What Separates a Dye from a Pigment Is Whether It Is Dissolved, So Only a Pigment Has a Particle Size

— halving the size multiplies the particle count by **8.000000** and the total geometric cross-section by **2.000000**, and quartering it gives **4.000000** — the separator is whether the colourant is dissolved as molecules or dispersed as particles — [Paper 720]

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— From thinking to syncing. —

Abstract

Dyes and pigments both colour things. What separates them is not the kind of molecule but whether it is dissolved.That single fact is shown, in numbers, to give only one of them a particle size to design.No new theorem or law is claimed. First, a dye's effect is set by concentration and path length alone——doubling the concentration doubles the absorbance and squares the transmittance, taking 0.316228 to 0.100000 (Section 2). **Second, so a dye has no particle size——the molecules are dissolved, so there is no size to choose in the first place** (Section 2). **Third, and this is the core. A pigment blocks more area at the same mass if divided finer——halving the size multiplies the count by 8.000000 and the total geometric cross-section by 2.000000** (Section 3). **Fourth, the factor goes as the reciprocal of the size——quartering it gives 4.000000, with no mass added at all** (Section 3). **Fifth, so a pigment has one more degree of freedom——where a dye has only concentration and path length, a pigment also has particle size** (Section 3). **Sixth, the separator is dissolved against dispersed——with the same chemical structure, dissolved it behaves as a dye and as particles it behaves as a pigment** (Section 4). **Keywords**: dye, pigment, dissolved and dispersed, particle size, geometric cross-section, number of design quantities.

Scope of this paper (scope note): **No new theorem or law is claimed——that the dye-pigment distinction rests on solubility, the Beer-Lambert law, and the dependence of hiding power on particle size are all standard (Bouguer 1729, Hunt and Pointer 2011).Scattering theory is not derived——Mie scattering is not entered; the account stops at the geometric cross-section, which is not the scattering cross-section itself, and in practice an optimal particle size exists.No real material is claimed——spectral properties, fastness and lightfastness of dyes and pigments are not treated.Dispersion stability is not treated——dispersants, agglomeration and settling are not treated; that finer particles agglomerate more readily is only mentioned.No precision is claimed for representative values——the particle density of 4000 kg/m³ and the absorption coefficient are order-of-magnitude values.Relation to earlier papers**: **Paper 442 showed that white is made by a difference in refractive index, not by a colour——there the subject was the cause of scattering by particles. Here we stand on the same particle side and show that being a particle at all is what separates it from a dye. The cause of scattering, and the consequence of being a particle.**What is added is **confirming the dye's exponential law as the agreement of two formulas**, **showing the count to rise by 8.000000 on halving**, **showing the total cross-section to rise by 2.000000**, **showing the reciprocal dependence as 4.000000 on quartering**, and **placing the separator on dissolved against dispersed**.

1. Notation and the Question

Setting: **a dye dissolves and acts as molecules; a pigment is dispersed and acts as particles.**

$$T = 10^{-\varepsilon c \ell}, \qquad N = \frac{m}{\rho \frac{\pi}{6} d^3}, \qquad S = N \cdot \frac{\pi}{4} d^2$$

T is the dye's transmittance, N the number of particles when a mass m is divided into spheres of diameter d, and S the total geometric cross-section.

Question: **what is it that separates a dye from a pigment?**

2. On the Dye's Side There Is No Particle Size

Computation 2.1: **with the absorption coefficient and path length fixed, the concentration was varied.**

concentration	absorbance	transmittance
1	0.500000	0.316228
2	1.000000	0.100000
3	1.500000	0.031623

Observation 2.2

doubling the concentration squares the transmittance.The square of 0.316228 and the value at concentration 2, namely 0.100000, agree to within 10^{-12}——derived from two formulas, this confirms the exponential law holds.

Observation 2.3

there are only two quantities to move.Concentration and path length——the molecules are dissolved, so there is no size to choose and no particle size is even defined.

3. On the Pigment's Side, Dividing Finer Adds Area

Computation 3.1: **with a mass of 1 g and a particle density of 4000 kg/m³, the particle size was varied.**

size	particle count	total geometric cross-section
1.00 μm	4.774648×10^{11}	0.375000 m²
0.50 μm	3.819719×10^{12}	0.750000 m²
0.25 μm	3.055775×10^{13}	1.500000 m²

Observation 3.2

this is the core: the blocked area grows with no mass added.Halving the size multiplies the count by 8.000000 and the total cross-section by 2.000000——the volume is one eighth so the count is eight times, while each cross-section is a quarter, leaving a factor of two.

Observation 3.3

so the effect goes as the reciprocal of the size.Quartering it gives 4.000000——the same quantity of pigment hides more when dispersed finer.

Observation 3.4

but finer is not indefinitely better.The geometric cross-section is not the scattering cross-section, and once a particle is smaller than the wavelength the scattering itself weakens——in practice an optimal size exists, and this paper points to its existence without finding it.

Observation 3.5

one more degree of freedom.A dye has two, concentration and path length; a pigment adds particle size——under the one word “colourant”, the number of knobs differs.

4. The Separator

Observation 4.1

the separator is dissolved against dispersed.With the same chemical structure, dissolved it behaves as a dye and as particles as a pigment——what separates them is not the kind of molecule but the state in which that molecule is present.

Observation 4.2

beside Paper 442.Paper 442 showed that white is made by a difference in refractive index, not by a colour——there the cause of scattering was the subject. Here we stand on the same particle side and count the consequence of being a particle. Cause and consequence.

Observation 4.3

what is not said.Scattering theory, real material properties and dispersion stability are not treated, and the account stops at the geometric cross-section——what is shown is that solubility settles how many design quantities there are.

5. Roll Call and Closing

1. **0.316228 at concentration 1** (Computation 2.1): **the dye side.**
2. **0.100000 at concentration 2** (Computation 2.1): **it squares.**
3. **0.031623 at concentration 3** (Computation 2.1): **the exponential law.**
4. **4.774648×10^{11} at 1 µm** (Computation 3.1): **the pigment side.**
5. **3.819719×10^{12} at 0.5 µm** (Computation 3.1): **the count grows.**
6. **cross-section 0.375000 m²** (Computation 3.1): **at 1 µm.**
7. **0.750000 m² when halved** (Computation 3.1): **the core.**
8. **count 8.000000 times** (Observation 3.2): **volume one eighth.**
9. **cross-section 2.000000 times** (Observation 3.2): **what is left over.**
10. **dissolved or dispersed** (Observation 4.1): **the separator; Paper 442.**

Closing: **What separates a dye from a pigment is not chemistry but whether it is dissolved, which is why only one of them has a particle size to design.A dye dissolves as molecules, so its effect is set by concentration and path length alone: doubling the concentration doubles the absorbance and squares the transmittance, taking 0.316228 to 0.100000——there are only two quantities to move, and since the molecules are dissolved no particle size is even defined.On the pigment's side, dividing 1 g into spheres of 1 µm gives 4.774648×10^{11} particles with a total cross-section of 0.375000 m², and halving the size multiplies the count by 8.000000 and the cross-section by 2.000000 to 0.750000 m²——the volume is one eighth so the count is eight times, while each cross-section is a quarter, leaving a factor of two.So the effect goes as the reciprocal of the size, quartering it giving 4.000000, with no mass added at all.Finer is not indefinitely better, though: the geometric cross-section is not the scattering cross-section, and once a particle is smaller than the wavelength the scattering weakens, so an optimal size exists——this paper points to its existence without finding it.The separator is dissolved against dispersed——with the same chemical structure, dissolved it behaves as a dye and as particles as a pigment.Placed among the earlier papers——Paper 442 treated the cause of scattering by particles; here the consequence of being a particle is counted.To be honest——scattering theory, real materials and dispersion stability are not treated, and the particle density is held fixed as representative.**

References

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