yolk or oil and an **extender** such as water or alcohol.

(This practical is best done with groups of four pupils each pupil could chose a single mineral and make both **tempera paint** and an **oil paint** for testing. Groups allow for good discussion between the pupils. Teachers can use the questions set as the stimulus for discussion and the answers can be used as a group report, article, presentation, poster or talk.)

Curriculum range:

It links with:

- asking questions and developing a line of enquiry based on observations of the real world, alongside prior knowledge and experience;
- using appropriate techniques, apparatus, and materials during fieldwork and laboratory work, paying attention to health and safety;
- making and recording observations and measurements using a range of methods for different investigations; and evaluating the reliability of methods and suggesting possible improvements;
- presenting observations and data using appropriate methods, including tables and graphs;
- interpreting observations and data, including identifying patterns and using observations, measurements and data to draw conclusions;
- presenting reasoned explanations, including explaining data in relation to predictions and hypotheses;
- the concept of a pure substance; and
- mixtures, including dissolving.

Hazard warnings:

Any of the powders can be an irritant if the fine dust is breathed into the lungs. The paint should not be put on the skin.

If the students are grinding the paint from large coarse lumps of mineral (this would only be appropriate with English KS4 students) then the students should cover the mortar with a large plastic bag and grind very gently until a fine powder. For English KS3 ensure the pigments are already finely ground and students can start at step 3.

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Alcohol is flammable (highly flammable and harmful) so ensure there are no naked flames in the laboratory and no other sources of ignition close to the ethanol.

Wear gloves when handling raw eggs. Wash hands and disinfect the work area thoroughly afterwards.

During the paint preparation it would also be advisable for the students to wear plastic gloves and safety glasses.

Linseed oil left on rags or paper towels has been known to ignite spontaneously. If oil is mopped up after a spillage, dampen the rags/paper towels before bagging them for disposal.

Ethanol (IDA) – Flammable liquid (Cat 2), Acute toxin (Cat 4 oral) specific target organ toxin on single exposure Cat 2

Copper(II) carbonate – Toxic (Cat 3 oral) and Irritant (Cat 2 skin, eye and respiratory)

Basic copper(II) carbonate – Acute toxin (Cat 4 oral) and Irritant (Cat 2 skin, eye and respiratory)

Calcium carbonate – Low hazard

Iron(III) oxide – Low hazard

Carbon powder – Eye irritant (Cat 2) Respiratory irritant (STOT SE3)

Equipment:

For each group of students:

- Newspaper to cover the surface of the bench
- 1 mortar and pestle (if using lumps of minerals)
- 1 large plastic bag to cover the mortar and large enough to allow easy movement inside (if using lumps of minerals)
- 1 spatula
- 1 egg
- 1 egg yolk separator (if available)
- 1 beakers (250 cm^3)
- Measuring cylinder; 10 cm^3
- 100 g of each of the following minerals: malachite, haematite, carbon or calcium carbonate in labelled screw top bottles or containers
- 50 cm^3 of each binder: linseed oil, and egg yolk (vegetable oil and craft glue could be used as substitutes for these)
- 50 cm^3 of each extender: ethanol (labelled inflammable) and distilled water, in a small labelled bottle
- 2 Petri dishes or plastic cups
- 2 eye droppers or plastic pipettes
- 2 fine paint brushes

- Square of MDF measuring 12 cm by 12 cm and 0.4 cm or white tile
- 1 sheet of thick white paper
- 1 small prepared canvas 5 cm by 5 m (or substitute)

Protective gloves, safety glasses and an apron

Access to:

Copper(II) carbonate

Calcium carbonate

Iron(III) oxide

Carbon powder

Disposable plastic cups

Washing up liquid

Paper towelling

Disposable apron

Disposable gloves

Newspapers to cover the work area

Technical notes:

Using three spatulas of each chemical is an appropriate amount to start with as each of the chemicals are of different weights. For example, three spatulas of iron(III) will weigh approximately 9 g; carbon powder 6 g; calcium carbonate 11 g and copper(II) carbonate 32 g.

The small pieces of canvas can be bought from a local art shop (£5 for three, if on sale!).

Using a piece of white cotton stretched (for example, over the base of an empty ice cream tub) and held tight with a rubber band can make a surface to paint on for comparison with canvas although it is more porous than prepared canvas.

MDF can be sourced from local DIY shops or stores.

MDF can be replaced by a white tile or any other item with a similar surface.

If necessary linseed oil could be substituted by any cooking oil and craft glue could be used instead of egg yolk and still yield good results for this practical.

Provide some washing up liquid to add to water in the glass beaker to assist with rinsing the brushes between using the different paints.

This is a messy practical so as well as providing the plastic disposable gloves and aprons it may be better to use plastic disposable cups that can simply be thrown away afterwards.

Results:

If lumps of minerals are to be used it would probably be best done as a teacher demonstration to minimise the risk of dust particles being breathed in.

This practical could be carried out with groups selecting one pigment powder each to use and sharing results instead.

The replacement of linseed oil and egg yolk by vegetable oil and craft glue works well.

The difference between them is that when using egg yolk as the binder with the calcium carbonate (white) it produces a yellowish- cream white instead of the white produced with the glue binder.

The vegetable oil is good while using it in the practical but it does not dry and hold the pigment in the same way as linseed oil, so the oil paint using vegetable oil was still wet after the linseed oil paint had dried.

The different pigments mix slightly differently with the binders, with calcium carbonate the easiest and carbon the least easy to mix, also with some needing more extender than others. This difference may be caused by the ability to grind some pigments (chemicals) into a smoother powder than others. Even the chemicals supplied in powder form can be seen to have a different fineness of powder from each other.

All the pigments used were easy to apply on paper, canvas and MDF. It was slightly less easy to apply to the substituted cotton for canvas but is still a reasonable comparison.

The oil also spread a bit more on the cotton carrying more of the iron(III) oxide pigment with it in comparison to the prepared canvas.

With each of the pigments used on each of the surfaces the tempera paints applied well and dried easily. The oil paints applied well and stayed wet to varying degrees depending on the surface it was applied to. The difference in opacity is also observable.

The calcium carbonate and copper(II) carbonate were the two pigments that may rub off more easily or were more powdery to the touch when dried. Carbon and iron(III) oxide were the most durable pigments.

Overall, the students would be able to achieve the learning objectives of this practical within the lesson time.

The hazards are minimal assuming the expected level of behaviour from students.

Example results sheet:

Criteria / Pigment	Paper	MDF	Canvas
Malachite + **Egg yolk** **(and water)**	Easy to apply Good colour and slight sheen Stays on paper well	Easy to apply with good colour Low sheen Slightly opaque Dries easily Can be scraped off easily when dried	Easy to apply Good colour No sheen Stays on well
or **Linseed oil**	Less easy to apply Good colour and is slightly opaque Oil is visible on the paper around the paint Dries slowly but once dried stays on paper well (can be rubbed off easily when still drying)	As above except high sheen did not dry and could be wiped away	As above except: high sheen
Haematite + **Egg yolk** **(and water)**	As above but also a more solid colour	As above	Easy to apply Very good colour Low sheen Stays on well
or **Linseed oil**	Easy to apply Good solid colour Only very slightly opaque Slow to dry but stays on paper well once dried	As above	As above except: Colour is more red-brown than seen in the other results High sheen

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Calcium carbonate **+** **Egg yolk** **(and water)**	Applies well and has the most noticeable colour differences. A creamy yellow white results from the egg yolk binder Less sheen apparent than the other colours Stays on paper well	As above	
or **Linseed oil**	Still powdery, will come off easily and visible oil around the paint	As above	
Carbon + **Egg yolk** **(and water)**	Applies well with good colour depth Slight sheen Slightly gritty	As above	As above
or **Linseed oil**	Slightly gritty, not as smooth as the others Oil visible around the paint Stays well once dried	As above	Easy to apply Good colour High sheen Stays on well