



NSTA Web Seminar:
Teach Science Concepts and Inquiry
with Food:
The Chemistry of Color Additives

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The Chemistry of Color Additives

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Modules

- Basic concepts of color
- History of color additives
- Definition of color additives
 - Properties of color additives
- Certified color additives
 - Structures
 - Uses
 - Specifications
- Certification-exempt color additives
 - Structures
 - Uses

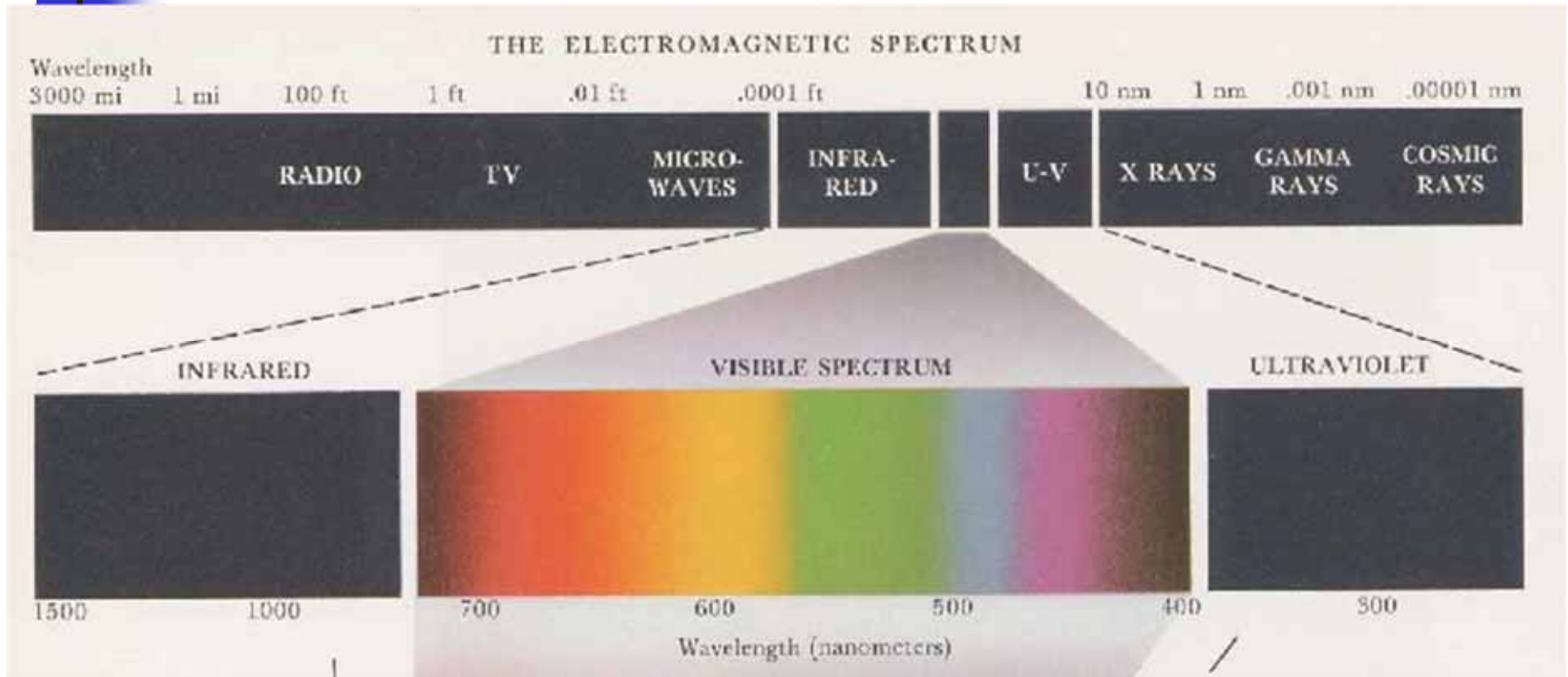


Module 1

Basic Concepts of Color



Electromagnetic spectrum





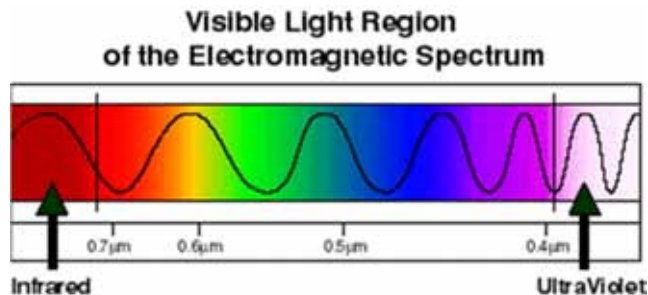
Basic concepts of color

- Interaction of visible light with a compound
 - Wavelengths of light
 - Types of atoms in the compound
- Dye molecules contain electrons at many energy levels
 - Some of the electrons can absorb visible light
 - These electrons undergo transitions from lower to higher energy levels
- Absorption removes some visible light
 - We see the complementary color

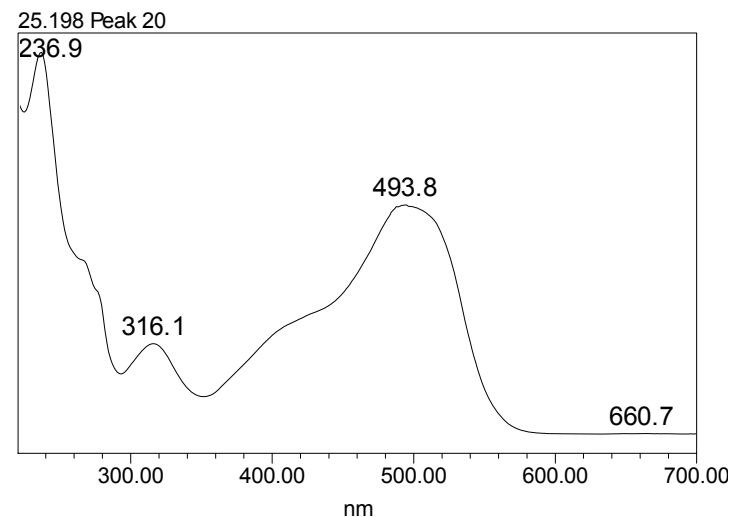


Production of complementary colors

Absorption bands



- 400-430 nm (violet) see yellow
- 430-480 nm (blue) see orange
- 480-550 nm (green) see red
- 550-600 nm (yellow) see violet
- 600-700 nm (red) see blue



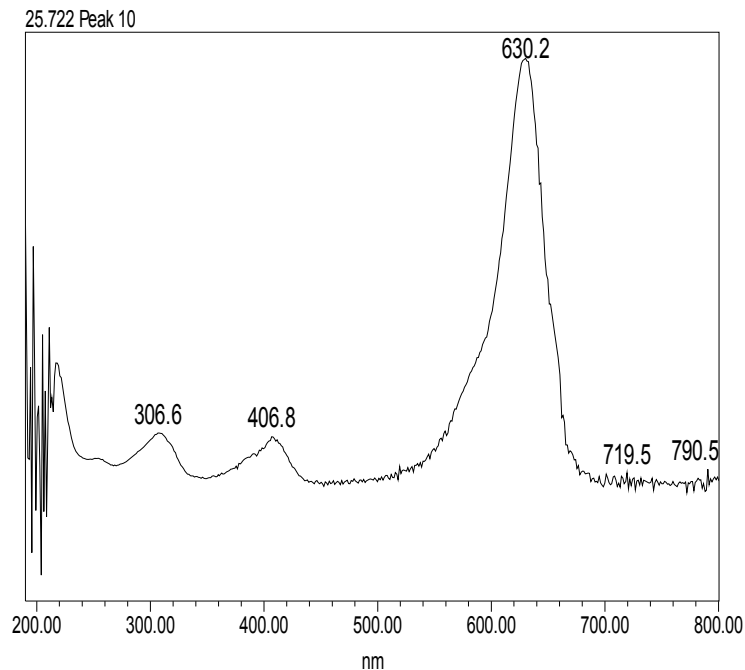
D&C Red No. 6



What color would you see?

Absorption bands

- | | |
|-----------------------|------------|
| • 400-430 nm (violet) | see yellow |
| • 430-480 nm (blue) | see orange |
| • 480-550 nm (green) | see red |
| • 550-600 nm (yellow) | see violet |
| • 600-700 nm (red) | see blue |



Multiple Choice

- A. Red
- B. Yellow
- C. Blue



*What color would you
see?*



Multiple Choice

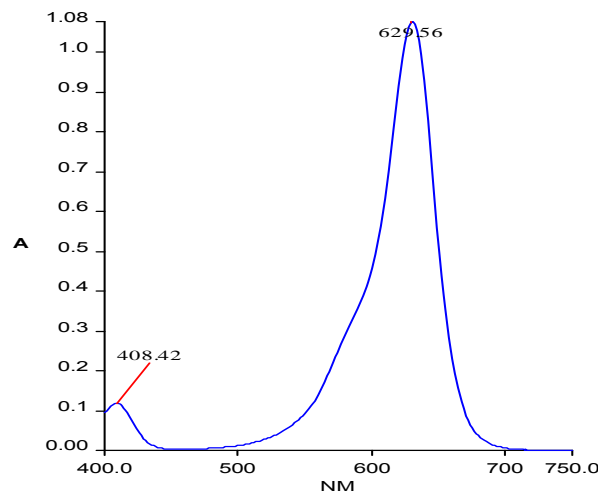
- A. Red
- B. Yellow
- C. Blue



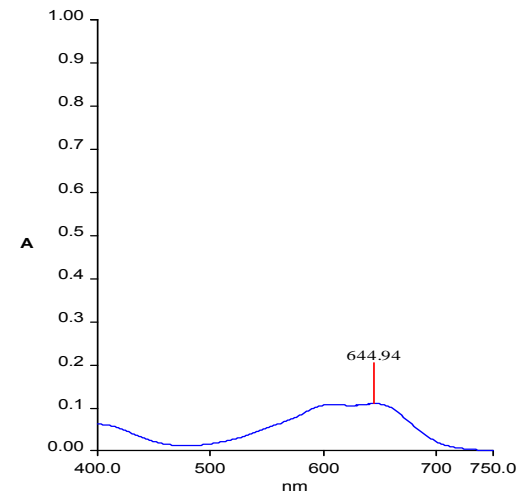
Absorptivity value



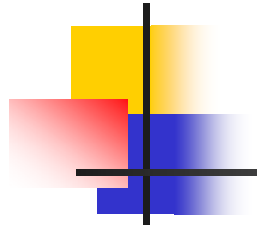
- Measure of dye's ability to absorb light
- High absorptivity value: more efficient, more economical
 - Dye absorbs a large amount of energy so you only need a small amount in the product
- Low absorptivity value: not as efficient, less economical
 - Dye absorbs less energy so more is needed in the product



FD&C Blue No. 1, $\alpha = 0.16$



D&C Green No. 5, $\alpha = 0.02$



Let's pause for two questions...



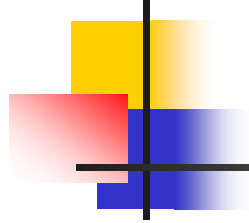


Module 2

History of color additives



Why do we use food coloring?



Use your chat box to respond.





Purpose of food coloring



- Provides identity to foods
 - Red coloring of maraschino cherries (naturally beige)
 - Flavors of Lifesaver candies



- For effect
 - Children's cereals
 - Green ketchup
 - Cake decoration



- To mask natural variation in color
 - Citrus Red No. 2 in orange skins



- For enhancing naturally occurring colors
 - Astaxanthin in salmon feed



- To protect flavors and vitamins from damage or color loss
 - Light, air, moisture
 - Temperature extremes, other storage conditions



Early food and cosmetic uses

- Foods colored with spices and minerals
 - Paprika, turmeric, saffron, iron oxides
 - Wine artificially colored in 300 B.C.
- Cosmetics from vegetable and mineral sources
 - White lead
 - Kohl (contains lead or antimony)
 - Copper ore for eye shadow
 - Vegetable extracts for the skin



Early hair dyes

- Used by ancient Egyptians
- First hair dyes were from plants



Nutmalls from oak trees

- Pyrogallol, tannic acid
- Rastik

Lawsonia plant

- Henna

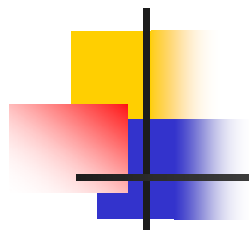
- Metallic dyes
 - Lead comb dipped in vinegar darkened hair
 - Copper salts made hair dark and brittle



Development of synthetic dyes

- Mauveine – first synthetic organic dye
 - 1856, William Henry Perkins
 - Accidental discovery, trying to synthesize quinine
 - Proved good for dyeing silk and other textiles
- Coal-tar dyes
 - By-products of coal processing
 - Made from petroleum or coal sources
- Today hundreds of synthetic dyes





Let's pause for two
questions...





Module 3

Definition of color additives



What is a color additive?

- Imparts color to a food, drug, cosmetic, or medical device
- Includes black, white, intermediate grays
- May form after reacting with skin (e.g., dihydroxyacetone)
- May have other functions in product (e.g., TiO_2 or ZnO in sunscreens)



What is a color additive, from a regulatory standpoint?

- Straight colors
 - 21 CFR Part 73 – exempt from certification
 - 21 CFR Part 74 – subject to certification
- Lakes
 - 21 CFR Part 82 – provisionally listed lakes, subject to certification
 - FD&C Red No. 40 lakes – listed in Part 74
 - Carmine – listed in Part 73



What is a straight color?

- 21 CFR Part 73-certification exempt
 - Synthetic organic dyes
 - Inorganic pigments
 - Plant (botanical) derivatives
 - Insect extract
- 21 CFR Part 74-certified color additives
 - Synthetic organic dyes (also called coal-tar dyes)
 - Carbon pigments



What is a lake?

- 21 CFR Parts 73, 74, and 82 all contain listed lakes
- A lake is a water-insoluble pigment composed of
 - a water-soluble straight color
 - an insoluble substratum
 - a cation precipitant



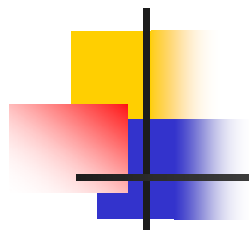
How many color additives are permitted in the U.S.?

20	64	109



Color additives permitted for use in various countries

<u>Country</u>	<u>No. of color additives permitted</u>
U.S. (straight colors)	64
Certified for food	9
Certified for drugs	36
Certified for cosmetics	35
Certified for medical devices	7
Certification-exempt for food	32
Certification-exempt for drugs	28
Certification-exempt for cosmetics	29
Certification-exempt for medical devices	21
E.U. (straight colors and lakes)	154
Japan (straight colors and lakes)	83



Let's pause for two
questions...





Module 4

Certified color additives

- Structures
- Uses
- Specifications



Properties of coal-tar dyes

- Conjugation from many double bonds
 - N=N (azo group)
 - C=O (carbonyl group)
 - C₆H₆ (phenyl group)
- Functional groups added for water solubility
 - SO₃⁻ (sulfonate group)
 - COO⁻ (carboxylate group)
- Water-soluble dyes
 - Na⁺ salts
- Insoluble pigments and lakes
 - Ca⁺² or Ba⁺² salts
 - Alumina or rosin substrata
- "Oil-soluble" dyes
 - Soluble in organic solvents



Types of certified coal-tar dyes

- Triphenylmethane
- Indigoid
- Fluoran
- Xanthene
- Anthraquinone
- Pyrene
- Monoazo
- Disazo
- Quinoline
- Carbon pigments



*What color do you think is
in blue Gatorade?*

Multiple Choice



- A. FD&C Blue No. 1
- B. FD&C Green No. 3
- C. D&C Blue No. 4



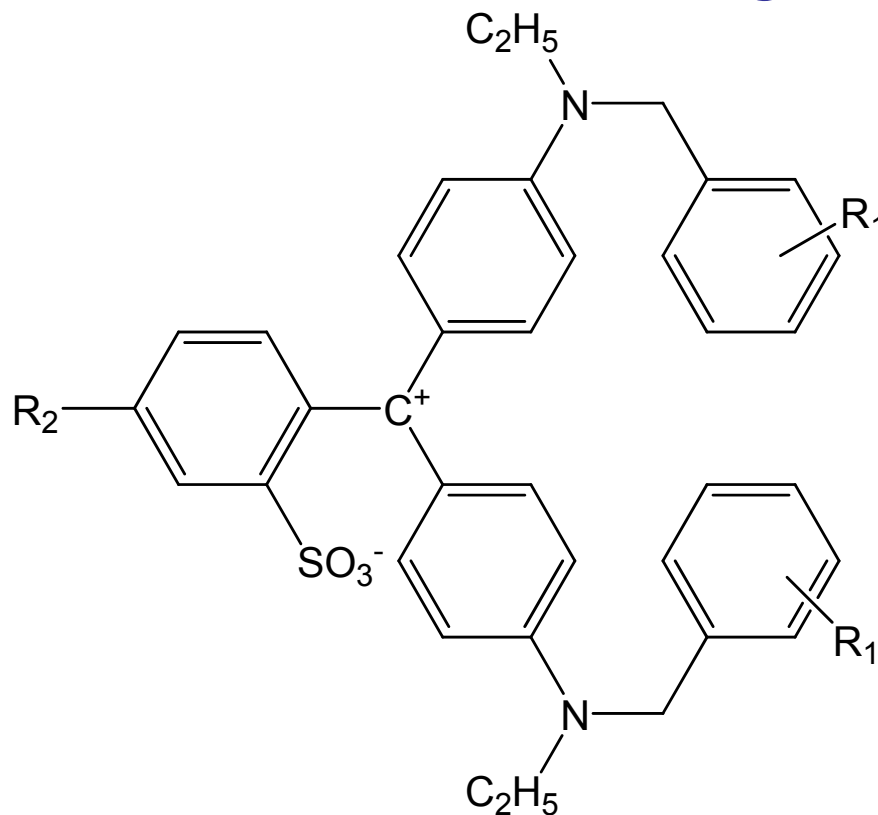
*What color do you think is
in blue Gatorade?*

Multiple Choice

- A. FD&C Blue No. 1
- B. FD&C Green No. 3
- C. D&C Blue No. 4



TRIPHENYLMETHANE DYES



Color Additive	R ₁	R ₂
FD&C Blue No. 1	SO ₃ Na	H
FD&C Green No. 3	SO ₃ Na	OH
D&C Blue No. 4	SO ₃ NH ₄	H



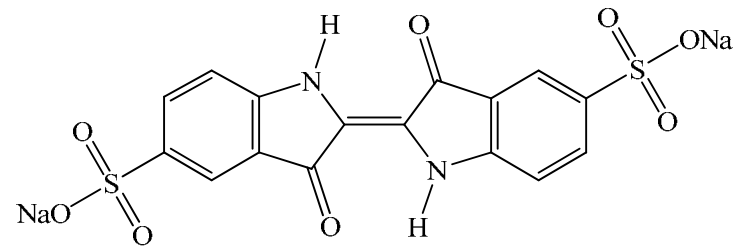


INDIGOID DYES

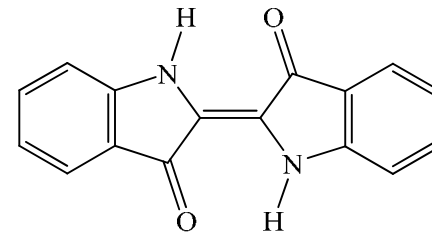


Color Additive

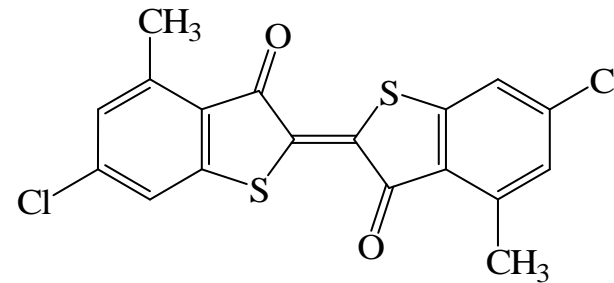
FD&C Blue No. 2



D&C Blue No. 6

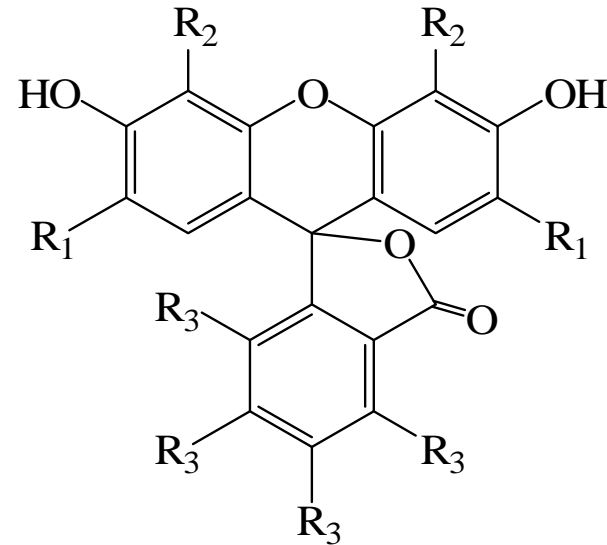


D&C Red No. 30





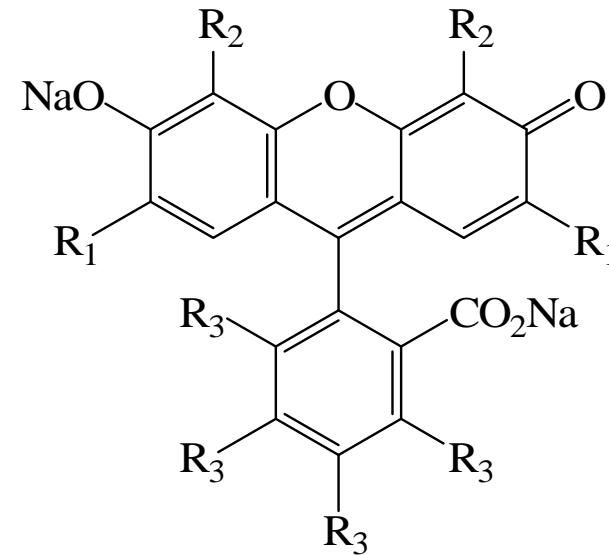
FLUORAN DYES



Color Additive	R ₁	R ₂	R ₃
D&C Orange No. 5	H	Br	H
D&C Orange No. 10	H	I	H
D&C Red No. 21	Br	Br	H
D&C Red No. 27	Br	Br	Cl
D&C Yellow No. 7H	H	H	



XANTHENE DYES

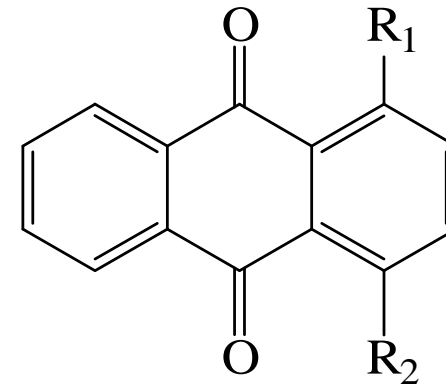


Color Additive	R ₁	R ₂	R ₃
D&C Orange No. 11	H	I	H
D&C Red No. 22	Br	Br	H
D&C Red No. 28	Br	Br	Cl
D&C Yellow No. 8	H	H	H
FD&C Red No. 3	I	I	H





ANTHRAQUINONE DYES



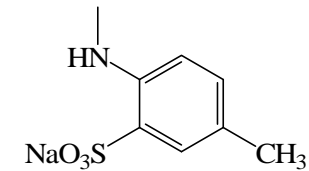
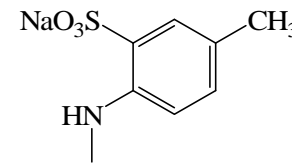
Color Additive

R₁

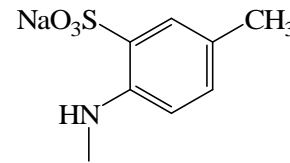
R₂



D&C Green No. 5

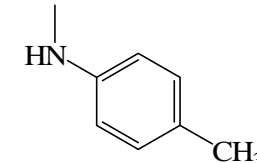
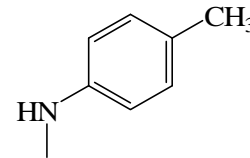


Ext D&C Violet No. 2

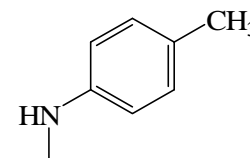


OH

D&C Green No. 6



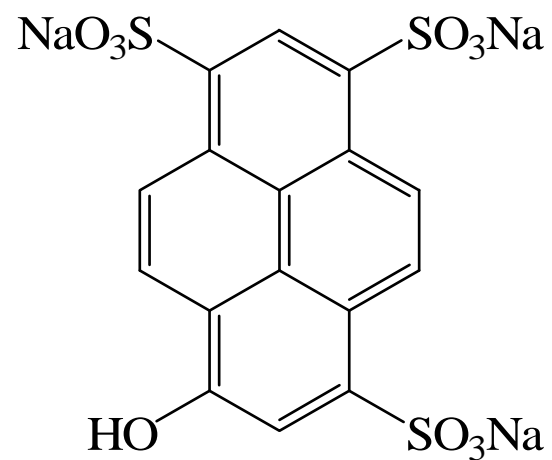
D&C Violet No. 2



OH



PYRENE DYE



Color Additive

D&C Green No. 8



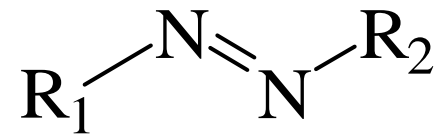


Which color additive is a suspected allergen?

FD&C Red No. 40	FD&C Blue No. 1	FD&C Yellow No. 5



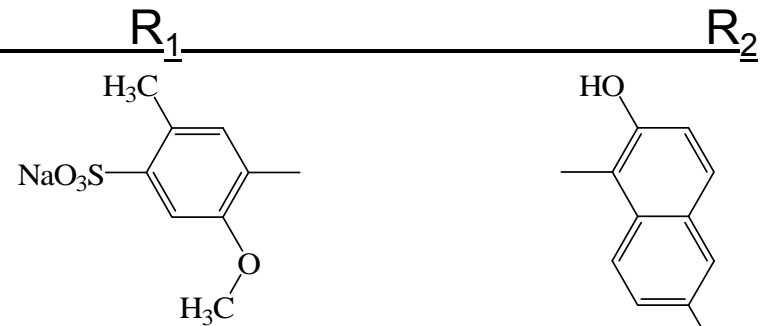
MONOAZO DYES



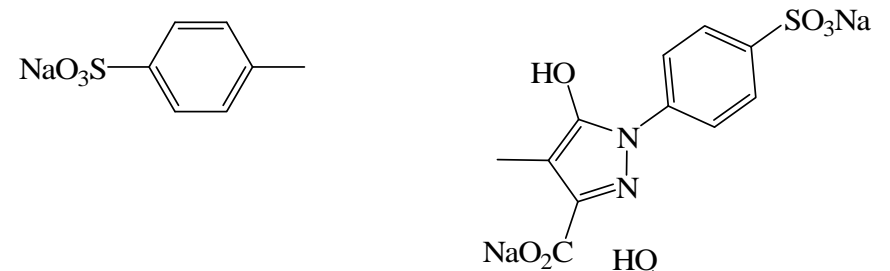
Color Additive



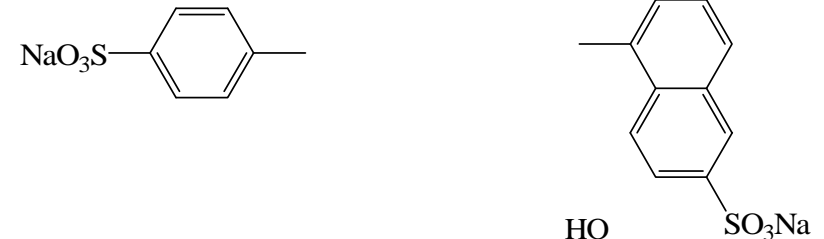
FD&C Red No. 40



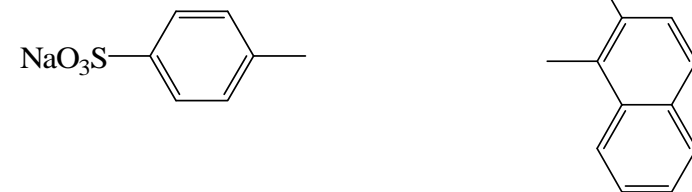
FD&C Yellow No. 5



FD&C Yellow No. 6

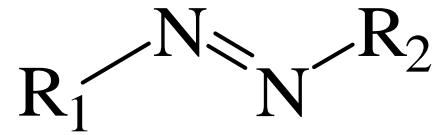


D&C Orange No. 4





MONOAZO DYES

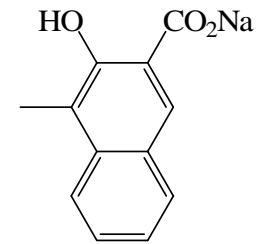
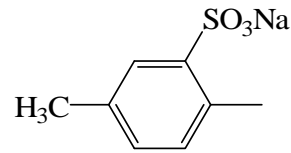


Color Additive

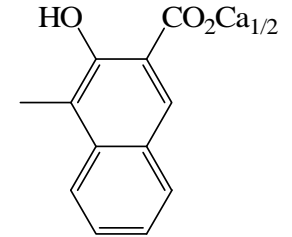
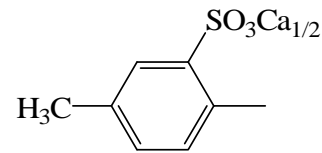
R_1

R_2

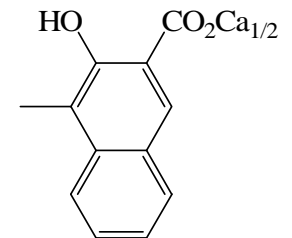
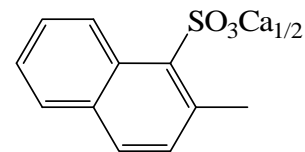
D&C Red No. 6



D&C Red No. 7

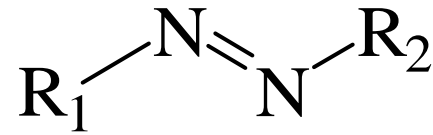


D&C Red No. 34





MONOAZO DYES



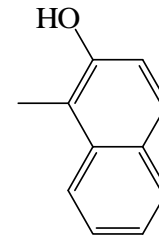
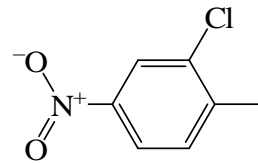
Color Additive

R_1

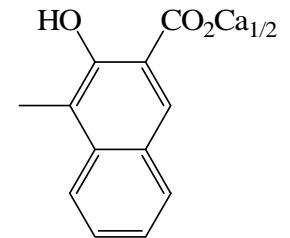
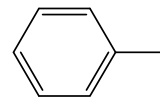
R_2



D&C Red No. 36

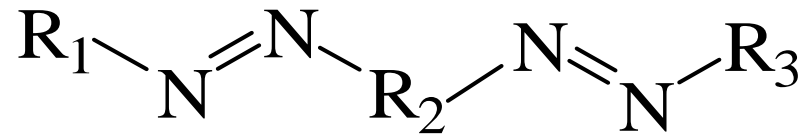


D&C Red No. 31





DISAZO DYES



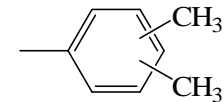
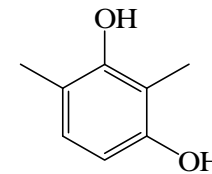
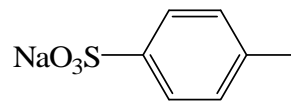
Color Additive

R₁

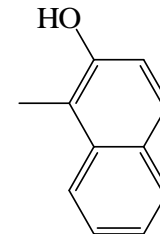
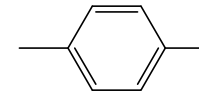
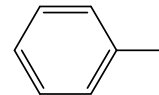
R₂

R₃

D&C Brown No. 1

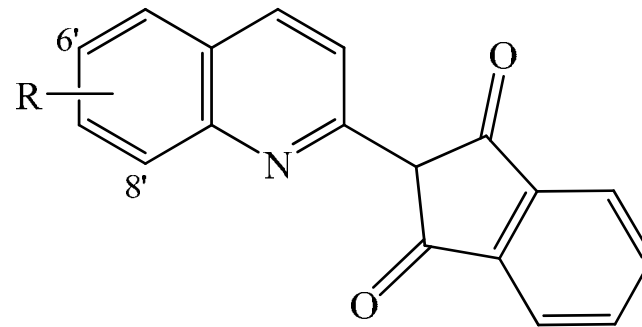


D&C Red No. 17





QUINOLINE DYES



Color Additive

R



D&C Yellow No. 10

SO₃Na (mixture of 6'- and 8'- isomers)



D&C Yellow No. 11

H



CARBON PIGMENTS



<u>Color Additive</u>	<u>Identity</u>
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D&C Black No. 2

high-purity carbon black

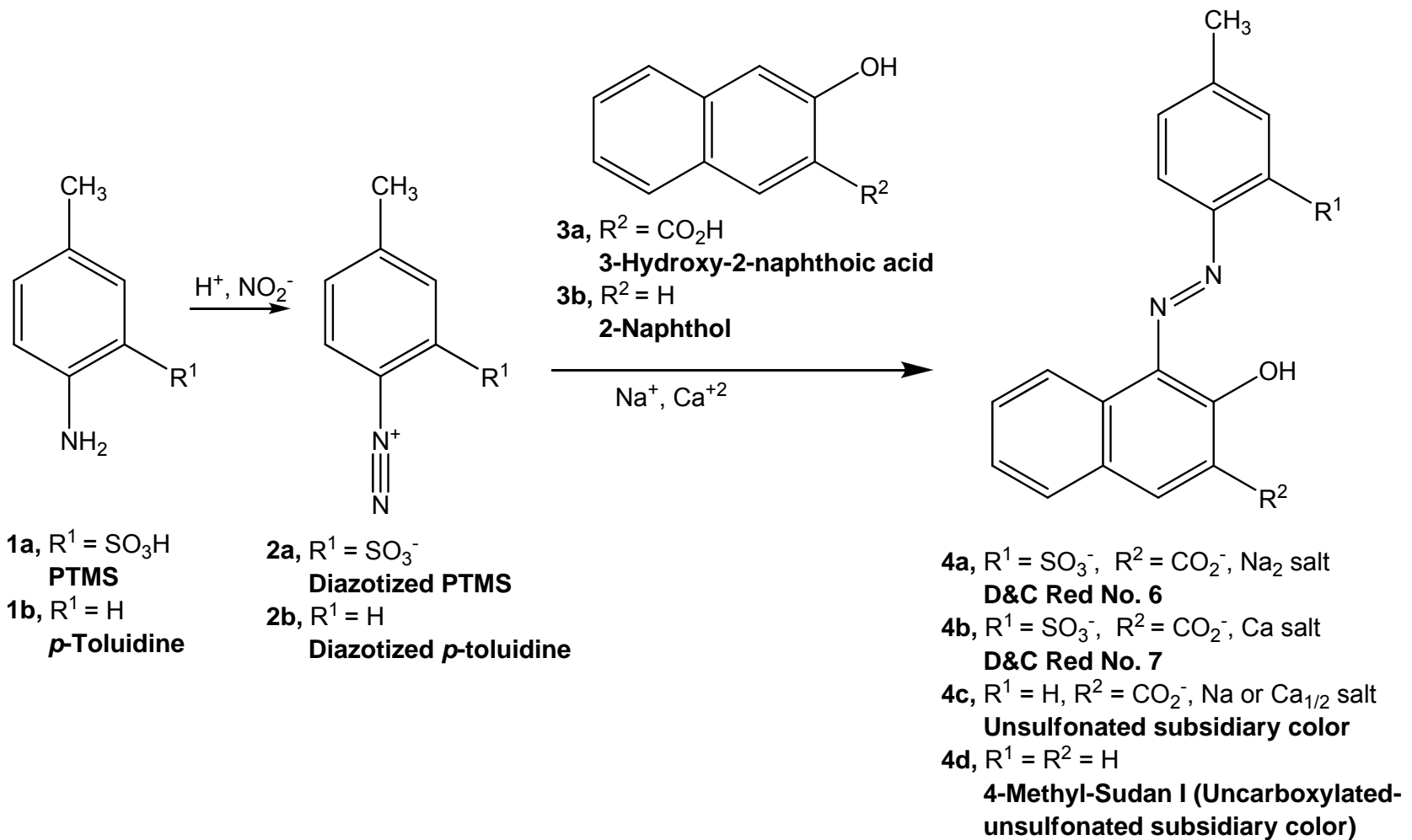
D&C Black No. 3

high-purity bone char





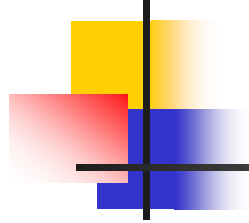
Manufacture of D&C Red No. 6





Specifications for D&C Red No. 6 (21 CFR 74.1306)

- Sum of volatile matter, < 10%
- Ether-soluble matter, pass test (Appendix A)
- 2-Amino-5-methylbenzenesulfonic acid, sodium salt, <0.2%
- 3-Hydroxy-2-naphthalenecarboxylic acid, sodium salt, <0.4%
- 3-Hydroxy-4-[4-(methylphenyl)azo]-2-naphthalenecarboxylic acid, sodium salt, 0.5%
- *p*-Toluidine, <15 ppm
- Lead, < 20 ppm
- Arsenic, < 3 ppm
- Mercury, < 1 ppm
- Total color, > 90%



Let's pause for two
questions...





Module 5

Certification-exempt color additives

- Structures
- Uses



Certification-exempt color additives (21 CFR Part 73)

- Not required to be certified by FDA
- Manufacturers are responsible for compliance with CFR specifications
- Can be inorganic or organic compounds
- Plant, animal, and mineral sources
- Have less coloring power
- Some are less stable and more variable in shade
- Can vary in composition from batch to batch
- Can introduce undesirable flavors and odors in products
- Can be contaminated with undesirable trace metals and bacteria



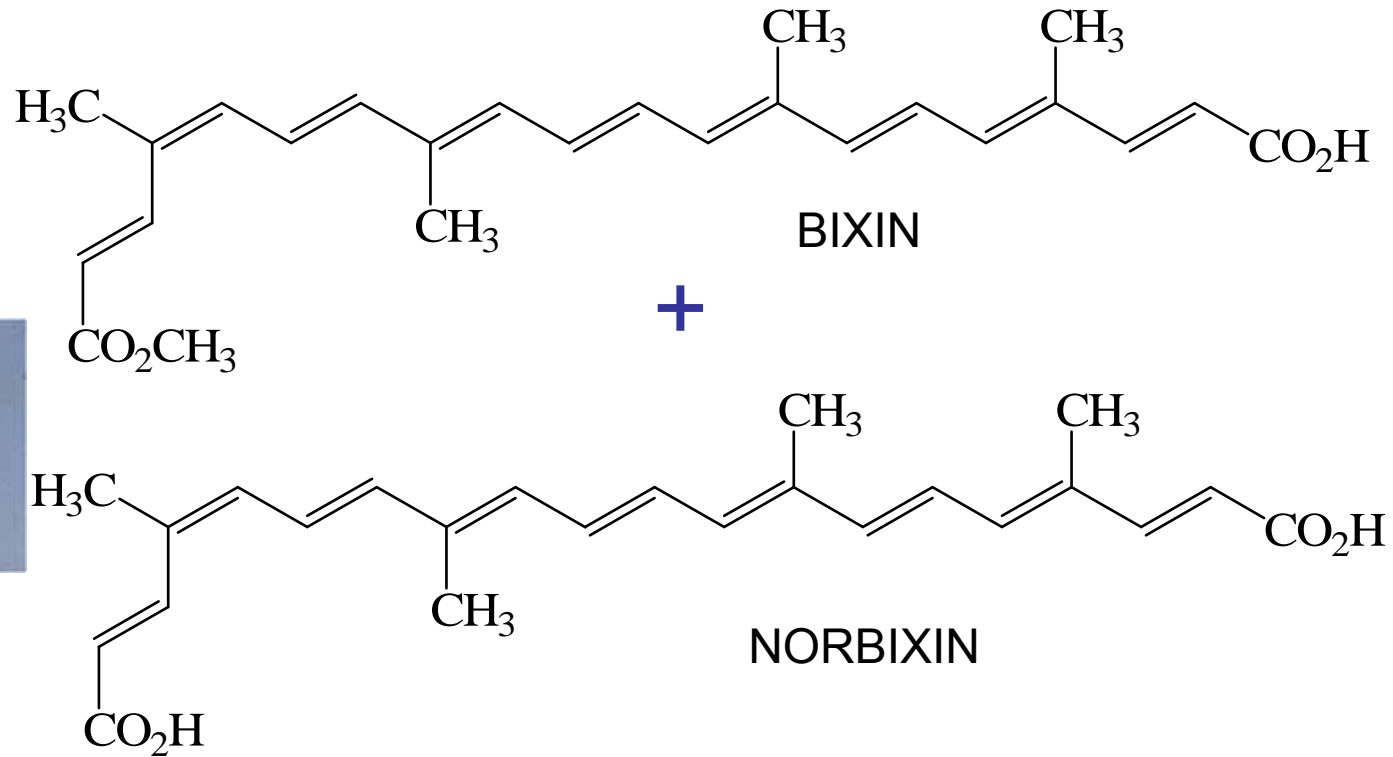
What are some examples of certification-exempt color additives?

Use your chat box to respond.





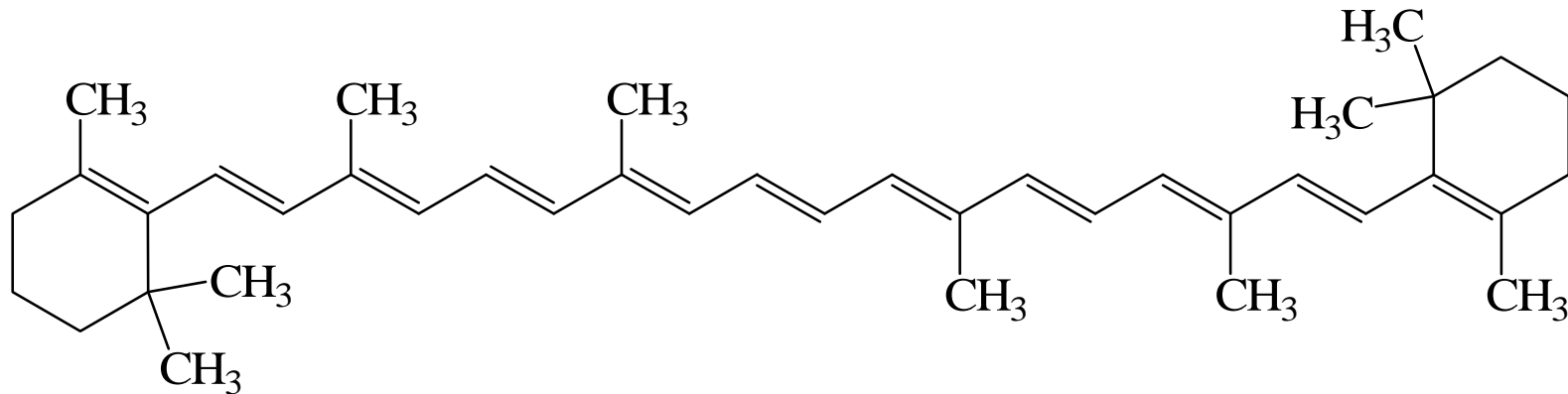
ANNATTO



- Annatto tree (*Bixa orellana*) produces seed with colored coating
- Seeds extracted with approved solvents
- Imparts butter yellow to peach color – used in butter, cheese, and ice cream



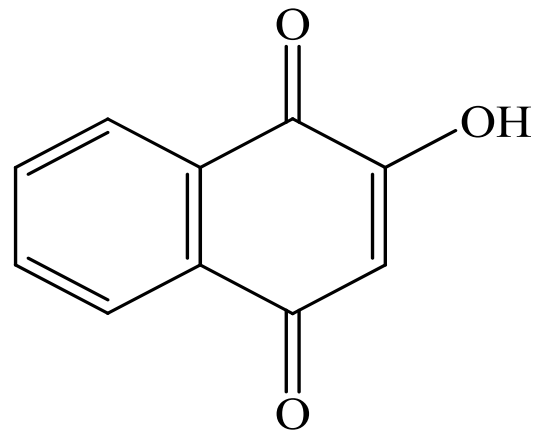
β -CAROTENE



- Isomer of carotene
- Synthetically produced from acetone as all *trans* form
- Has nutritional value – converted by humans to Vitamin A
- Imparts yellow to orange shades in butter, cheese, juice, baked goods



HENNA



- Dried leaf of lawsonia plant
- Imparts a brown, orange-brown, or reddish-brown tint
- Used for hair coloring
- Not permitted for use on skin



Spices

- Saffron



- Turmeric



- Paprika





***Do you think chicken is
artificially colored? How
about salmon?***

Raise your hand if you think they are.





Certification-exempt color additives for food use



- Tagetes (Aztec marigold) meal and extract – for chicken feed
- Astaxanthin – for fish feed
- Dehydrated beets (beet powder)
- Ferrous gluconate – for olives
- Riboflavin
- Tomato lycopene



Inorganic color additives

- Iron oxides
 - FeO – green
 - Fe₂O₃ – reddish brown
 - FeO(OH)·H₂O – yellow or brown
 - Fe₃O₄ – black
- White color additives
 - Mica – K₂Al₄(Al₂Si₆O₂₀)(OH)₄
 - Talc – Mg₃Si₄O₁₀(OH)₂
 - Titanium dioxide – TiO₂
 - Zinc oxide – ZnO
- Ultramarines (blue, green, violet) –
Na_v(Al_wSi_xO_y)S_z





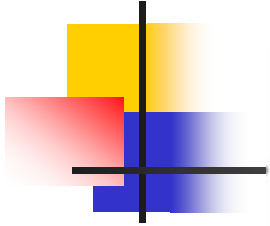
Certification-exempt color additives for drug and cosmetic use

- Bismuth citrate (for coloring hair)
- Dihydroxyacetone (for skin tanning)
- Guanine (comes from fish scales)
- Lead acetate (for coloring hair)
- Pyrogallol (for sutures)
- Luminescent zinc sulfide (for holiday make-up)





Questions?



www.fda.gov search color additives



Thanks to our presenter,
Dr. Bhakti Petigara Harp,
and to the FDA for
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