CPMA

CLASSIFICATION AND CHEMICAL DESCRIPTIONS

OF THE

COMPLEX INORGANIC COLOR PIGMENTS

Fourth Edition

Complex Inorganic Color Pigments Committee

Color Pigments Manufacturers Association, Inc.
2010

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*The First and Second Editions were titled *Classification and Chemical Description of the Mixed Metal Oxide Inorganic Colored Pigments.*

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FOREWORD
to the
Fourth Edition

The "Classification and Chemical Description of the Complex Inorganic Color Pigments" (the "Handbook") was first published in October of 1978. This important reference work has now been in print and worldwide usage for over thirty years. All four Editions of the Handbook were prepared by the Color Pigments Manufacturers Association, Inc. ("CPMA"), Complex Inorganic Color Pigments Committee, formerly known as the "Dry Color Manufacturers Association, Metal Oxides and Ceramic Colors Subcommittee".

The publication of this Handbook provided the first systematic description of complex inorganic color pigments based on chemical crystal structure. This publication established an internationally accepted description adopted by manufacturers of these pigments worldwide and by many national chemical inventories, including the U.S. Toxic Substances Control Act ("TSCA") Inventory. As a result of the work of the CPMA Committee, the classification system of the Handbook and the variable chemistry used in manufacture of the complex inorganic color pigments shown in the Handbook are also reflected in the American Chemical Society Chemical Abstracts Service registration definitions for these pigments.

The First Edition of the Handbook described the pigments and modifiers that Committee members intended to submit to the Environmental Protection Agency ("EPA") by survey to the first TSCA inventory. The Fourth Edition reflects updates in the modifiers listed for many pigments. Extensive research and collection of the original TSCA Inventory reporting forms submitted to the EPA in 1978 have resulted in the identification and addition of a number of new modifiers which are published here for the first time. The detailed description of each pigment, beginning on page 10, has also been updated to reflect additional usage categories, where applicable. New, modern diagrams depicting the various inorganic crystal structures that the classification system is based upon have been added to this Fourth Edition.

Since this Fourth Edition is the result of work by Committee members over a period of thirty years, the original authors of the First, Second and Third Editions of this Handbook are not available, and we no longer have full documentation for the basis of every listing, every pigment and every modifier. Users are therefore cautioned to ensure that any combination of pigment and modifiers is suitable for your formulation in the jurisdictions in which the user operates and sells products.

We would like to thank all of the members of the Committee that have tirelessly worked to prepare this Fourth Edition.

Those interested in a complete understanding of the evolution of this publication may wish to review the Forewords to the First, Second and Third Editions included in this Edition in Appendix B.

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THE CPMA CLASSIFICATION SYSTEM
OF THE
COMPLEX INORGANIC COLOR PIGMENTS
CPMA-NUMBER CODE

The CPMA Number Code assigned to each pigment consists of three sets of numbers each separated by hyphens.

The first set of numbers identifies the pigment(s) by the crystal structure in which it is classified i.e. Crystal Class.

1. Baddeleyite
2. Borate
3. Corundum-Hematite
4. Garnet
5. Olivine
6. Periclase
7. Phenacite
8. Phosphate
9. Priderite
10. Pyrochlore
11. Rutile-Cassiterite
12. Sphene
13. Spinel
14. Zircon

The second set is the CPMA Category Number identifying each pigment within a given crystal class.

The third set of numbers identifies the color of the pigment as follows:

1. violet & red-blue
2. blue & blue-green
3. green
4. yellow & primrose
5. pink, orchid, coral & peach
6. buff
7. brown
8. gray
9. black

DEFINITION OF MODIFIER

A modifier is a compound or an element which, if added, may alter the color properties of the pigment phase without changing its crystal structure.

CAS NUMBERS

CAS Registry Numbers assigned to the mixed metal oxide inorganic colored pigments are marked by an asterisk (*) to indicate that their composition is variable. Their chemical substance definitions coincide with that of the CPMA System Chemical Descriptions from which they were adopted. The definitions are listed in Appendix A of Volume I of the Initial Inventory.

USE STATEMENTS

Statements regarding the use of the complex inorganic color pigments listed in this booklet are general in nature. They are only guidelines for their selection and no warranty of any kind has been implied or was meant to be implied regarding their performance and applicability.

Specific performance, application and use data for a whole group of individual pigments that each one of the pigment categories represents cannot be given and the user must rely on the pigment manufacturer, or, supplier for these.

USE CATEGORIES

Based upon the predominant use of these pigments, three use categories were adopted for guidance.

Category A deals with pigments suspended in glass matrixes which require the highest degree of heat stability and chemical resistance to withstand the attack of molten glass.

They are predominantly (but not exclusively) used for coloring ceramic glazes, ceramic bodies, porcelain enamels, glass enamels, roofing granules, and other coatings of high temperature performance requirements.

Category B deals with pigments suspended in plastics and other polymers which require only moderate heat stability.

They are predominantly (but not exclusively) used for coloring thermoplastics, thermosetting and high temperature engineering resins, and high performance industrial coatings such as coil coatings, powder coatings, wire coatings, vinyl sidings, automotive and other finishes of medium temperature performance requirements.

Category C deals with pigments suspended in liquid vehicles which require little, or no heat stability.

They are predominantly (but not exclusively) used for coloring inks, and other organic coatings of low temperature performance requirements.

CHEMICAL DESCRIPTIONS AND USAGE OF THE COMPLEX INORGANIC COLOR PIGMENTS

CLASS I. BADDELEYITE

CPMA 1-01-4 ZIRCONIUM VANADIUM YELLOW BADDELEYITE
C.I. 77991 C.I. Pigment Yellow 160
CAS 68187-O1-9* Baddeleyite, vanadium yellow

Zirconium Vanadium Yellow Baddeleyite, an inorganic pigment, is a reaction product of high temperature calcination in which Zirconium (IV) Oxide and Vanadium (V) Oxide in varying amounts are homogeneously and ionically interdiffused to form a crystalline matrix of baddeleyite.
Basic Chemical Formula: $(Zr,V)O_2$

Its composition may include any one or a combination of the modifiers
Al_20_3, Fe_20_3, In_20_3, Mg_2O_3, SiO_2, SnO or TiO_2

Use Category A
Exceptionally suitable for coloring ceramic glazes and clay bodies. Not generally used in porcelain enamels.

CLASS II. BORATE

CPMA 2-02-1 COBALT MAGNESIUM RED-BLUE BORATE
C.I. 77352 C.I. Pigment Violet 48
CAS 68608-93-5* Boric Acid (H_3B0_3), cobalt magnesium salt, red-blue.

Cobalt Magnesium Red-Blue Borate, an inorganic pigment, is a reaction product of high temperature calcination in which Cobalt (II) Oxide, Magnesium (II) Oxide, and Boron (III) Oxide in varying amounts are homogeneously and ionically interdiffused to form a crystalline borate.
Basic Chemical Formula: $(Co,Mg)_2B_20_5$

Use Category B
Predominantly used as a decolorizer and for functional rather than decorative effect.

CLASS III. CORUNDUM-HEMATITE

CPMA 3-03-5 CHROME ALUMINA PINK CORUNDUM
C.I. 77003 C.I. Pigment Red 230
CAS 68187-27-9* Corundum, chromium pink

CHROME ALUMINA PINK CORUNDUM, an inorganic pigment, is a reaction product of high temperature calcination in which Aluminum (III) Oxide and Chromium (III) Oxide in varying amounts are homogeneously and ionically interdiffused to form a crystalline matrix of corundum.
Basic Chemical Formula: $(Al,Cr)_2 0_3$

Its composition may include Mn_2O, SnO_2 ZnO as modifiers.

Use Category A
Exceptionally suitable for coloring ceramic glazes. Not generally used in clay bodies, or, porcelain enamels.

CPMA 3-04-5 MANGANESE ALUMINA PINK CORUNDUM
C.1. 77005 C.I. Pigment Red 231
CAS 68186-99-2* Corundum, manganese pink

Manganese Alumina Pink Corundum, an inorganic pigment, is a reaction product of high temperature calcination in which Aluminum (III) Oxide and Manganese (III) Oxide in varying amounts are homogeneously and ionically interdiffused to form a crystalline matrix of corundum.
Basic Chemical Formula: $(Al,Mn)_2 0_3$

Its composition may include $P_2 0_5$ as a modifier.

Use Category A
Exceptionally suitable for coloring clay bodies. Not generally used in ceramic glazes, or, porcelain enamels.

CPMA 3-05-3 CHROMIUM GREEN-BLACK HEMATITE
C.I. 77288 C. I. Pigment Green 17
CAS 68909-79-5* Hematite, chromium green black

Chromium Green-Black Hematite, an inorganic pigment, is a reaction product of high temperature calcination consisting principally of Chromium (III) Oxide as crystalline hematite.
Basic Chemical Formula: Cr_2O_3

Its composition may include any one or a combination of the modifiers
Al_20_3, Fe_20_3, or $Mn0_3$

Use Category A, B and C
Predominantly used for coloring clay bodies.

CPMA 3-06-7 IRON BROWN HEMATITE
C.I. 77491 C. I. Pigment Red 101 & 102
CAS 1317-63-1 Hematite, brown

Iron Brown Hematite, an inorganic pigment, is a reaction product of high temperature calcination consisting principally of Iron (III) Oxide as crystalline hematite.
Basic Chemical Formula: Fe_2O_3

Its composition may include any one or a combination of the modifiers
$Cr_2\,0_3$, FeO, Mn_20_3, or NiO

Use Category A, B and C
Exceptionally suitable for coloring clay bodies, ceramic glazes, and, porcelain enamels.

CLASS IV. GARNET

CPMA 4-07-3 VICTORIA GREEN GARNET
C.I. 77300 C. I. Pigment Green 51
CAS 68553-01-5* Garnet, calcium chromium silicon green

Victoria Green Garnet, an inorganic pigment, is a reaction product of high temperature calcination in which Calcium (II) Oxide, Chromium (III) Oxide, and Silicon (IV) Oxide in varying amounts are homogeneously and ionically interdiffused to form a crystalline matrix of garnet.
Basic Chemical Formula: $3CaO:Cr_20_3:3SiO_2$

Its composition may include any one or a combination of the modifiers Al_20_3, B_20_3, CaF_2, CoO, PbO, or ZrO_2

Use Category A
Exceptionally suitable for coloring ceramic glazes. Not generally used in clay bodies, or, porcelain enamels.

CLASS V. OLIVINE

CPMA 5-08-2 COBALT SILICATE BLUE OLIVINE
C.I. 77364 C. I. Pigment Blue 73
CAS 68187-40-6* Olivine, cobalt blue

Cobalt Silicate Blue Olivine, an inorganic pigment, is a reaction product of high temperature calcination in which Cobalt (II) Oxide and Silicon (IV) Oxide in varying amounts are homogeneously and ionically interdiffused to form a crystalline matrix of olivine.
Basic Chemical Formula: Co_2SiO_4

Its composition may include any one or a combination of the modifiers Al_2O_3 , B_20_3, CaO, PbO, or ZnO

Use Category A
Exceptionally suitable for coloring ceramic glazes and clay bodies. Not generally used in porcelain enamels.

CPMA 5-45-3 NICKEL SILICATE GREEN OLIVINE
C.I. 777850 C.I. Pigment Green 56
CAS 685I5-84-4* Olivine, nickel green

Nickel Silicate Green Olivine, an inorganic pigment, is a reaction product of high temperature calcination in which Nickel (II) Oxide and Silicon (IV) Oxide in varying amounts are homogeneously and ionically interdiffused to form a crystalline matrix of olivine.
Basic Chemical Formula: Ni_2Si0_4

Its composition may include any one or a combination of the modifiers alkali or alkaline earth halides.

Use Category A
Predominantly used for coloring clay bodies.

CLASS VI. PERICLASE

CPMA 6-09-8 COBALT NICKEL GRAY PERICLASE
C.I. 77332 C.I. Pigment Black 25
CAS 68186-89-0* Periclase, cobalt nickel gray

Cobalt Nickel Gray Periclase, an inorganic pigment, is a reaction product of high temperature calcination in which Cobalt (II) Oxide and Nickel (II) Oxide in varying amounts are homogeneously and ionically interdiffused to form a crystalline matrix of periclase.
Basic Chemical Formula: (Co,Ni)O

Its composition may include any one or a combination of the modifiers Al_2O_3, CaO, Cr_2O_3, FeO, Fe_2O_3, MgO, MnO, SiO_2, TiO_2, ZnO, or ZrO_2

Use Category A
Exceptionally suitable for coloring ceramic glazes and clay bodies. Not generally used in porcelain enamels.

CLASS VII. PHENACITE

CPMA 7-10-2 COBALT ZINC SILICATE BLUE PHENACITE
C.I. 77366 C.I. Pigment Blue 74
CAS 68412-74-8* Phenacite, cobalt zinc blue

Cobalt Zinc Silicate Blue Phenacite, an inorganic pigment, is a reaction product of high temperature calcination in which Cobalt (II) Oxide, Zinc (II) Oxide, and Silicon (IV) Oxide in varying amounts are homogeneously and ionically interdiffused to form a crystalline matrix of phenacite.
Basic Chemical Formula: $(Co,Zn)_2SiO_4$

Its composition may include B_20_3 as a modifier.

Use Category A
Exceptionally suitable for coloring ceramic glazes. Not generally used in any clay bodies or porcelain enamels.

CLASS VIII. PHOSPHATE

CPMA 8-11-1 COBALT VIOLET PHOSPHATE
C.1. 77360 C.1. Pigment Violet 14
CAS 13455-36-2* Phosphoric acid, cobalt (2+) salt (2:3) Co.2/
3 H_3O_4P

Cobalt Violet Phosphate, an inorganic pigment, is a reaction product of high temperature calcination in which Cobalt (II) Oxide and Phosphorus (V) Oxide in varying amounts are homogeneously and ionically interdiffused to form a crystalline phosphate.
Basic Chemical Formula: $Co_3(PO_4)_2$

Use Category A, B and C
Predominantly used as decolorizer and for functional rather than decorative effect.

CPMA 8-12-1 COBALT LITHIUM VIOLET PHOSPHATE
C.I. 77363 C.I. Pigment Violet 47
CAS 68610-13-9* Phosphoric acid, cobalt lithium salt, violet

Cobalt Lithium Violet Phosphate, an inorganic pigment, is a reaction product of high temperature calcination in which Cobalt (II) Oxide, Lithium (I) Oxide, and Phosphorus (V) Oxide in varying amounts are homogeneously and ionically interdiffused to form a crystalline phosphate.
Basic Chemical Formula: $CoLiPO_4$

Use Category B
Predominately used as decolorizer and for functional rather than decorative effect.

CLASS IX. PRIDERITE

CPMA 9-13-4 NICKEL BARIUM TITANIUM PRIMROSE PRIDERITE
G I. 77900 C.I. Pigment Yellow 157
CAS 68610-24-2* Priderite, nickel

Nickel Barium Titanium Primrose Priderite, an inorganic pigment, is a reaction product of high temperature calcination in which Nickel (II) Oxide, Barium (II) Oxide, and Titanium (IV) Oxide in varying amounts are homogeneously and ionically interdiffused to form a crystalline matrix of priderite.
Basic Chemical Formula: $2NiO:3BaO:17TiO_2$

Use Category A, B, and C
Predominantly used for coloring category B substrates. Performs equally well in ceramic bodies, porcelain enamels, roofing granules and exterior paints. Seldom used in ceramic glazes.

CLASS X. PYROCHLORE

CPMA 10-14-4 LEAD ANTIMONATE YELLOW PYROCHLORE
C.I. 77588 C. I. Pigment Yellow 41
CAS 8012-00-8

Lead Antimonate Yellow Pyrochlore, an inorganic pigment, is a reaction product of high temperature calcination in which Lead (II) Oxide and Antimony (V) Oxide in varying amounts are homogeneously and ionically interdiffused to form a crystalline matrix of pyrochlore.
Basic Chemical Formula: $Pb_2Sb_20_7$

Its composition may include any one or a combination of the modifiers
$A1_20_3$, CdO, Fe_2O_3, MgO, SnO_2, TiO_2, or ZnO

Use Category A
Predominantly used for coloring porcelain enamels, glass enamels and ceramic glazes. Not generally used in clay bodies.

CLASS XI RUTILE-CASSITERITE

CPMA 11-15-4 NICKEL ANTIMONY TITANIUM YELLOW RUTILE
C.I. 77788 C.I. Pigment Yellow 53
CAS 8007-18-9

Nickel Antimony Titanium Yellow Rutile, an inorganic pigment, is a reaction product of high temperature calcination in which Titanium (IV) Oxide, Nickel (II) Oxide, and Antimony (V) Oxide in varying amounts are homogeneously and ionically interdiffused to form a crystalline matrix of rutile.
Basic Chemical Formula: $(Ti,Ni,Sb)O_2$

Its composition may include any one or a combination of the modifiers CdO, Cr_20_3, or Li_2O

Use Category A, B, and C
Predominantly used for coloring category B substrates. Performs equally well in ceramic bodies, porcelain enamels, roofing granules and exterior paints. Seldom used in ceramic glazes.

CPMA 11-16-4 NICKEL NIOBIUM TITANIUM YELLOW RUTILE
C.I. 77895 C.I. Pigment Yellow 161
CAS 68611-43-8* Rutile, nickel niobium yellow

Nickel Niobium Titanium Yellow Rutile, an inorganic pigment, is a reaction product of high temperature calcination in which Titanium (IV) Oxide, Nickel (II) Oxide, and Niobium (V) Oxide in varying amounts are homogeneously and ionically interdiffused to form a crystalline matrix of rutile.
Basic Chemical Formula: $(Ti,Ni,Nb)O_2$

Its composition may include either or both of the modifiers Cr_20_3 or SrO

Use Category A, B, and C
Predominantly used for coloring category B substrates. Performs equally well in ceramic bodies, porcelain enamels, roofing granules and exterior paints. Seldom used in ceramic glazes.

CPMA 11-52-4 NICKEL TUNGSTEN YELLOW RUTILE
C.I. 77902 C.I. Pigment Yellow 189
CAS 69011-05-8* Rutile, nickel tungsten yellow

Nickel Tungsten Yellow Rutile, an inorganic pigment, is a reaction product of high temperature calcination in which Titanium (IV) Oxide, Nickel (II) Oxide, and Tungsten (VI) Oxide in varying amounts are homogeneously and ionically interdiffused to form a crystalline matrix of rutile.
Basic Chemical Formula: $(Ti,Ni,W)O_2$

Its composition may include any one or a combination of the modifiers
CeO_2, Li_20 or MgO

Use Category A, B, and C

Predominantly used for coloring category B substrates. Performs equally well in ceramic bodies, porcelain enamels, roofing granules and exterior paints. Seldom used in ceramic glazes.

CPMA 11-17-6 CHROME ANTIMONY TITANIUM BUFF RUTILE
C.I. 77310 C.I. Pigment Brown 24
CAS 68186-90-3* Rutile, antimony chromium buff

Chrome Antimony Titanium Buff Rutile, an inorganic pigment, is a reaction product of high temperature calcination in which Titanium (IV) Oxide, Chromium (III) Oxide, and Antimony (V) Oxide in varying amounts are homogeneously and ionically interdiffused to form a crystalline matrix of rutile.
Basic Chemical Formula: $(Ti,Cr,Sb)O_2$

Its composition may include any one or a combination of the modifiers Al_2O_3, MnO, NiO, SrO, WO_3, or ZnO

Use Category A, B, and C
Predominantly used for coloring category B substrates. Performs equally well in ceramic bodies, porcelain enamels, roofing granules and exterior paints. Seldom used in ceramic glazes.

CPMA 11-18-6 CHROME NIOBIUM TITANIUM BUFF RUTILE
C.L 77896 C.I. Pigment Yellow 162
CAS 68611-42-7* Rutile, chromium niobium buff

Chrome Niobium Titanium Buff Rutile, an inorganic pigment, is a reaction product of high temperature calcination in which Titanium (IV) Oxide, Chromium (III) Oxide, and Niobium (V) Oxide in varying amounts are homogeneously and ionically interdiffused to form a crystalline matrix of rutile.
Basic Chemical Formula: $(Ti,Cr,Nb)O_2$

Its composition may include either or both of the modifiers NiO or SrO

Use Category A, B, and C
Predominantly used for coloring category B substrates. Performs equally well in ceramic bodies, porcelain enamels, roofing granules and exterior paints. Seldom used in ceramic glazes.

CPMA 11-19-6 CHROME TUNGSTEN TITANIUM BUFF RUTILE
C.I. 77897 C.I. Pigment Yellow 163
CAS 68186-92-5* Rutile, chromium tungsten buff

Chrome Tungsten Titanium Buff Rutile, an inorganic pigment, is a reaction product of high temperature calcination in which Titanium (IV) Oxide, Chromium (III) Oxide, and Tungsten (VI) Oxide in varying amounts are homogeneously and ionically interdiffused to form a crystalline matrix of rutile.
Basic Chemical Formula: $(Ti,Cr,W)O_2$

Its composition may include NiO as a modifier.

Use Category A, B, and C
Predominantly used for coloring category B substrates. Performs equally well in ceramic bodies, porcelain enamels, roofing granules and exterior paints. Seldom used in ceramic glazes.

CPMA 11-20-6 MANGANESE ANTIMONY TITANIUM BUFF RUTILE
C.I. 77899 C.I. Pigment Yellow 164
CAS 68412-38-4* Rutile, antimony manganese buff

Manganese Antimony Titanium Buff Rutile, an inorganic pigment, is a reaction product of high temperature calcination in which Titanium (IV) Oxide, Manganese (II) Oxide, and Antimony (V) Oxide in varying amounts are homogeneously and ionically interdiffused to form a crystalline matrix of rutile.
Basic Chemical Formula: $(Ti,Mn,Sb)O_2$

Its composition may include any one or a combination of the modifiers
Al_2O_3, Cr_2O_3, NiO, WO_3, or ZnO

Use Category A, B, and C
Predominantly used for coloring category B substrates. Performs equally well in ceramic bodies, porcelain enamels, roofing granules and exterior paints. Seldom used in ceramic glazes.

CPMA 11-21-8 TITANIUM VANADIUM ANTIMONY GRAY RUTILE
C.I. 77898 C.I. Pigment Black 24
CAS 68187-00-8* Rutile, antimony vanadium gray

Titanium Vanadium Antimony Gray Rutile, an inorganic pigment, is a reaction product of high temperature calcination in which Titanium (IV) Oxide, Vanadium (IV) Oxide, and Antimony (V) Oxide in varying amounts are homogeneously and ionically interdiffused to form a crystalline matrix of rutile.
Basic Chemical Formula: $(Ti,V,Sb)O_2$

Use Category A
Predominantly used for coloring porcelain enamels.

CPMA 11-22-4 TIN VANADIUM YELLOW CASSITERITE
C.I. 77862 C.I. Pigment Yellow 158
CAS 68186-93-6* Cassiterite, vanadium yellow

Tin Vanadium Yellow Cassiterite, an inorganic pigment, is a reaction product of high temperature calcination in which Tin (IV) Oxide and Vanadium (V) Oxide in varying amounts are homogeneously and ionically interdiffused to form a crystalline matrix of cassiterite.
Basic Chemical Formula: $(Sn,V)O_2$

Its composition may include any one or a combination of the modifiers Al_2O_3, Fe_2O_3, MgO, NiO, SiO_2, or TiO_2

Use Category A
Exceptionally suitable for coloring ceramic glazes. Not generally used in clay bodies, or porcelain enamels.

CPMA 11-23-5 CHROME TIN ORCHID CASSITERITE
C.I. 77863 C.I. Pigment Red 236
CAS 68187-53-1* Cassiterite, Chromium orchid

Chrome Tin Orchid Cassiterite, an inorganic pigment, is a reaction product of high temperature calcination in which Tin (IV) Oxide and Chromium (III) Oxide in varying amounts are homogeneously and sonically interdiffused to form a crystalline matrix of cassiterite.
Basic Chemical Formula: $(Sn,Cr)0_2$

Its composition may include any one or a combination of the modifiers B_20_3, CaO, or CeO_2

Use Category A
Exceptionally suitable for coloring ceramic glazes. Not generally used in clay bodies, or porcelain enamels.

CPMA 11-24-8 TIN ANTIMONY GRAY CASSITERITE
C. l. 77865 C.I. Pigment Black 23
CAS 68187-54-2* Cassiterite, antimony gray

Tin Antimony Gray Cassiterite, an inorganic pigment, is a reaction product of high temperature calcination in which Tin (IV) Oxide and Antimony (V) Oxide in varying amounts are homogeneously and sonically interdiffused to form a crystalline matrix of cassiterite.
Basic Chemical Formula: $(Sn,Sb)O_2$

Its composition may include any one or a combination of the modifiers CaO, CeO_2, MnO, SiO_2, TiO_2, or V_2O_5

Use Category A
Predominantly used for coloring ceramic glazes and bone china bodies. Not generally used in porcelain enamels.

CPMA 11-46-7 MANGANESE CHROME ANTIMONY TITANIUM BROWN RUTILE
C.I. 77891 C.I. Pigment Brown 40
CAS 69991-68-0* Rutile, antimony chromium manganese brown

Manganese Chrome Antimony Titanium Brown Rutile, an inorganic pigment, is a reaction product of high temperature calcination in which Titanium (IV) Oxide, Manganese (II) Oxide; Chromium (III) Oxide, and Antimony (V) Oxide in varying amounts are homogeneously and ionically interdiffused to form a crystalline matrix of rutile.
Basic Chemical Formula: $(Ti,Mn,Cr,Sb)O_2$

Use Category A, B, and C
Predominantly used for coloring category B substrates. Performs equally well in ceramic bodies, porcelain enamels, roofing granules and exterior paints. Seldom used in ceramic glazes.

CPMA 11-47-7 MANGANESE NIOBIUM TITANIUM BROWN RUTILE
C.I. 77890 C.I. Pigment Brown 37
CAS 70248-09-8* Rutile, manganese niobium brown

Manganese Niobium Titanium Brown Rutile, an inorganic pigment, is a reaction product of high temperature calcination in which Manganese (II) Oxide, Niobium (V) Oxide, and Titanium (IV) Oxide in varying amounts are homogeneously and ionically interdiffused to form a crystalline matrix of rutile.
Basic Chemical Formula: $(Ti,Mn,Nb)O_2$

Its composition may include Sb_2O_5 as modifier

Use Category A, B, and C
Predominantly used for coloring category B substrates. Performs equally well in ceramic bodies, porcelain enamels, roofing granules and exterior paints. Seldom used in ceramic glazes.

CLASS XII. SPHENE

CPMA 12-25-5 CHROME TIN PINK SPHENE
C.I. 77301 C.I. Pigment Red 233
CAS 68187-12-2* Sphene, chromium tin pink

Chrome Tin Pink Sphene, an inorganic pigment, is a reaction product of high temperature calcination in which Calcium (II) Oxide, Tin (IV) Oxide, Silicon (IV) Oxide, and Chromium (III) Oxide in varying amounts are homogeneously and ionically interdiffused to form a crystalline matrix of tin sphene.
Basic Chemical Formula: $CaO:SnO:SiO_2:Cr_2O_3$

Its composition may include either or both of the modifiers B_2O_3 and PbO

Use Category A
Exceptionally suitable for coloring ceramic glazes. Not generally used in clay bodies, or porcelain enamels.

CLASS XIII SPINEL

CPMA 13-26-2 COBALT ALUMINATE BLUE SPINEL
C.I. 77346 C.I. Pigment Blue 28
CAS 1345-16-0

Cobalt Aluminate Blue Spinel, an inorganic pigment, is a reaction product of high temperature calcination in which Cobalt (II) Oxide, and Aluminum (III) Oxide in varying amounts are homogeneously and ionically interdiffused to form a crystalline matrix of spinel.
Basic Chemical Formula: $CoAl_2O_4$
Its composition may include any one or a combination of the modifiers Li_2O, MgO, SiO_2, TiO_2, or ZnO

Use Category A, B, and C

CPMA 13-27-2 COBALT TIN BLUE-GRAY SPINEL
C.I. 77368 C.I. Pigment Blue 35
CAS 68187-05-3* Spinels, cobalt tin gray

Cobalt Tin Blue-Gray Spinel, an inorganic pigment, is a reaction product of high temperature calcination in which Cobalt (II) Oxide and Tin (IV) Oxide in varying amounts are homogeneously and ionically interdiffused to form a crystalline matrix of spinel.
Basic Chemical Formula: Co_2SnO_4

Its composition may include any one or a combination of the modifiers Al_2O_3, Fe_2O_3, or NiO

Use Category A, B, and C
Exceptionally suitable for coloring ceramic glazes. Not generally used in clay bodies, or, porcelain enamels.

CPMA 13-28-2 COBALT ZINC ALUMINATE BLUE SPINEL
C.I. 77347 C.I. Pigment Blue 72
CAS 68186-87-8* Spinel, aluminum cobalt zinc blue

Cobalt Zinc Aluminate Blue Spinel, an inorganic pigment, is a reaction product of high temperature calcination in which Cobalt (II) Oxide, Zinc (II) Oxide, and Aluminum (III) Oxide in varying amounts are homogeneously and ionically interdiffused to form a crystalline matrix of spinel.
Basic Chemical Formula: $(Co,Zn)Al_2O_4$

Its composition may include any one or a combination of the modifiers
Li_2O, MgO, SiO_2, SnO or TiO_2

Use Category A, B, and C

CPMA 13-53-2 ZINC CHROME COBALT ALUMINUM SPINEL

C.I. 77343:1 C.I. Pigment Blue 36:1

CAS 74665-01-3* Spinels, Aluminum Chromium Cobalt Zinc Blue

Zinc Chrome Cobalt Aluminum Spinel, an inorganic pigment, is a reaction product of high temperature calcination in which Zinc (II) Oxide, Chromium (III) Oxide, Cobalt (II) Oxide, and Aluminum (III) Oxide in varying amounts are homogeneously and ionically interdiffused to form a crystalline matrix of spinel.

Basic Chemical Formula: $(Zn,Co)(Cr,Al)_2O_4$

Its composition may include any one or a combination of the modifiers MgO, SrO_2, TiO_2, ZnO or ZrO_2

Use Category A, B, and C

CPMA 13-29-2 COBALT CHROMITE BLUE-GREEN SPINEL

C.I. 77343 C.I. Pigment Blue 36

CAS 68187-11 -I * Spinels, aluminum chromium cobalt bluegreen

Cobalt Chromite Blue-Green Spinel, an inorganic pigment, is a reaction product of high temperature calcination in which Cobalt (II) Oxide, Chromium (III) Oxide, and Aluminum (III) Oxide in varying amounts are homogeneously and ionically interdiffused to form a crystalline matrix of spinel.

Basic Chemical Formula: $Co(Al,Cr)_2O_4$

Its composition may include any one or a combination of the modifiers
MgO, SiO_2, SrO_2, TiO_2 or ZnO

Use Category A, B, and C

CPMA 13-30-3 COBALT CHROMITE GREEN SPINEL
C.I. 77344 C.I. Pigment Green 26
CAS 68187-49-5* Spinels, chromium cobalt green

Cobalt Chromite Green Spinel, an inorganic pigment, is a reaction product of high temperature calcination in which Cobalt (II) Oxide and Chromium (III) Oxide in varying amounts are homogeneously and ionically interdiffused to form a crystalline matrix of spinel.
Basic Chemical Formula: $CoCr_2O_4$

Its composition may include any one or a combination of the modifiers Al_2O_3, B_2O_3, CaO, MgO, PbO, SiO_2, TiO_2, ZnO, or ZrO_2

Use Category A, B, and C

CPMA 13-31-3 COBALT TITANATE GREEN SPINEL
C.I. 77377 C.I. Pigment Green 50
CAS 68186-85-6" * Spinels, cobalt titanium green

Cobalt Titanate Green Spinel, an inorganic pigment, is a reaction product of high temperature calcination in which Cobalt (II) Oxide and Titanium (IV) Oxide in varying amounts are homogeneously and ionically interdiffused to form a crystalline matrix of inverse spinel.
Basic Chemical Formula: Co_2TiO_4

Its composition may include any one or a combination of the modifiers Al_2O_3, CaO, Cr_2O_3, Fe_2O_3, Li_2O_3, MgO, NiO, Sb_2O_5, or ZnO

Use Category A, B and C
Exceptionally suitable for use in systems requiring infrared reflectance.

CPMA 13-32-5 CHROME ALUMINA PINK SPINEL
C.I. 77290 C.I. Pigment Red 235
CAS 68201-65-0* Spinels, aluminum chromium zinc pink

Chrome Alumina Pink Spinel, an inorganic pigment, is a reaction product of high temperature calcination in which Aluminum (III) Oxide, Zinc (II) Oxide and Chromium (III) Oxide in varying amounts are homogeneously and ionically interdiffused to form a crystalline matrix of spinel.
Basic Chemical Formula: $Zn(Al,Cr)_2O_4$

Its composition may include any one or a combination of the modifiers
B_2O_3, Fe_2O_3, MgO or PbO

Use Category A
Exceptionally suitable for coloring ceramic glazes. Not generally used in clay bodies, or, porcelain enamels.

CPMA 13-33-7 IRON CHROMITE BROWN SPINEL
C.I. 77501 C.I. Pigment Brown 35
CAS 68187-09-7* Spinels, Chromium iron brown

Iron Chromite Brown Spinel, an inorganic pigment, is a reaction product of high temperature calcination in which Iron (II) Oxide, Iron (III) Oxide, and Chromium (III) Oxide in varying amounts are homogeneously and ionically interdiffused to form a crystalline matrix of spinel.
Basic Chemical Formula: $Fe(Fe,Cr)_2O_4$

Its composition may include any one or a combination of the modifiers Al_2O_3, B_2O_3, CoO, LiO, MgO, NiO, SiO_2, SnO_2, or TiO_2

Use Category A, B, and C

CPMA 13-34-7 IRON TITANIUM BROWN SPINEL
C.I. 77543 C.I. Pigment Black 12
CAS 68187-02-0* Spinels, iron titanium brown

Iron Titanium Brown Spinel, an inorganic pigment, is a reaction product of high temperature calcination in which Iron (II) Oxide and Titanium (IV) Oxide in varying amounts are homogeneously and ionically interdiffused to form a crystalline matrix of inverse spinel.
Basic Chemical Formula: Fe_2TiO_4

Its composition may include any one or a combination of the modifiers $A1_2O_3$, CoO, Cr_2O_3, Fe_2O_3, MnO, or ZnO

Use Category A, B and C

CPMA 13-35-7 NICKEL FERRITE BROWN SPINEL
C.I. 77497 C.I. Pigment Brown 34
CAS 68187-10-0* Spinels, iron nickel brown

Nickel Ferrite Brown Spinel, an inorganic pigment, is a reaction product of high temperature calcination in which Iron (III) Oxide and Nickel (11) Oxide in varying amounts are homogeneously and ionically interdiffused to form a crystalline matrix of spinel.
Basic Chemical Formula: $NiFe_2O_4$

Its composition may include any one or a combination of the modifiers $A1_2O_3$, FeO, SiO_2, SnO_2, or TiO_2

Use Category A
Predominantly used for coloring porcelain enamels and clay bodies.

CPMA 13-36-7 ZINC FERRITE BROWN SPINEL:
C.I. 77496 C.I. Pigment Yellow 119
CAS 12063-19-3 C.I. Pigment Yellow 119 also Fe_2O_4Zn
CAS 68187-51-9* Spinels, iron zinc brown

Zinc Ferrite Brown Spinel, an inorganic pigment, is a reaction product of high temperature calcination in which Zinc (II) Oxide, Iron (II) Oxide, and Iron (III) Oxide in varying amounts are homogeneously and ionically interdiffused to form a crystalline matrix of spinel.
Basic Chemical Formula: $(Zn,Fe)Fe_2O_4$

Its composition may include any one or a combination of the modifiers
Al_2O_3, InO_2, NiO, SiO_2, SnO_2 or TiO_2

Use Category A, B, and C
Predominantly used for coloring category B substrates. Performs equally well in ceramic bodies, porcelain enamels, roofing granules and exterior paints. Seldom used in ceramic glazes.

CPMA 13-37-7 ZINC IRON CHROMITE BROWN SPINEL
C.I. 77503 C.I. Pigment Brown 33
CAS 68186-88-9* Spinels, chromium iron zinc brown

Zinc Iron Chromite Brown Spinel, an inorganic pigment, is a reaction product of high temperature calcination in which Zinc (II) Oxide, Iron (II) Oxide, Iron (III) Oxide, and Chromium (III) Oxide in varying amounts are homogeneously and ionically interdiffused to form a crystalline matrix of spinel.
Basic Chemical Formula: $(Zn,Fe)(Fe,Cr)_2O_4$

Its composition may include any one or a combination of the modifiers
Al_2O_3, NiO, PbO, Sb_2O_5, SiO_2, SnO_2, or TiO_2

Use Category A, B, and C

CPMA 13-38-9 COPPER CHROMITE BLACK SPINEL
C.I. 77428 C.I. Pigment Black 28
CAS 68186-91-4* Spinels, chromium copper black

Copper Chromite Black Spinel, an inorganic pigment, is a reaction product of high temperature calcination in which Copper (II) Oxide and Chromium (III) Oxide in varying amounts are homogeneously and ionically interdiffused to form a crystalline matrix of spinel.
Basic Chemical Formula: $CuCr_2O_4$

Its composition may include either one or both of the modifiers Fe_2O_3 and MnO

Use Category A, B, and C

CPMA 13-39-9 IRON COBALT BLACK SPINEL
C.1. 77498 C.I. Pigment Black 29
CAS 68187-50-8* Spinels, cobalt iron black

Iron Cobalt Black Spinel, an inorganic pigment, is a reaction product of high temperature calcination in which Iron (II) Oxide, Cobalt (II) Oxide, and Iron (III) Oxide in varying amounts are homogeneously and ionically interdiffused to form a crystalline matrix of spinel.
Basic Chemical Formula: $(Fe,Co)Fe_2O_4$

Its composition may include any one or a combination of the modifiers Al_2O_3, B_2O_3, MnO, NiO, SiO_2 or SnO_2

Use Category A
Predominantly used for coloring clay bodies.

CPMA 13-40-9 IRON COBALT CHROMITE BLACK SPINEL
C.I. 77502 C.I. Pigment Black 27
CAS 68186-97-0* Spinels, chromium cobalt iron black

Iron Cobalt Chromite Black Spinel, an inorganic pigment, is a reaction product of high temperature calcination in which Iron (II) Oxide, Cobalt (II) Oxide, Iron (III) Oxide, and Chromium (III) Oxide in varying amounts are homogeneously and ionically interdiffused to form a crystalline matrix of spinel.
Basic Chemical Formula: $(Co,Fe)(Fe,Cr)_2O_4$

Its composition may include any one or a combination of the modifiers Al_2O_3, B_2O_3, CuO, MnO, NiO, or SiO_2

Use Category A, B, and C
Predominantly used for coloring category A substrates.

CPMA 13-41-9 MANGANESE FERRITE BLACK SPINEL
C.I. 77494 C.I. Pigment Black 26
CAS 68186-94-7* Spinels, iron manganese black

Manganese Ferrite Black Spinel, an inorganic pigment, is a reaction product of high temperature calcination in which Manganese (II) Oxide, Manganese (III) Oxide, Iron (II) Oxide, and Iron (III) Oxide in varying amounts are homogeneously and ionically interdiffused to form a crystalline matrix of spinel.
Basic Chemical Formula: $(Fe,Mn)(Fe,Mn)_2O_4$

Its composition may include any one or a combination of the modifiers Al_2O_3, CoO, CuO, NiO, SiO_2, or TiO_2

Use Category B and C

CPMA 13-48-7 CHROME IRON MANGANESE BROWN SPINEL
C.I. 774945 C.I. Pigment Brown 46
CAS 68555-06-6* Spinels, chromium iron manganese brown
CAS 68186-96-9* Spinels, chromium iron manganese zinc brown

Chrome Iron Manganese Brown Spinel, an inorganic pigment, is a reaction product of high temperature calcination in which Chromium (III) Oxide, Iron (II & III) Oxide, and Manganese (II & III) Oxide in varying amounts are homogeneously and ionically interdiffused to form a crystalline matrix of spinel.
Basic Chemical Formula: $(Fe,Mn)(Fe,Cr,Mn)_2O_4$

Its composition may include the modifier ZnO.

Use Category A, B, and C

CPMA 13-49-2 COBALT TIN ALUMINA BLUE SPINEL
C. I. 773465 C.I. Pigment Blue 81
CAS 68608-09-3* Spinels, aluminum cobalt tin

Cobalt Tin Alumina Blue Spinel, an inorganic pigment, is the reaction product of high temperature calcination in which Aluminum (III) Oxide, Cobalt (II) Oxide, and Tin (IV) Oxide in varying amounts are homogeneously and ionically interdiffused to form a crystalline matrix of spinel.
Basic Chemical Formula: $CoA1_2O_4/Co_2SnO_4$

Its composition may include either one or both of the modifiers SiO_2, or ZnO

Use Category A
Exceptionally suitable for coloring ceramic glazes. Not generally used in clay bodies, or, porcelain enamels.

CPMA 13-50-9 CHROME IRON NICKEL BLACK SPINEL
C.I. 77504 C.I. Pigment Black 30
CAS 71631-15-7* Spinels, chromium iron nickel black

Chrome Iron Nickel Black Spinel, an inorganic pigment, is a reaction product of high temperature calcination in which Chromium (II) Oxide, Iron (II) Oxide, Iron (III) Oxide, and Nickel (II) Oxide in varying amounts are homogeneously and ionically interdiffused to form a crystalline matrix of spinel.
Basic Chemical Formula: $(Ni,Fe)(Cr,Fe)_2O_4$

Its composition may include any one or a combination of the modifiers CuO, MnO, or Mn_2O_3

Use Category A, **B and C**

CPMA 13-51-7 CHROME MANGANESE ZINC BROWN SPINEL
C.I. 77312 C.I. Pigment Brown 39
CAS 71750-83-9* Spinels, chromium manganese zinc brown

Chrome Manganese Zinc Brown Spinel, an inorganic pigment, is a reaction product of high temperature calcination in which Chromium (III) Oxide, Manganese (II) Oxide and Zinc (II) Oxide in varying amounts are homogeneously and ionically interdiffused to form a crystalline matrix of spinel.
Basic Chemical Formula: $(Zn,Mn)Cr_2O_4$

Its composition may include any one or a combination of the modifiers $A1_2O_3$, NiO, SiO_2, SnO_2, or TiO_2

Use Category A, B, and C

CLASS XIV. ZIRCON

CPMA 14-42-2 ZIRCONIUM VANADIUM BLUE ZIRCON
C.I. 77998 C.I. Pigment Blue 71
CAS 68186-95-8* Zircon, vanadium blue

Zirconium Vanadium Blue Zircon, an inorganic pigment, is a reaction product of high temperature calcination in which Zirconium (IV) Oxide, Silicon (IV) Oxide, and Vanadium (IV) Oxide in varying amounts are homogeneously and ionically interdiffused to form a crystalline matrix of zircon.
Basic Chemical Formula: $(Zr,V)SiO_4$

Its composition may include any one or a combination of the modifiers alkali or alkaline earth halides

Use Category A
Exceptionally suitable for coloring ceramic glazes and clay bodies. Not generally used in porcelain enamels.

CPMA 14-43-4 ZIRCONIUM PRASEODYMIUM YELLOW ZIRCON
C1. 77997 C.I. Pigment Yellow 159
CAS 68187-15-5* Zircon, praseodymium yellow

Zirconium Praseodymium Yellow Zircon, an inorganic pigment, is a reaction product of high temperature calcination in which Zirconium (IV) Oxide, Silicon (IV) Oxide, and Praseodymium (III, IV) Oxide (Pr_6O_{11}) in varying amounts are homogeneously and ionically interdiffused to form a crystalline matrix of zircon.
Basic Chemical Formula: $(Zr,Pr)SiO_4$

Its composition may include any one or a combination of the modifiers alkali or alkaline earth halides

Use Category A
Exceptionally suitable for coloring ceramic glazes and clay bodies. Not generally used in porcelain enamels.

CPMA 14-44-5 ZIRCONIUM IRON PINK ZIRCON
C.I. 77996 C.I. Pigment Red 232
CAS 68187-13-3* Zircon, iron coral
CAS 68412-79-3* Zircon, iron pink

Zirconium Iron Pink (peach, coral) Zircon, an inorganic pigment, is a reaction product of high temperature calcination in which Zirconium (IV) Oxide, Silicon (IV) Oxide, and Iron (III) Oxide in varying amounts are homogeneously and ionically interdiffused to form a crystalline matrix of zircon.
Basic Chemical Formula: $(Zr,Fe)SiO_4$

Its composition may include any one or a combination of the modifiers alkali or alkaline earth halides

Use Category A
Exceptionally suitable for coloring ceramic glazes. Not generally used in clay bodies, or, porcelain enamels.

Additional Pigment Categories may be added to the CPMA System from time to time when appropriate.

THE CPMA CLASSIFICATION SYSTEM OF THE COMPLEX INORGANIC COLOR PIGMENTS

XI. RUTILE

XII. SPHENE

XIII. SPINEL

XIV. ZIRCON

CLASSIFICATION BY COLOR

CLASSIFICATION BY USAGE

C.I. Number	CPMA Identification	
77003	03-03-5 Chrome Alumina Pink Corundum	11
77005	03-04-5 Manganese Alumina Pink Corundum	11
77288	03-05-3 Chromium Green-Black Hematite	12
77290	13-32-5 Chrome Alumina Pink Spinel	28
77300	04-07-3 Victoria Green Garnet	13
77301	12-25-5 Chrome Tin Pink Sphene	24
77310	11-17-6 Chrome Antimony Titanium Buff Rutile	19
77312	13-51-7 Chrome Manganese Zinc Brown Spinel	34
77332	06-09-8 Cobalt Nickel Gray Periclase	14
77343	13-29-2 Cobalt Chromite Blue-Green Spinel	26
77343:1	13-53-2 Zinc Chrome Cobalt Aluminum Spinel	26
77344	13-30-3 Cobalt Chromite Green Spinel	27
77346	13-26-2 Cobalt Aluminate Blue Spinel	24
773465	13-49-2 Cobalt Tin Alumina Blue Spinel	33
77347	13-28-2 Cobalt Zinc Aluminate Blue Spinel	25
77352	02-02-I Cobalt Magnesium Red-Blue Borate	10
77360	08-11-1 Cobalt Violet Phosphate	15
77363	08-12-1 Cobalt Lithium Violet Phosphate	16
77364	05-08-2 Cobalt Silicate Blue Olivine	13
77366	07-10-2 Cobalt Zinc Silicate Blue Phenacite	15
77368	13-27-2 Cobalt Tin Blue-Gray Spinel	25
77377	13-31-3 Cobalt Titanate Green Spinel	27
77428	13-38-9 Copper Chromite Black Spinel	31
77491	03-06-7 Iron Brown Hematite	12
77494	13-41-9 Manganese Ferrite Black Spinel	32
774945	13-48-7 Chrome Iron Manganese Brown Spinel	33
77496	13-36-7 Zinc Ferrite Brown Spinel	30
77497	13-35-7 Nickel Ferrite Brown Spinel	29
77498	13-39-9 Iron Cobalt Black Spinel	31
77501	13-33-7 Iron Chromite Brown Spinel	28
77502	13-40-9 Iron Cobalt Chromite Black Spinel	32
77503	13-37-7 Zinc Iron Chromite Brown Spinel	30
77504	13-50-9 Chrome Iron Nickel Black Spinel	34
77543	13-34-7 Iron Titanium Brown Spinel	29
77588	10-14-4 Lead Antimonate Yellow Pyrochlore	17
77788	11-15-4 Nickel Antimony Titanium Yellow Rutile	17
777850	5-45-3 Nickel Silicate Green Olivine	14
77862	11-22-4 Tin Vanadium Yellow Cassiterite	21
77863	11-23-5 Chrome Tin Orchid Cassiterite	22
77865	11-24-8 Tin Antimony Gray Cassiterite	22
77890	11-47-7 Manganese Niobium Titanium Brown Rutile	23
77891	11-46-7 Manganese Chrome Antimony Brown Rutile	23
77895	11-16-4 Nickel Niobium Titanium Yellow Rutile	18
77896	11-18-6 Chrome Niobium Titanium Buff Rutile	19

C.I. Number	CPMA Identification	
77897	11-19-6 Chrome Tungsten Titanium Buff Rutile	20
77898	11-21-8 Titanium Vanadium Antimony Gray Rutile	21
77899	11-20-6 Manganese Antimony Titanium Buff Rutile	20
77900	09-13-4 Nickel Barium Titanium Primrose Priderite	16
77902	11-52-4 Nickel Tungsten Yellow Rutile	18
77991	01-01-4 Zirconium Vanadium Yellow Baddeleyite	10
77996	14-44-5 Zirconium Iron Pink Zircon	36
77997	14-43-4 Zirconium Praseodymium Yellow Zircon	35
77998	14-42-2 Zirconium Vanadium Blue Zircon	35

CLASSIFICATION BY CAS REGISTRY NUMBERS

The following table provides the Chemical Abstract Service ("CAS") number for each of the complex inorganic color pigments listed in this volume. The asterisks shown in the following tables and in the entries provided above indicate those pigments which are classified as Unknown Variable Composition or Biologicals within the U.S. Toxic Substances Control Act inventory. Additional reference notes on the asterisks which denote variable composition in prior editions of this Handbook and a table describing the CAS registration numbers deleted by the CAS are located in Appendix C, page 70.

REGISTRY NUMBERS ASSIGNED BY THE CHEMICAL ABSTRACTS SERVICE

68553-01-5*	04-07-3 Victoria Green Garnet	13
68555-06-6*	13-48-7 Chrome Iron Manganese Brown Spinel	33
68608-08-2*	13-32-5 Chrome Alumina Pink Spinel	28
68608-09-3*	13-49-2 Cobalt Tin Alumina Blue Spinel	33
68608-93-5*	02-02-1 Cobalt Magnesium Red-Blue Borate	10
68610-13-9*	08-12-1 Cobalt Lithium Violet Phosphate	16
68610-24-2*	09-13-4 Nickel Barium Titanium Primrose Priderite	16
68611-42-7*	11-18-6 Chrome Niobium Titanium Buff Rutile	19
68611-43-8*	11-16-4 Nickel Niobium Titanium Yellow Rutile	18
68909-79-5*	03-05-3 Chromium Green-Black Hematite	12
69011-05-8*	11-52-4 Nickel Tungsten Yellow Rutile	18
69991-68-0*	11-46-7 Manganese Chrome Antimony Titanium Brown Rutile	23
70248-09-8*	11-47-7 Manganese Niobium Titanium Brown Rutile	23
71631-15-7*	13-50-9 Chrome Iron Nickel Black Spinel	34
71750-83-9*	13-51-7 Chrome Manganese Zinc Brown Spinel	34
74665-01-3*	13-53-2 Zinc Chrome Cobalt Aluminum Spinel	26

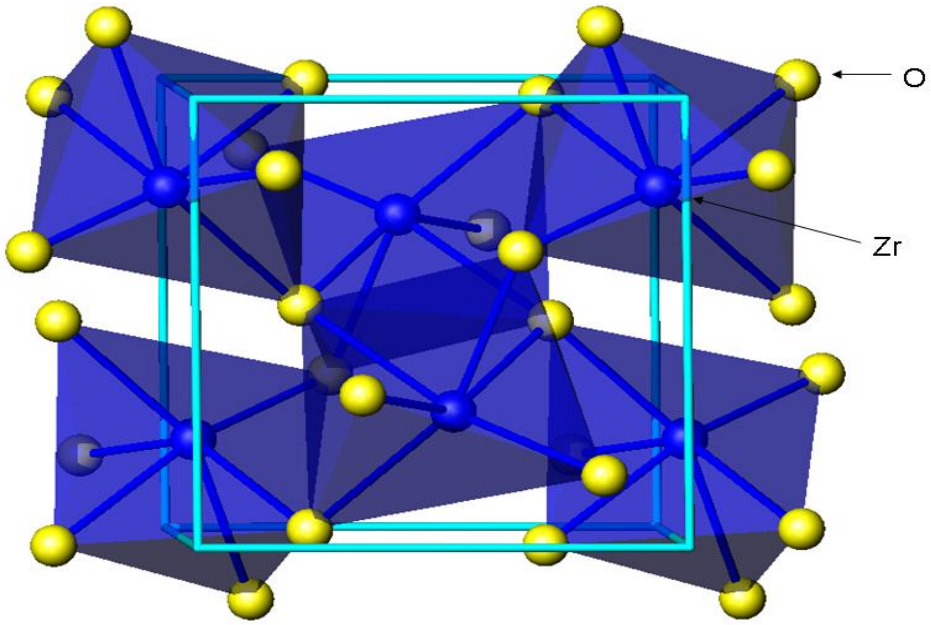
CLASSIFICATION BY METAL IN THE BASIC CHEMICAL FORMULA

Appendix A

CRYSTAL STRUCTURE DIAGRAMS
OF THE
FOURTEEN CRYSTAL CLASSES

(Structure drawings were prepared using ATOMS by Shape Software)

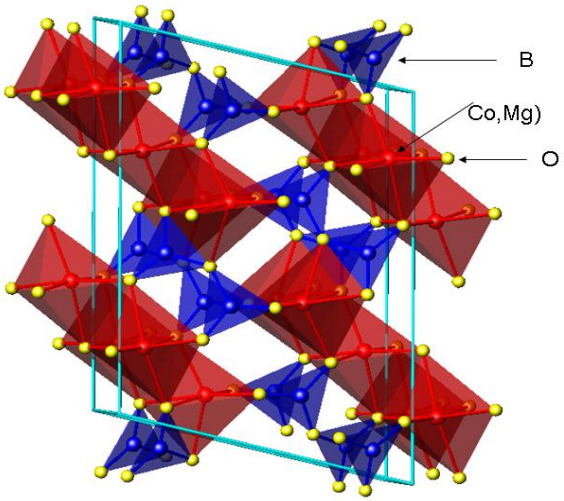
CLASS I: BADDELEYITE STRUCTURE



ZIRCONIUM VANADIUM YELLOW $(Zr,V)O_2$

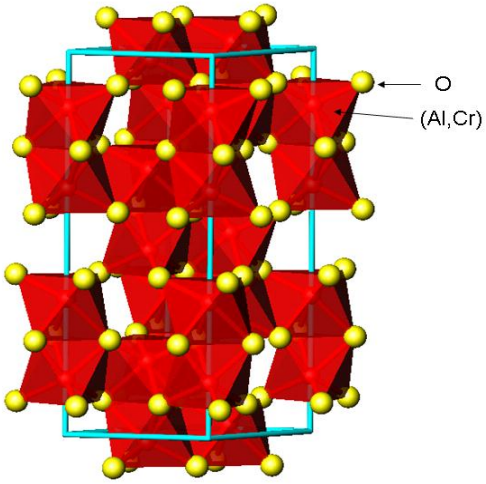
This drawing was produced with ATOMS by Shape Software.

CLASS II: BORATE STRUCTURE



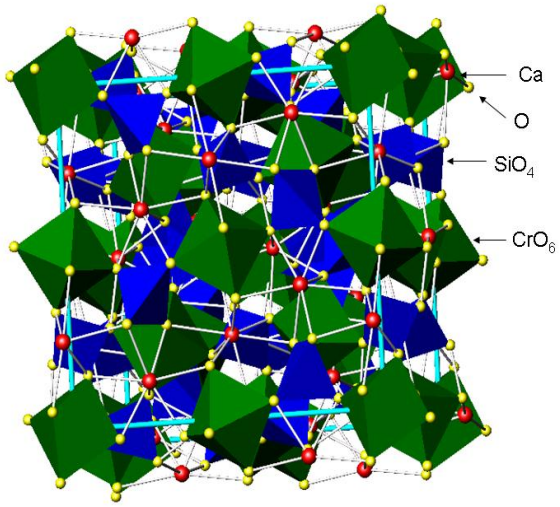
COBALT MAGNESIUM RED-BLUE BORATE $(CO,Mg)_2B_2O_5$
This drawing was produced with ATOMS by Shape Software.

CLASS III: CORUDUM - HEMATITE STRUCTURE



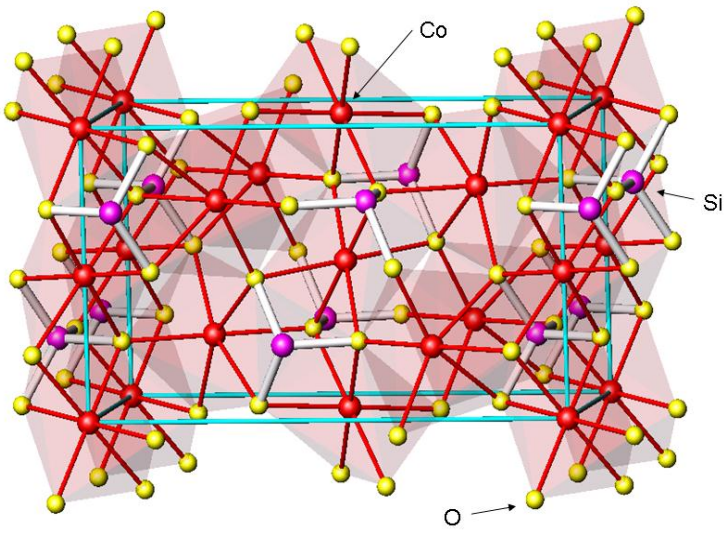
CHROME ALUMINA PINK $(Al,Cr)_2O_3$
This drawing was produced with ATOMS by Shape Software

CLASS IV: GARNET STRUCTURE



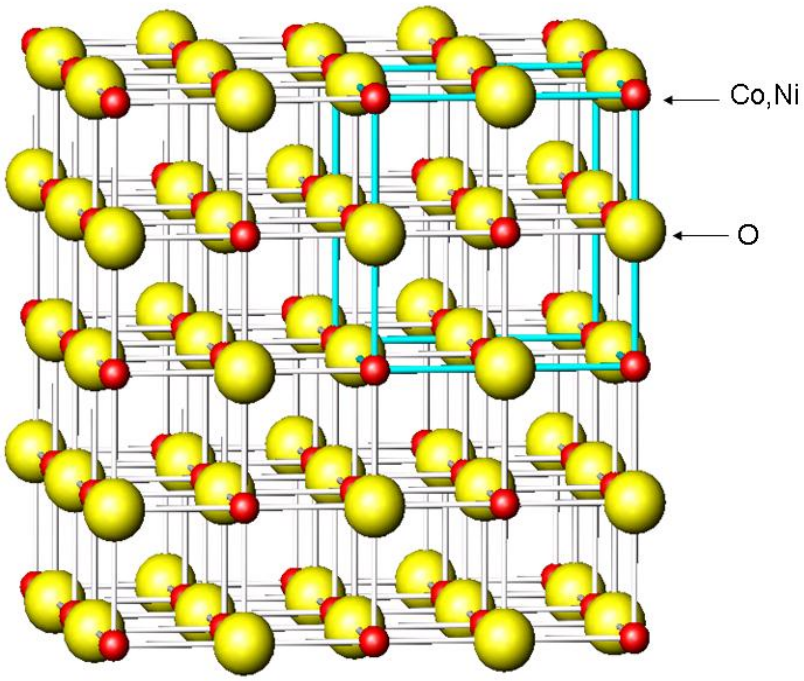
VICTORIA GREEN GARNET $3CaO.Cr_2O_3.3SiO_2$
This drawing was produced with ATOMS by Shape Software.

CLASS V: OLIVINE STRUCTURE



COBALT SILICATE BLUE Co_2SiO_4
This drawing was produced with ATOMS by Shape Software.

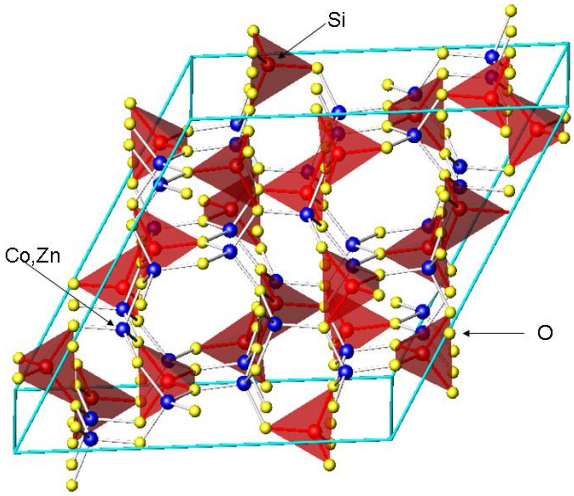
CLASS VI: PERICLASE STRUCTURE



COBALT NICKEL GRAY (Co,Ni) O

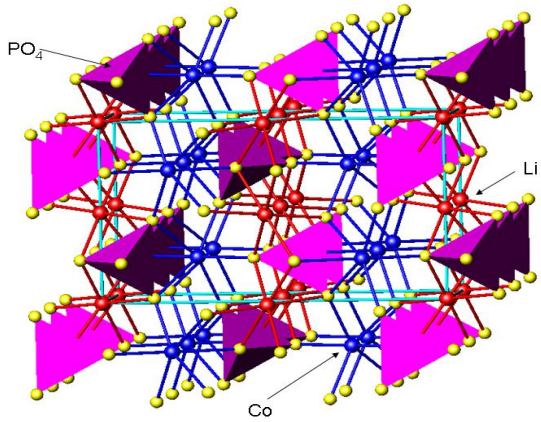
This drawing was produced with ATOMS by Shape Software.

CLASS VII: PHENACITE STRUCTURE



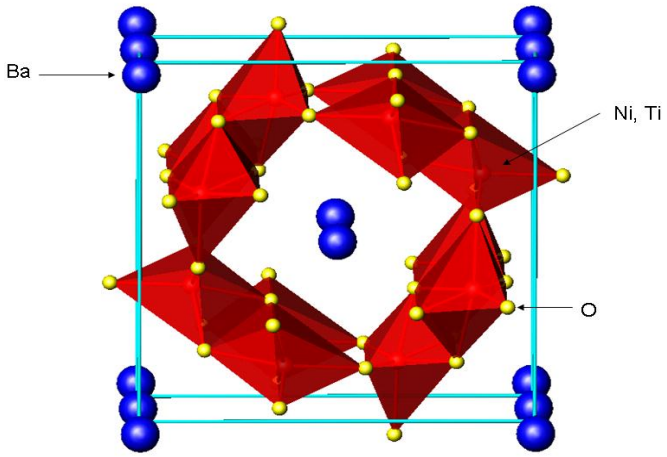
COBALT ZINC SILICATE BLUE $(C0,Zn)_2$ SiO_4
This drawing was produced with ATOMS by Shape Software.

CLASS VIII: PHOSPHATE STRUCTURE



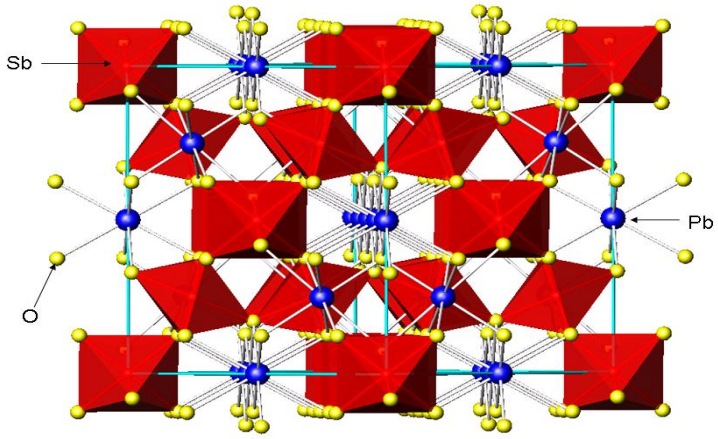
COBALT LITHIUM VIOLET $CoLiPO_4$
This drawing was produced with ATOMS by Shape Software.

CLASS IX: PRIDERITE STRUCTURE



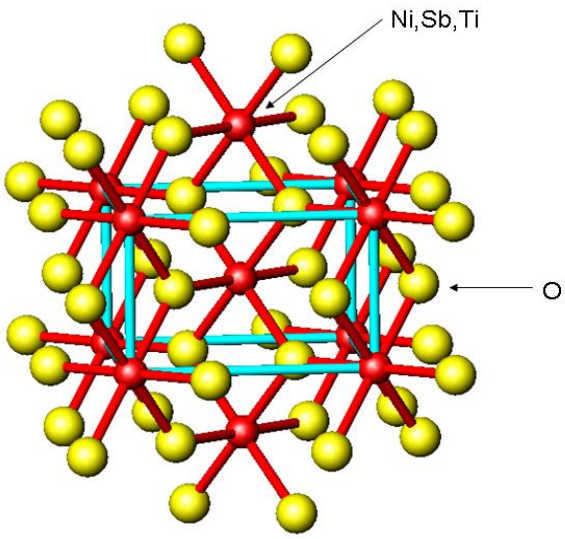
NICKEL BARIUM TITANIUM YELLOW $2NiO.3BaO.17TiO_2$
This drawing was produced with ATOMS by Shape Software.

CLASS X: PYROCHLORE STRUCTURE



LEAD ANTIMONATE YELLOW $PB_2Sb_2O_7$
This drawing was produced with ATOMS by Shape Software.

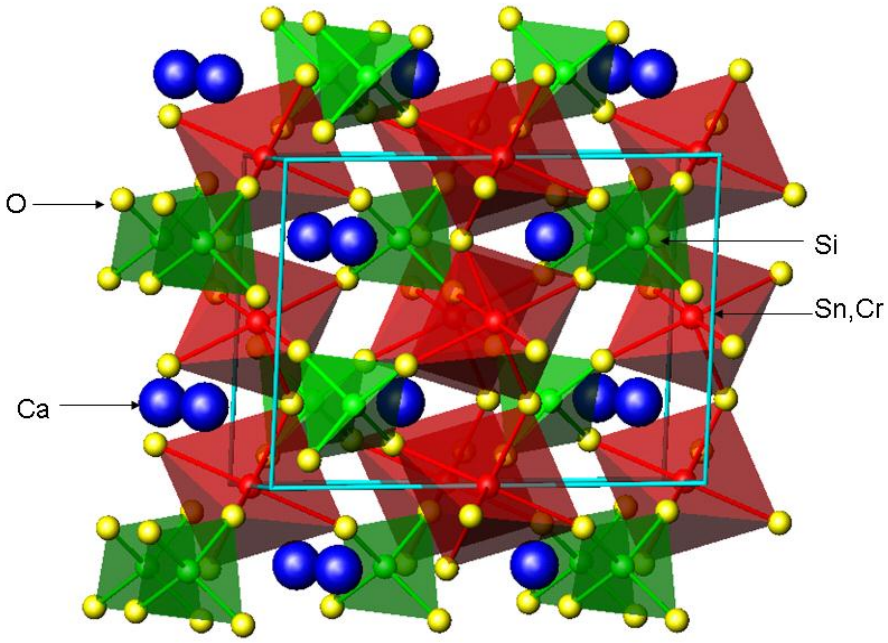
CLASS XI: RUTILE - CASSETERITE STRUCTURE



NICKEL ANTIMONY TITANIUM YELLOW $(Ni,Sb,Ti)O_2$

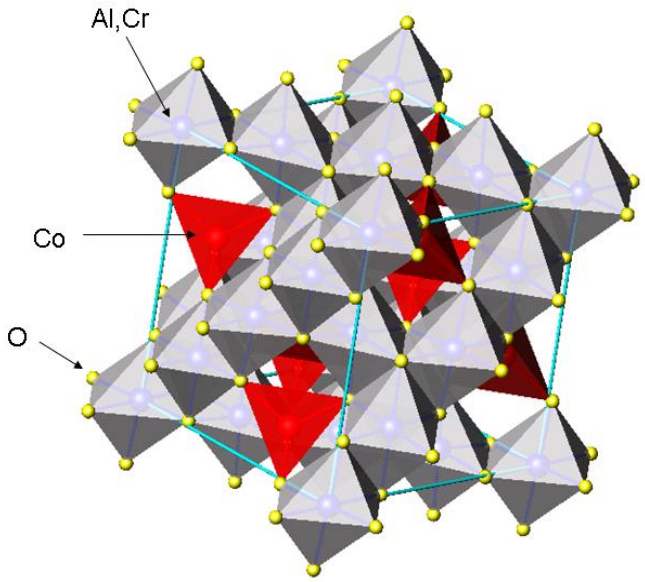
This drawing was produced with ATOMS by Shape Software.

CLASS XII: SPHENE STRUCTURE



CHROME TIN PINK $CaO.SnO_2.SiO_2:Cr_2O_3$
This drawing was produced with ATOMS by Shape Software.

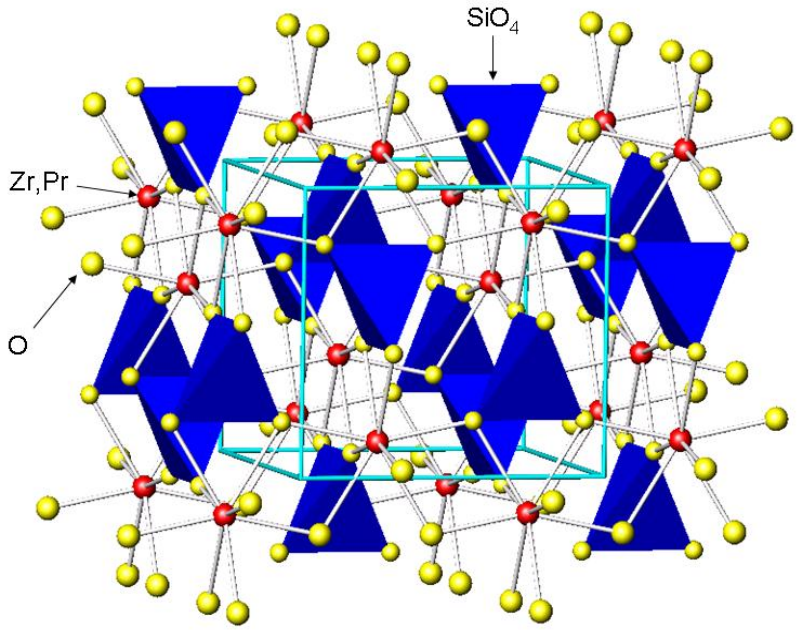
CLASS XIII: SPINEL STRUCTURE



COBALT CHROMITE BLUEGREEN SPINEL $Co(Al,Cr)_2O_4$

This drawing was produced with ATOMS by Shape Software.

CLASS XIV: ZIRCON STRUCTURE



ZIRCONIUM PRAESEODYMIUM YELLOW $(Zr,Pr)SiO_4$
This drawing was produced with ATOMS by Shape Software.

APPENDIX B

FOREWORD

to the

First, Second and Third Editions

APPENDIX B-1

FOREWORD
to the
First Edition

This system of classification and nomenclature applies to that diversified and extensive group of complex inorganic color products known as "porcelain enamel oxides," "ceramic stains," "ceramic colors," and encompassing inorganic metal oxide color pigments generally. Devised originally to fill a specific need, this system is herewith offered for general use in the business and technical communities dealing in any way with these materials.

Need for uniform terminology in this field became pointedly clear when U.S. manufacturers of ceramic colors and metal oxide color pigments came to face the Chemical Substance Inventory required by Section 8(b) of the Toxic Substances Control Act (Public Law 94-469) which became effective January I , 1977.

The basic problem was how to name and identify products to satisfy the EPA Inventory reporting regulations. Not only did each manufacturer have his own lengthy product list to contend with, but there was wide diversity in both code-name designation and composition of` similar materials throughout the industry. Irrespective of the terminology to be used, each manufacturer wanted to ensure that all the chemical substances in each of his products would appear on the final Inventory. But it was hoped that burdening the Inventory with each individual commercial product would he avoided.

With these common problems in mind, representatives from some ceramic color manufacturers met under the auspices of the Dry Color Manufacturers' Association on September 7, 1977. This project attracted wide enough attention that soon all eleven domestic manufacturers of metal oxide color pigments had joined the group which now comprised both members and non-members of DCMA. Designated as the Metal Oxides and Ceramic Colors Subcommittee, this group developed and adopted the present scheme of classification and definitions. This booklet presents, as the DCMA System, the Subcommittee's final listing as of September 7, 1978.

Although a ceramic color or metal oxide pigment product may consist of a mixture of different chemical phases, each phase is a distinct chemical substance characterized by a particular crystallographic structure. Each phase may encompass a range in concentration of its constituent oxides, or put the other way, some variability in stoichiometry and the presence of minor or dopant elements may be accommodated by the host crystal lattice constituting that phase.

The DCMA System categorizes all phases in ceramic color products first according to crystal structure, second according to color-range, and then according to the principal oxides comprising that phase. Thus any specific set of principal oxides imparting color to a phase constitutes a category of materials within which there may be variability in both stoichiometry and hue.
In addition, a given category of materials may include the presence of certain modifiers incorporated into the crystal structure.

A modifier is a compound or element which may alter the properties of the phase without changing its structure. Each category is also a separate chemical substance by virtue of its homogeneity and possession of properties distinct from the component oxides, and the terms "phase," "substance" and "category" are interchangeable in this context.

There are other ceramic colorants, such as cadmium sulfides and colloidal dispersions of gold or silver, which are not included in this classification because they are not mixed metal oxides. But insofar as the best exhaustive efforts of the Subcommittee has accomplished the task, all mixed metal oxide ceramic pigments are included here.

The DCMA System is comprehensive. The Chemical Descriptions of each category are broad and flexible enough to allow each product of every company to fit in, and allow for future developments as well. Products of the ceramic color industry have been reported for the Toxic Substances Control Act Inventory in the consistent nomenclature of the DCMA System.

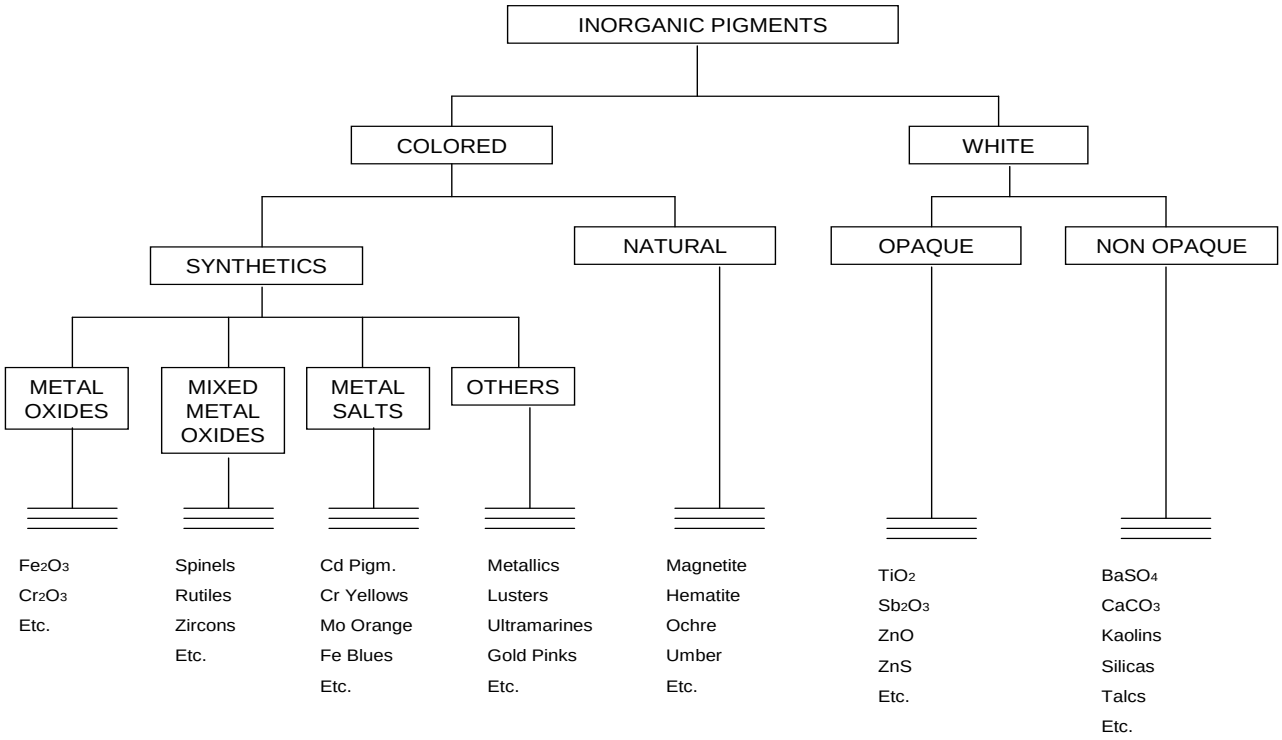
The Metal Oxides and Ceramic Colors Subcommittee has an ongoing program of developing information to support writing sensible regulations for the safe handling and use of metal oxide color products.

David J. Heiser, Chairman
Metal Oxides and Ceramic Colors Subcommittee
October 1978

APPENDIX B-2

FOREWORD
to the
Second Edition

The mixed metal oxide inorganic colored pigments represent only a small, but an important part of the entire family of the Inorganic Pigments, which may be classified as follows:[1]



Small as they may be the pigments of the mixed metal oxide inorganic group are the most heat resistant, chemically inert, light and weather fast pigments known to man. They are the result of high temperature calcinations and they consist exclusively of metal cations and oxygen ions. They are man made minerals which closely duplicate the properties of their natural parents which withstood the corrosive action of the sun, wind and rain for untold centuries.

[1]In the past these pigments were used almost exclusively for the coloration of glass matrixes and ceramic bodies. Today, however, their use has increased and covers the coloration of plastics and paints especially when heat and weather resistance are required.

The second edition of this booklet is an expansion and an update of the first edition.

It now contains all those colored inorganic mixed metal oxide pigments which are manufactured, imported, or processed in the United States.

These colored inorganic mixed metal oxide specialty pigments have all been reported to the United States Environmental Protection Agency (EPA) for the TSCA Inventory of Chemical Substances as required by Section 8(b) of the Toxic Substances Control Act. (Public Law 94-469) The U.S. Environmental Protection Agency (EPA) has listed each of these pigments in the Inventory by using a Registry Number assigned by the Chemical Abstract Service (CAS) organization. Some of the pigments are listed by more than just one CAS number. However, those numbers represent the same substance and may be used interchangeably.

Most of the CAS Registry Numbers assigned to the mixed metal oxide inorganic colored pigments are marked by an asterisk (*) to indicate that their composition is variable. Their chemical substance definitions coincide with that of the DCMA System Chemical Descriptions from which they were

[1] Aladar Burgyan "Characterization and Identification of The Mixed Metal Oxides and Ceramic Pigments Manufactured in the U.S." INTERCERAM, Vol. 28, No. 1, 1979.

adopted. The definitions are listed in Appendix A of Volume I of the Initial Inventory.

The Subcommittee requested and obtained C.I. Generic Names and C.I. Constitution Numbers for the mixed metal oxide pigments from the Society of Dyers and Colorists and the American Association of Textile Chemists and Colorists, publishers of the "Colour Index."

The "Colour Index" has long been established as the leading work in the field of colorant classification. It is officially recognized by Departments of many Governments, for both scientific and commercial purposes. Inclusion of our pigments in their listing will only enhance their value and will certainly be beneficial.

The Second Edition of the DCMA Booklet on Classification and Chemical Description of the Mixed Metal Oxide Inorganic Colored Pigments added seven new pigment categories to its list.

It now includes the CAS Registry Numbers from the TSCA Chemical Substances Inventory, the Colour Index Generic Names and the Colour Index Constitution Numbers, where available.

In addition, the pigments are classified and indexed according to their (I) Colors (2) Use Categories (3) Crystal Classes (4) C.1. Generic Names (5) C.I. Constitution Numbers and (6) their Metal Contents.

And finally, an Appendix containing the Crystal Structure Diagrams for the 14 Crystal Classes based on the works of the authors referred to has also been included.

The members of the Metal Oxides and Ceramic Colors Subcommittee of the Dry Color Manufacturers' Association offer this booklet to the scientific and technical community at large not without satisfaction and some degree of pride.

This is the first time that this entire group of complex inorganic color products known as "porcelain enamel oxides," "ceramic stains," "ceramic colors," etc. have been defined, identified, characterized, classified and named.

May this booklet serve well the ceramic coatings, plastics, and organic coatings industries as well as all those users of these specialty inorganic colored pigments who need information regarding their nature, classification, and manufacture.

Aladar Burgyan, Chairman
Metal Oxides and Ceramic Colors Subcommittee
January 1982

Appendix B-3

FOREWORD
to the
Third Edition

The *DCMA Classification and Chemical Description of the Complex Inorganic Color Pigments* booklet has now been in print for more than ten years. It has achieved worldwide usage by both the manufacturers and users of the complex inorganic color pigments. (Previous editions of the booklet were entitled *DCMA Classification and Chemical Description of the Mixed Metal Oxide Inorganic Colored Pigments.* The Committee that prepared the booklet now identifies these colorants as Complex Inorganic Pigments and the name of this booklet has been changed accordingly. It is felt that this name more accurately describes the type of pigments under discussion.)

The Third Edition updates the major expansion that occurred since the Second Edition*. This edition responds to the elimination of the duplicate CAS numbers by the Environmental Protection Agency and includes additional Color Index identification. Two new pigments have been included namely, CPMA 11-52-4 Nickel Tungsten Yellow Rutile and CPMA 13-53-2 Zinc Chrome Cobalt Aluminum Spinel. We have also added a definition for a Mineralizer and refined the definition for a Modifier.

We hope the booklet will continue to be a widely-used reference throughout our industry, at universities and wherever our products are used or studied. As pointed out in the First Edition* of our booklet, the impetus for our starting this work was the need for uniform terminology to report our products for the Chemical Substance Inventory of the Toxic Substances Control Act (Public Law 94-469). That need is before us once more as our Canadian neighbors go through the preliminary steps to develop their Inventory List. We hope this booklet will simplify the incorporation of the complex inorganic color pigments in this new inventory.

The membership list continues to change, and we have continued the practice of recognizing past committee members who have contributed so much to the development and expansion of this booklet. Those of us who have been involved since that first meeting in September 1977 when we had a "clean sheet of paper" on the table can look back with satisfaction and pride in being a part of this program. This is not to say those who have joined since have not contributed equally. They surely have, and continue to do so. In this respect I would like to especially thank Demetra Balmer, Ferro Corporation and John Dickenson, Engelhard, for their tireless work in bringing about this Third Edition.

A hearty thanks to each and every Complex Inorganic Color Pigments Committee member for their help and continued support of committee activities.

Ted E. Potter, Chairman Complex Inorganic Color Pigments Committee

*Those interested in a complete understanding of the evolution of this publication may wish to review the Foreword to the First Edition and the Foreword to the Second Edition, in Appendix B.

Appendix C

REGISTRY NUMBERS DELETED BY THE CHEMICAL ABSTRACTS SERVICE

CAS Number	CPMA No.	PIGMENT NAME	Deleted CAS No.	Deleted CAS No.	Pg
1317-63-1*	03-06-7	Iron Brown Hematite	12425-99-9	68187-35-9	12
1345-16-0	13-26-2	Cobalt Aluminate Blue Spinel	6186-86-7	160936-12-9	24
8007-18-9	11-15-4	Nickel Antimony Titanium Yellow Rutile	12227-91-7	71077-18-4 90552-50-4	17
8012-00-8	10-14-4	Lead Antimonate Yellow Pyrochlore	12710-25-7	68187-20-2	17
12063-19-3	13-36-7	Zinc Ferrite Brown Spinel	882315-44-8 164250-66-2 548491-80-1 1005291-42-8 263842-41-7	651053-04-2 71615-25-3 745830-57-3 116094-82-7	30
13455-36-2	08-11-1	Cobalt Violet Phosphate	137525-12-3		15
68186-85-6*	13-31-3	Cobalt Titanate Green Spinel	130938-79-3		27
68186-87-8*	13-28-2	Cobalt Zinc Aluminate Blue Spinel			25
68186-88-9*	13-37-7	Zinc Iron Chromite Brown Spinel	131461-87-5		30
68186-89-0*	06-09-8	Cobalt Nickel Gray Periclase			14
68186-90-3*	11-17-6	Chrome Antimony Titanium Buff Rutile	68859-62-1 72779-94-3	72779-95-4 146908-55-6 179606-69-0	19
68186-91-4*	13-38-9	Copper Chromite Black Spinel			31
68186-92-5*	11-19-6	Chrome Tungsten Titanium Buff Rutile			20
68186-93-6*	11-22-4	Tin Vanadium Yellow Cassiterite			21
68186-94-7*	13-41-9	Manganese Ferrite Black Spinel	69234-82-8	86090-41-7 206452-06-2	32
68186-95-8*	14-42-2	Zirconium Vanadium Blue Zircon	75367-22-5		35
68186-96-9*	13-48-7	Chrome Iron Manganese Brown Spinel			33
68186-97-0*	13-40-9	Iron Cobalt Chromite Black Spinel	95046-45-0	68477-07-6 68608-10-6	32
68186-99-2*	03-04-5	Manganese Alumina Pink Corundum	95193-78-5		11
68187-00-8*	11-21-8	Titanium Vanadium Antimony Gray Rutile			21
68187-01-9*	01-01-4	Zirconium Vanadium Yellow Baddeleyite			10
68187-02-0*	13-34-7	Iron Titanium Brown Spinel	94945-25-2	68477-08-7	29
68187-05-3*	13-27-2	Cobalt Tin Blue-Gray Spinel			25
68187-09-7*	13-33-7	Iron Chromite Brown Spinel			28
68187-10-0*	13-35-7	Nickel Ferrite Brown Spinel			29
68187-11-1*	13-29-2	Cobalt Chromite Blue-Green Spinel	12224-91-8		26
68187-12-2*	12-25-5	Chrome Tin Pink Sphene			24
68187-13-3*	14-44-5	Zirconium Iron Pink Zircon			36
68187-15-5*	14-43-4	Zirconium Praseodymium Yellow Zircon	95193-94-5		35
68187-27-9*	03-03-5	Chrome Alumina Pink Corundum	68512-46-9		11
68187-40-6*	05-08-2	Cobalt Silicate Blue Olivine			13
68187-49-5*	13-30-3	Cobalt Chromite Green Spinel	8011-88-9		27
68187-50-8*	13-39-9	Iron Cobalt Black Spinel			31
68187-51-9*	13-36-7	Zinc Ferrite Brown Spinel	61512-66-1	68477-09-8 68608-11-7	30
68187-53-1*	11-23-5	Chrome Tin Orchid Cassiterite			22

68187-54-2*	11-24-8 Tin Antimony Gray Cassiterite		22
68201-65-0*	13-32-5 Chrome Alumina Pink Spinel	68608-08-2	28
68412-38-4*	11-20-6 Manganese Antimony Titanium Buff Rutile		20
68412-74-8*	07-10-2 Cobalt Zinc Silicate Blue Phenacite		15
68412-79-3*	14-44-5 Zirconium Iron Pink Zircon		36
68553-01-5*	04-07-3 Victoria Green Garnet	68153-74-2	13
68555-06-6*	13-48-7 Chrome Iron Manganese Brown Spinel		33
68608-08-2*	13-32-5 Chrome Alumina Pink Spinel		28
68608-09-3*	13-49-2 Cobalt Tin Alumina Blue Spinel		33
68608-93-5*	02-02-1 Cobalt Magnesium Red-Blue Borate		10
68610-13-9*	08-12-1 Cobalt Lithium Violet Phosphate		16
68610-24-2*	09-13-4 Nickel Barium Titanium Primrose Priderite		16
68611-42-7*	11-18-6 Chrome Niobium Titanium Buff Rutile		19
68611-43-8*	11-16-4 Nickel Niobium Titanium Yellow Rutile		18
68909-79-5*	03-05-3 Chromium Green-Black Hematite		12
69011-05-8*	11-52-4 Nickel Tungsten Yellow Rutile		18
69991-68-0*	11-46-7Manganese Chrome Antimony Titanium Brown Rutile		23
70248-09-8*	11-47-7 Manganese Niobium Titanium Brown Rutile		23
71631-15-7*	13-50-9 Chrome Iron Nickel Black Spinel		34
71750-83-9*	13-51-7 Chrome Manganese Zinc Brown Spinel		34
74665-01-3*	13-53-2 Zinc Chrome Cobalt Aluminum Spinel		26

* The asterisks shown with most Chemical Abstracts Service ("CAS") Numbers above designate variable composition. These asterisks were first used in the Second Edition of the Handbook. According to statements included in the Forward to the Second Edition of the Handbook and included in this Edition at Appendix B-2 on Page 67, the asterisks designate pigments which are defined by the CAS as variable.

The CAS does not assign asterisks to variable composition substances. The TSCA inventory does use asterisks to signify Unknown Variable Composition or Biological ("UVCB") substances. The use of the asterisks in the Second and Third Editions of the Handbook was likely intended to reflect the TSCA designation of UVCBs, not a definition created by the CAS.

The First Edition of this Handbook was prepared in anticipation of registering the listed complex inorganic color pigments on the TSCA inventory. The CPMA Committee applied for and received CAS registration numbers for virtually all of the complex inorganic color pigments included in the First Edition of the Handbook. The CAS numbers were used for TSCA registration by individual members and subsequently were included in the Second Edition of the Handbook. Some of the complex inorganic color pigments were at that time already associated with existing CAS registration numbers.

The CAS numbers obtained by the Committee can be easily identified since the registration numbers are shown in a rough sequence which begins with similar digits. For example, 46 pigments listed in this Edition begin with the digits 68, two pigments begin with the digits 69, and two pigments begin with the the digits 71. All of the CAS registration numbers obtained by the Committee are defined by CAS with the same variable composition definition for the pigments as is incorporated above.

After the initial TSCA Inventory was published, the CAS deleted numerous CAS numbers which were determined to be duplicates. In some cases, the CAS registration numbers deleted are the those assigned to the registration submitted to CAS by the Committee.

In the Second Edition of this Handbook (January, 1982), some of the deleted registration numbers and all of the Committee CAS numbers retained by the CAS were presented in the appended table of CAS registration numbers. Several such pigments were listed twice, once for each CAS number. In those cases, the Second Edition Handbook shows both the deleted CAS number, originally obtained by the CPMA Committee as variable in composition, by adding an asterisk and a second CAS registry number which does not reflect the Committee's variable definition for the pigments and does not therefore show an asterisk. In the list above, the CAS registration numbers for these pigments, which do not reflect the definitions generated by the Committee, do not have the asterisk indicating that the substance is

variable. In the Third Edition of the Handbook (1991), the deleted CAS registry numbers were removed without explanation, such that each listed pigment had only one CAS registry number. For the five pigments in the Third Edition of the Handbook where the CAS registry number was not the registration obtained by, and defined by, the CPMA Committee, the CAS registration numbers were not shown with an asterisk.

The asterisks in the Second and Third Editions of this Handbook did not reflect any specific parameter for variable structure defined by the CAS. Instead, the asterisks are designations made by the Committee members in the process of editing the Second and Third Editions of the Handbook. All of the pigment CAS numbers shown with an asterisk in the Third Edition of the Handbook are the CAS definitions originally written by the Committee for the First Edition of this Handbook. The CAS numbers representing the same chemical structures with definitions that were not written by the Committee are not shown as variable in the Third Edition of this Handbook. The CAS definitions for pigment structures registered with CAS by others do not include modifiers which would make the structure variable.

It is likely that the asterisks used in the Second and Third Editions of the Handbook were intended to reflect the TSCA Inventory. UVCB's in the TSCA inventory are identified with asterisks. In the majority of cases, where the CAS has maintained the Committee's CAS registration and deleted other CAS registration numbers for the same chemical structures, these substances are classified properly on the Inventory as UVCBs with variable composition based on modifiers incorporated in the definition.