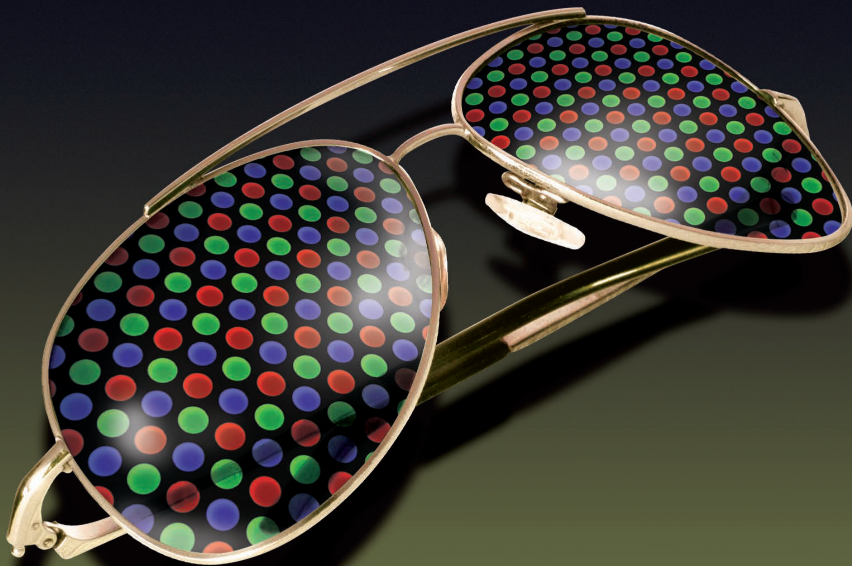
Materials for Energy Applications

Photovoltaics, Fuel Cells, LED/Quantum Dots, Energy Storage, Hydrogen Storage, Metal Organic Frameworks



Dealloyed Pt core-shell nanoparticles: Active and durable electrocatalysts for low-temperature Polymer Electrolyte Membrane Fuel Cells (PEMFCs)

by Professor Dr. Peter Strasser

Strem Chemicals Chemist Finds New Way to Drive to Work

by Dr. Antony Wright

STREM

Table of Contents

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Glossary of Terms

$[\alpha]_D$	....	Specific rotation
AAS	....	Atomic Absorption Standard
ACS	....	Conforms to American Chemical Society specifications
air sensitive	....	Product may chemically react with atmospheric oxygen or carbon dioxide at ambient conditions. Handle and store under an inert atmosphere of nitrogen or argon.
amp	....	Ampouled
b.p.	....	Boiling point in °C at 760mm, unless otherwise noted
d.	....	Density
dec.	....	Decomposes
elec. gr.	....	Electronic Grade, suitable for electronic applications
f.p.	....	Flash point in °F
gran.	....	Granular
heat sensitive	....	Product may chemically degrade if stored for prolonged periods of time at ambient temperatures or higher. Store at 5°C or lower.
hydrate	....	Unspecified water content which may vary slightly from lot to lot
hygroscopic	....	Product may absorb water if exposed to the atmosphere for prolonged periods of time (dependent on humidity and temperature). Handle and store under an inert atmosphere of nitrogen or argon.
light sensitive	....	Product may chemically degrade if exposed to light
liq.	....	Liquid
m.p.	....	Melting point in °C
moisture sensitive	....	Product may chemically react with water. Handle and store under an inert atmosphere of nitrogen or argon.
NMR grade		Suitable as a Nuclear Magnetic Resonance reference standard
optical grade	....	For optical applications
pwdr.	....	Powder
primary standard	....	Used to prepare reference standards and standardize volumetric solutions
PURATREM	....	Product has a minimum purity of 99.99% (metals basis)
purified	....	A grade higher than technical, often used where there are no official standards
P. Vol.	....	Pore volume
pyrophoric	....	Product may spontaneously ignite if exposed to air at ambient conditions
reagent	....	High purity material, generally used in the laboratory for detecting, measuring, examining or analyzing other substances
REO	....	Rare Earth Oxides. Purity of a specific rare-earth metal expressed as a percentage of total rare-earths oxides.
SA	....	Surface area
store cold	....	Product should be stored at -18°C or 4°C, unless otherwise noted (see product details)
subl.	....	Sublimes
superconductor grade	....	A high purity, analyzed grade, suitable for preparing superconductors
tech. gr.	....	Technical grade for general industrial use
TLC	....	Suitable for Thin Layer Chromotography
v.p.	....	Vapor pressure mm of Hg
xtl.	....	Crystalline

About Purity

Chemical purity	....	is reported after the chemical name, e.g. Ruthenium carbonyl, 99%
Metals purity	....	is reported in parentheses with the respective element, e.g. Gallium (III) bromide, anhydrous, granular (99.999%-Ga) PURATREM where 100% minus the metal purity is equal to the maximum allowable percentage of trace metal impurity

Biographical Sketches

Professor Peter Strasser holds a chaired professorship in the Chemical Engineering Division of the Department of Chemistry at the Technical University of Berlin. Prior to his appointment, he was a Professor at the Department of Chemical and Biomolecular Engineering at the University of Houston. Before moving to Houston, Prof. Strasser served as Senior Member of staff at Symyx Technologies, Inc. in Santa Clara, California. He supervised a research team in the Electronic Materials, Electrocatalysis and the Heterogeneous Catalysis Group.

In 1999, Prof. Strasser earned his doctoral degree in Physical Chemistry and Electrochemistry from the 'Fritz-Haber-Institute' of the Max-Planck-Society, Berlin, Germany, under the direction of the 2007 Chemistry Noble Laureate, Professor Gerhard Ertl. In the same year, he was awarded the 'Otto-Hahn Research Medal' for the 'outstanding dissertation of the year 1999' by the Max-Planck Society.

In 1996, Dr. Strasser was visiting scientist with Sony Central Research, Yokohama, Japan. He studied chemistry at Stanford University (1991-1992), the University of Tuebingen, Germany (1988-1995), and the University of Pisa, Italy (1992-1993), and received his diploma degree (MS) in chemistry in 1995.

Professor Strasser is interested in fundamental and applied aspects of the Materials Science and Electrocatalysis of electrified liquid solid interfaces.

Dr. Antony P. Wright joined the Strem Chemicals family in 2001 as the Regulatory and Quality Control Consultant (Pharmaceutical Intermediates). He has published 23 Academic papers and 26 US Patents.

Tony received his Bachelor of Science degree in Chemistry in 1963 from McGill University. In 1973 he graduated from the University of Wisconsin-Madison with a Doctor of Philosophy degree in Inorganic Chemistry.

From 1963-1967 Tony served in the U.S. Navy as a Supply Officer, accounting and stores management, on the USS Uvalde. After his time with the Navy he was employed by Wacker Silicones Company in Adrian, Michigan as a Process Research Chemist. He spent many years, from 1973-1999, at Dow Corning Corporation in Midland, Michigan as a Scientist in Silicone Intermediates, Catalysis, and Elastomers and Coatings. He was also a Visiting Scientist at MIT from 1999-2000.

Dealloyed Pt core-shell nanoparticles: Active and durable electrocatalysts for low-temperature Polymer Electrolyte Membrane Fuel Cells (PEMFCs)

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Polymer electrolyte membrane fuel cells (PEMFCs) represent an important emerging power generation technology for stationary as well as medium and long range transportation applications. This is because PEMFCs show favorable gravimetric power densities, while the fuels they run on typically exhibit high gravimetric energy densities(1-5) compared to state-of-art metal ion batteries. However, wider use of PEMFC technology is hampered by performance, cost, and durability issues associated with materials and components. Figure 1 displays a cross section of the layered structure of a low temperature PEMFC showing the anode (left) and cathode (right) gas diffusion layers (GDLs), which sandwich the anode and cathode catalyst layers and the proton exchange membrane. Figure 1 also schematically shows the molecular as well as electrical pathways of hydrogen fuel molecules, oxygen molecules, protons as well as of electrons. The overall performance of a PEMFC in terms of its practical cell voltage is limited by kinetic, ohmic, and mass transport processes for low, medium and high current densities, respectively. Of these, the kinetic surface catalytic reactions cause the most severe fuel cell voltage losses.

The electrocatalytic Oxygen Reduction Reaction (ORR) at the cathode according to

$$O_2 + 4\,H^+ + 4\,e^- \rightarrow 2\,H_2O \qquad E^0 = +1.23\ \text{V/RHE} \qquad (1)$$

represents a key challenge in PEMFC technology(5-7). In acidic media, Pt catalysts supported on high surface area carbons are the ORR catalysts of choice.(8,9) Dating back to catalysis research for Phosphoric acid fuel cells (PAFCs), many experimental ORR catalysis studies during the 1990s focused on Pt-rich bimetallic alloys which typically exhibited a modest intrinsic activity improvement of a factor of 2-3x at 900 mV cell voltage compared to pure Pt.(10-17)

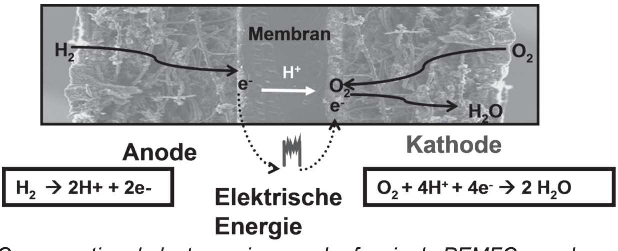

***Figure 1**: Cross sectional electron micrograph of a single PEMFC membrane electrode assembly. Chemical catalytic reaction and transport processes are indicated.*

At the beginning of this millennium, consensus was reached that virtually all metal alloy ORR catalysts leach their non-noble metal component to some degree. This implies that ORR catalyst form a core-shell structure under operando conditions of a fuel cell. So, in subsequent years focus shifted toward core-shell ORR catalyst concepts. Such structures show a two-fold advantage. First, the expensive noble metal is enriched in the shell, while nearly absent in the particle core; this helps minimize the noble metal content for a given catalyst surface area. Second, the nature and composition of the particle core controls the surface catalytic behavior of the active noble metal in the shell through electronic and geometric effects. This can significantly increase the intrinsic surface-area normalized catalyst activity. Taken together, owing to their core-shell structure, technologically relevant and economically viable fuel cell catalyst performances have been realized over the past years.

This article addresses dealloyed Pt core-shell fuel cell electrocatalysts.[18-39] Dealloying is the selective removal of a less noble component from the surface of a bimetallic alloy [40-42]; dealloying of macroscopic alloys has been studied in the corrosion science community for several decades. Exploring the atomic processes of dealloying of nanoscale alloys, however, is poorly understood and has become a research area of much interest. Owing to their compositional and geometric structure, dealloyed Pt alloy particle catalysts are active materials for the oxygen electroreduction at the fuel cell cathode, exhibiting a multi-fold increase in the Pt mass based ORR activity as well as their surface-area normalized activity. Also, dealloyed core shell nanocatalysts lend themselves well for use in carbon-supported high-surface area catalyst formats as used in Membrane Electrode Assemblies (MEAs) of Polymer Electrolyte fuel cells (PEMFCs).

The concept of dealloyed Pt core-shell nanocatalysts

Figure 2 illustrates a dealloying process of a precursor particle that results in a Pt core-shell nanoparticle. A bimetallic alloy precursor consisting of a more noble and a less noble component is enriched in the less noble component and undergoes a chemical or electrochemical leaching, which selectively removes the less noble metal from the surface of the alloy nanoparticle. The more noble component remains at the surface of the particle in a highly under-coordinated state and diffuses along the surface until it binds to a step or kink site. This interplay of dissolution and surface diffusion eventually forms a dealloyed core-shell particle with a Pt-enriched surface region (particle shell).

The thickness of the Pt enriched shell of the dealloyed particles can be controlled by choice of dealloying conditions such as dealloying potential, acid type and concentration, or leaching time. Studies have revealed that all these parameters affect the rate of leaching and the rate of Pt surface diffusion, which are the underlying controlling parameters in the dealloying process. Dealloyed particle shells typically consist of multiple Pt layers. Aside from dealloying process parameters, the initial particle size and composition affect the rate of dissolution and Pt surface diffusion, as well, and, as such, control the emerging morphology of the resulting dealloyed particles.

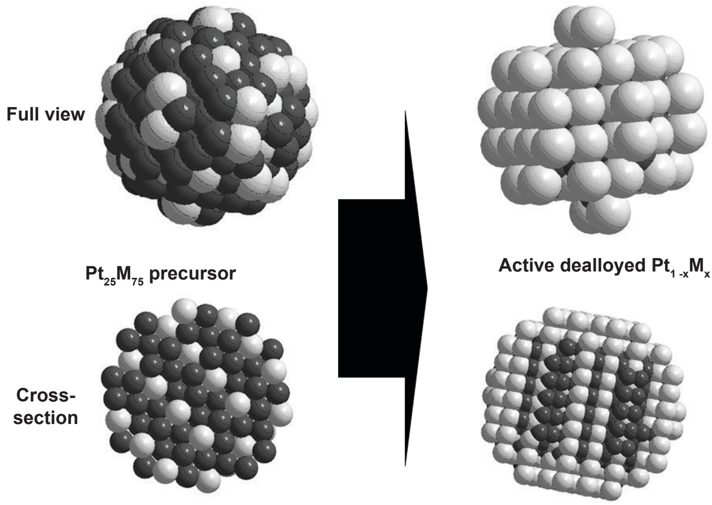

***Figure 2**: The notion of dealloyed Pt core-shell nanoparticles: an alloy particle precursor is chemically leached or electrochemically dealloyed. As the less noble alloy component selective leaches out, a Pt shell remains surrounding a Pt alloy core. Reproduced from ref.(30)*

Synthesis and characterization of alloy catalyst precursors

Dealloyed Pt ORR electrocatalysts are prepared from bimetallic Pt-M alloy precursors consisting of Pt and a less noble metal ‘M’. The alloy precursor is generally designed to be enriched in the less noble component to ensure ready bulk dealloying, that is, it exhibits stoichiometries of Pt_xM_{1-x} with x=0.1–0.5. Preferably, the less noble metal M is miscible with Pt. Copper and other face center cubic metals fulfill this condition well.

The synthesis of M rich precursor materials may involve stepwise impregnation of aqueous salt solutions of Pt and M onto weighted amounts of highly dispersed carbon supports. The impregnation is followed by freeze drying, chemical reduction, and thermal alloying of the carbon/ Pt / M composite. Surfactants, organic capping ligands, or even polymers have been used to improve the dispersion of the catalyst precursors, yet the complete removal of the surfactant/polymer has remained a challenge.

Figure 3 shows examples of typical X-ray diffraction profiles of $Pt_{25}M_{75}$ (here M=Cu) precursors thermally reduced and annealed at 600°C, 800°C, and 950°C. The overall peak profiles suggest the formation of disordered face centered cubic (fcc) alloys. The peak pattern further suggests that annealing at 600°C and 800°C was insufficient to form perfectly homogeneous Pt-Cu alloys phases: sharp reflections consistent with a pure Cu phase with large crystallite size (in special cases related to the mean particle size) remain visible in the XRD profile. The alloy uniformity improves for increasing annealing temperatures; while this is typically desirable, the crystallite size also increases.

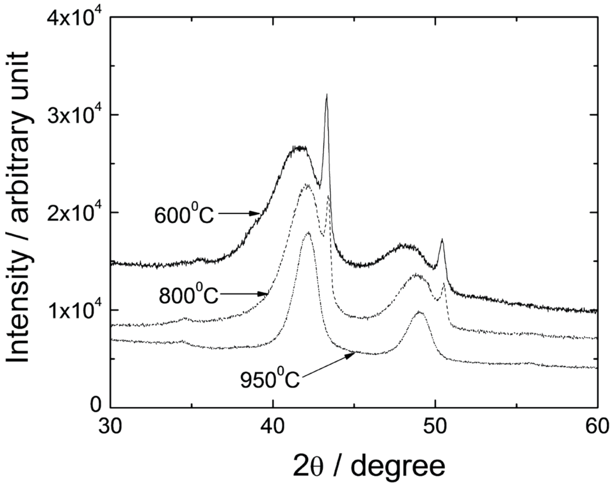

***Figure 3**: X-ray diffraction profiles of Pt-Cu alloy nanoparticle precursors, prepared at three different temperatures. Reproduced from ref.(30)*

Catalyst activation and oxygen reduction reaction (ORR) activity

The selective dissolution of the less noble alloy component is a key process in the formation of the active core-shell catalyst. Figure 4 reports the cyclic voltammograms (CVs) during the initial stage of the dealloying process for three $PtCo_3$ and one $PtCu_3$ precursor. The first voltammetric dealloying cycle of both the Pt-Co and the Pt-Cu materials exhibited broad and intense Co and Cu dissolution peaks. On the cathodic scans, first, surface Pt oxides are reduced to metallic Pt followed by sharp anodic feature commensurate with renewed dissolution of Co (slightly positive current waves in Figure 4a-c and, in case of the Pt-Cu materials in a stagnant electrolyte, by the deposition of Cu (Figure 4d). During subsequent voltammetric dealloying cycles, the voltammetric profile gradually approaches that of a pure Pt surface in accordance with the notion of the formation of a Pt particle shell. During the dealloying process the material loses significant amounts of Co and Cu and, depending on initial alloy composition and the dealloying conditions (upper turning potential, potential scan rate, acid conditions, temperature etc), may reach final compositions of the core-shell structures of up to $Pt_{80}M_{20}$ (M=Cu or Co).

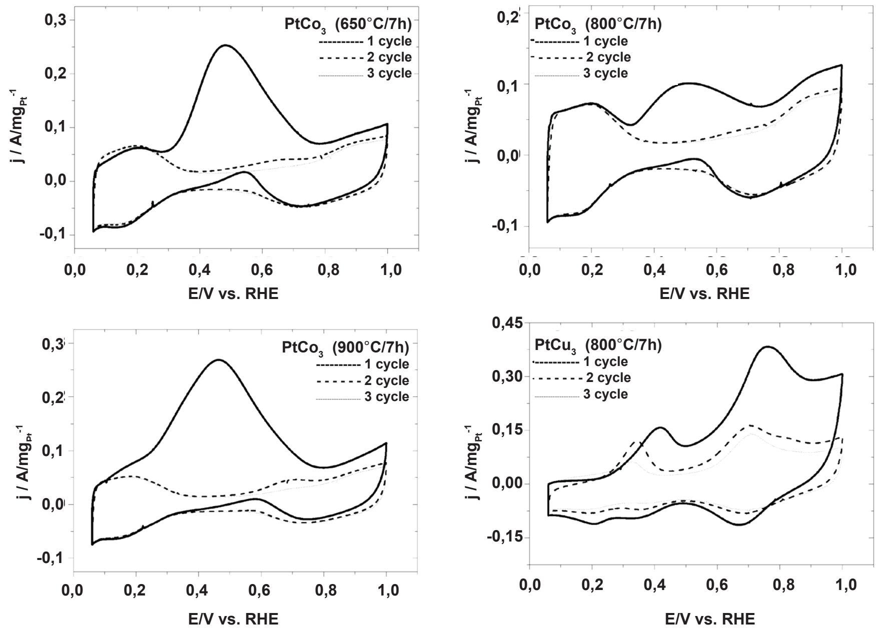

Figure 4*: Initial CV profiles of three different $PtCo_3$ precusor alloy nanoparticles, and one $PtCu_3$. Annealing condtions for each material is indicated. Conditions: 100 mV s^{-1}, 0.1 M $HClO_4$. Reproduced from ref.(25)*

The electrocatalytic oxygen reduction reaction (ORR) activity of dealloyed core shell Pt-Cu catalyst was measured by sweep voltammetry in O_2 saturated $HClO_4$ electrolyte using a Rotating Disk Electrode (Figures 5 and 6). The inset presents the time-stable voltammogram of the dealloyed core-shell catalysts after dealloying and before catalytic activity testing. The steep portion of the ORR voltammetric activity profiles are shifted to more positive electrode potentials indicating increased catalytic ORR activity compared to pure Pt. Figure 6 provides a direct comparison of the Pt-mass based activity (units A/mg_{Pt}), the Pt surface-area based activity, also referred to as specific activity (units in $\mu A/cm^3{}_{Pt}$), and the electrochemical surface area A (units m^2/g) for the de-alloyed Pt-Cu catalysts compared to a Pt electrocatalyst. At an electrode potential of 0.9 V, the dealloyed $Pt_{25}Cu_{75}$ nanoparticle catalysts, in particular the one annealed at 800°C outperformed pure Pt particle catalysts by a factor of 4-6x. Notably, the electrochemical active surface areas of the three dealloyed catalysts show no increase compared to pure Pt ruling out pure surface area enhancement effects.

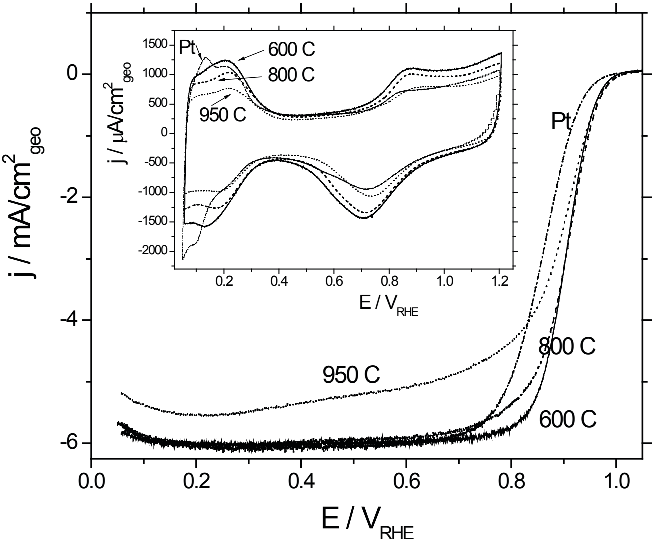

Figure 5*: Oxygen reduction linear sweep voltammetry of dealloyed Pt-Cu core shell catalysts compared to a state-of-art Pt catalyst. Reproduced from ref.(30)*

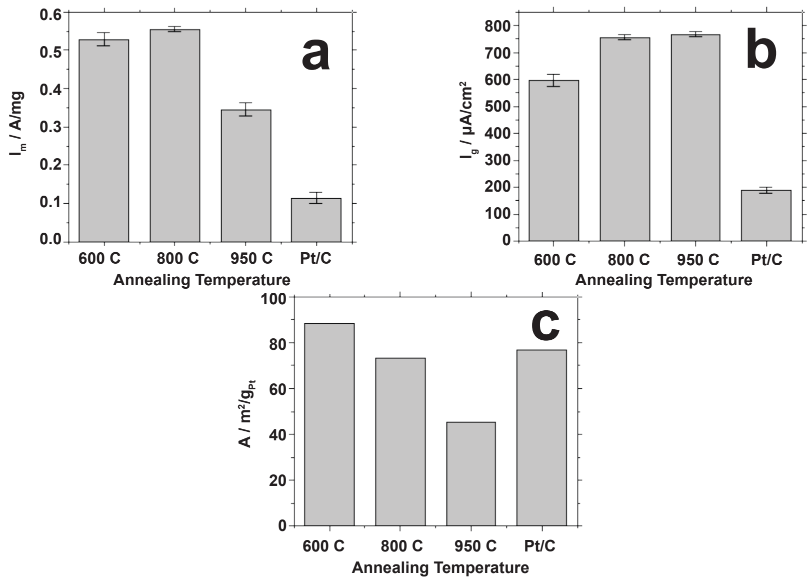

Figure 6*: Comparison of (a) Pt mass based oxygen reduction reaction (ORR) activity (im), (b) specific ORR activity (is), and (c) the electrochemical surface area of three dealloyed Pt-Cu core-shell catalysts (see Fig 3 and 5) and a Pt catalyst. Reproduced from ref.(30)*

Similar voltammetric ORR activity profiles and catalytic activity values were measured for dealloyed $PtCo_3$ core shell catalysts, see Figure 7 and Table 1.

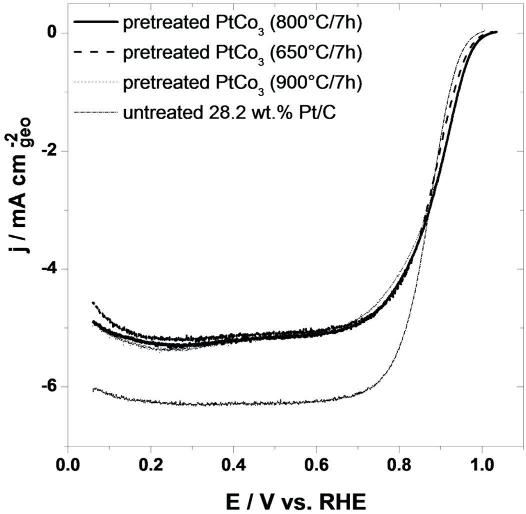

***Figure 7**: ORR linear sweep voltammetry of dealloyed ("pretreated") $PtCo_3$ and a $PtCu_3$ catalyst. Reproduced from ref. (30)*

catalyst	chemical composition nominal via EDS (at. %)	chemical composition final via EDS (at. %)	electro chemical surface area (ECSA) ($m^2\ g_{Pt}^{-1}$)	specific current density at 0.90 V/RHE ($pA\ cm_{Pt}^{-2}$)	Pt mass based current density at 0.90 V/RHE ($A\ mg_{Pt}^{-1}$)
$PtCo_3$ (650°C/7h)	$Pt_{28}Co_{72}$	$Pt_{82}Co_{18}$	40 ± 4	701 ± 68	0.28 ± 0.05
$PtCo_3$ (800°C/7h)	$Pt_{37}Co_{63}$	$Pt_{80}Co_{20}$	45 ± 4	804 ± 146	0.38 ± 0.05
$PtCo_3$ (900°C/7h)	$Pt_{27}Co_{73}$	$Pt_{73}Co_{27}$	36 ± 2	811 ± 99	0.29 ± 0.04
Pt/HSAC	Pt_{100}	Pt_{100}	73 ± 3	179 ± 4	0.13 ± 0.01

***Table 1**: Chemical compositions before ("nominal") and after ("final") voltammetric dealloying and ORR activity testing, catalytic Pt mass and specific ORR activities of dealloyed $PtCo_3$, $PtCu_3$ core shell catalysts and a Pt catalyst from Figure 7. Reproduced from ref. (30)*

Of great concern for membrane and fuel cell durability is the formation of hydrogen peroxide (H_2O_2) and OH radicals at the cathode catalyst. These species are known to have the capability to rapidly degrade the polymer membrane through an "unzipping mechanism" resulting in pinholes, gas cross over and severe cell failures. The H_2O_2 selectivities of the dealloyed Pt-Cu and Pt-Co cathode catalysts are shown in Figure 8. The measurements confirmed that the H_2O_2 production is quite favorable and largely comparable to pure Pt catalysts in the typically electrode potential ranges of a fuel cell cathode (0.5 – 1.0 V). As expected, pure carbon support materials form quite significant amounts of H_2O_2.

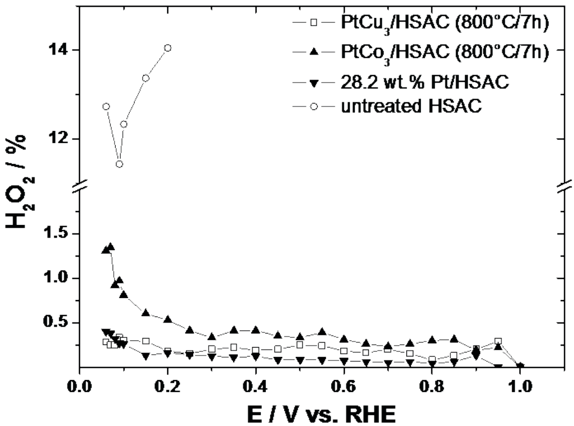

***Figure 8**: Hydrogen peroxide production versus electrode potential during the O_2 reduction for dealloyed $PtCo_3$, $PtCu_3$, pure Pt, and a pure carbon electrocatalysts. Reproduced from ref. (30)*

Membrane Electrode Assembly (MEA) implementation and single cell performance

The practical usefulness of a novel ORR electrocatalyst critically depends on the feasibility to incorporate it in Membrane Electrode Assemblies (MEAs) and eventually fuel cell stacks for performance and durability studies.[26,36,38,43,44] To demonstrate this, a number of different bimetallic and trimetallic dealloyed Pt alloy nanoparticle catalysts were prepared, incorporated in MEAs, tested and compared against a state-of-the-art pure Pt catalysts. Figure 9 displays the measured polarization curves of dealloyed bimetallic Pt-Cu, Pt-Co, and Pt-Ni core shell catalysts compared to a state-of-art carbon-supported 45 wt% Pt catalyst. It is evident that MEAs with dealloyed Pt cathodes show comparable or improved current densities over a broad current density range despite their drastically reduced geometric Pt loadings (0.1-0.17 mg_{Pt}/cm^2 for alloys compared to 0.3 mg_{Pt}/cm^2 for Pt). In particular, Figure 9a shows that the dealloyed catalysts do not cause detrimental effects in the ohmic and mass transport region of the polarization curve. To contrast the kinetic activity of dealloyed Pt catalysts against that of commercial pure Pt cathode catalysts, the kinetic current density of the single cell measurements of Figure 9a was normalized with respect to the Pt loading of the ORR electrode, yielding Tafel lines as shown in Figure 9b. The dealloyed Pt catalysts clearly outperform the Pt standard catalyst by a factor 3x – 4x in the kinetic regime, suggesting lower activation barriers presumably associated with more favorable chemisorption energies of reaction intermediates.

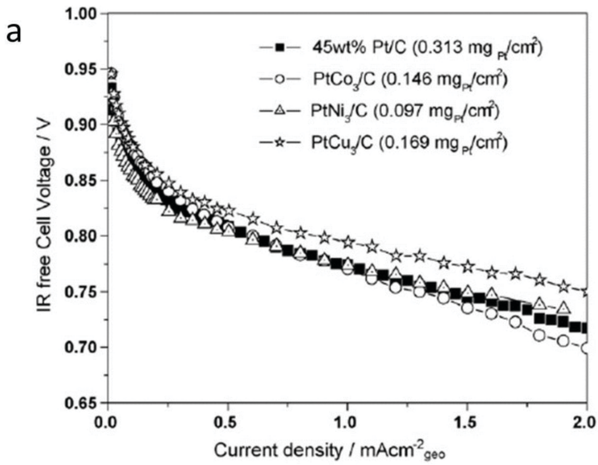

***Figure 9a**: Current-voltage characteristics of 10 cm^2 single H_2/O_2 fuel cells using dealloyed $PtCu_3$, dealloyed $PtNi_3$ and dealloyed $PtCo_3$ cathode catalyst, in comparison with standard Pt cathode catalysts.*

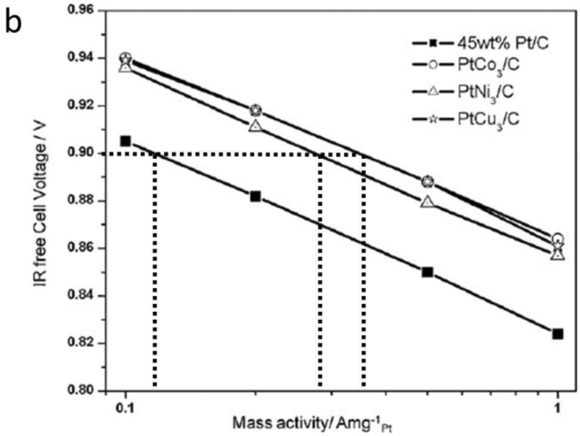

***Figure 9b**: Tafel plot of Pt-mass activities at 0.9V of the dealloyed Pt-bimetallic cathode catalysts compared to the Pt catalyst. Reproduced from ref. (26)*

The precise origin of the high activity of the alloy catalysts in these realistic environments, however, is not fully resolved. It is likely that electronic and geometric enhancement effects, studied and proved in well-defined model catalyst formats, play a major role. Under the current conditions, dealloyed $PtCo_3$ and $PtCu_3$ appear somewhat more active than dealloyed $PtNi_3$. Detailed compositional and performance data of the three dealloyed cathode catalysts are provided in Table 2.

Nominal composition	EDS composition (as prepared) [at. %]	XPS composition (as prepared) [at. %]	ICP composition (after dealloying) [at. %]	XPS composition (after dealloying) [at. %]	$ECSA_{Pt}$ [$m^2\ g_{Pt}^{-1}$]	Mass activity @ 0.9V [$A\ mg_{Pt}^{-1}$]	Specific activity @ 0.9V [μAcm_{Pt}^{-2}]
Pt	-	-	-	-	63	0.104	166
$Pt_{25}Co_{75}$	$Pt_{26}Co_{74}$	$Pt_{42}Co_{58}$	$Pt_{83}Co_{17}$	$Pt_{86}Co_{14}$	70	0.346	491
$Pt_{25}Ni_{75}$	$Pt_{18}Ni_{82}$	$Pt_{38}Ni_{62}$	$Pt_{82}Ni_{18}$	$Pt_{77}Ni_{23}$	111	0.275	248
$Pt_{25}Cu_{75}$	$Pt_{35}Cu_{65}$		$Pt_{87}Cu_{13}$	$Pt_{98}Cu_{2}$	72	0.340	472

***Table 2:** Comparison of bulk and surface composition as well as fuel cell performance parameters of dealloyed Pt-M catalysts compared to a state-of-art Pt catalyst. Reproduced from ref. (26)*

Finally, the performance of electrochemically dealloyed $PtNi_3M$ (M = Cu, Co, Fe, Cr) ternaries were compared with that of the dealloyed binary PtNi3 ORR catalyst and that of a state-of-the-art commercial 45wt% Pt/C catalyst, Figure 10. From the Figure it is apparent that $PtNi_3Co$ and $PtNi_3Cu$ outperform commercial 45wt% Pt/C catalysts, whereas $PtNi_3Fe$ and $PtNi_3Cr$ show comparable performance even with only 1/3 of geometric Pt loading of the commercial catalysts. No mass transport limitations were discernible over the entire current density range.

Comparing the mass and specific ORR activities in Table 3 in the kinetic region, there is clear synergy between the Pt-Ni bimetallic alloy and additional third alloying components. The largest activity advantage over $PtNi_3$ was observed for $PtNi_3Co$ and $PtNi_3Cu$ ternaries with a Pt mass activity improvement of 1.7 times over $PtNi_3$. $PtNi_3Cr$ still showed 1.3 times improvement and $PtNi_3Fe$ showed negligible advantage in mass activity over the Pt-Ni compounds. Synergistic effects of combining Co, Cu or Cr with the $PtNi_3$ amounted to previously unobserved and unprecedented Pt mass activity improvements of a factor of 5x for $PtNi_3Co$ and $PtNi_3Cu$ and 3.5 times for $PtNi_3Cr$ compared to pure Pt.

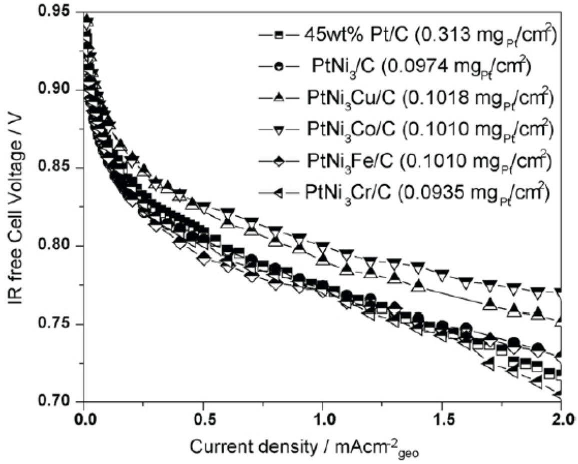

Figure 10: *Current-voltage characteristics (polarization behavior) of 10 cm² single H_2/O_2 fuel cells using various dealloyed ternaries Pt cathode catalyst, in comparison with a dealloyed PtNi and a standard Pt cathode catalyst. Reproduced from ref. (26)*

Nominal composition	EDS composition (as prepared) [at. %]	XPS composition (as prepared) [at. %]	ICP composition (after dealloying) [at. %]	XPS composition (after dealloying) [at. %]	$ECSA_{Pt}$ [$m^2\ g_{Pt}^{-1}$]	Mass activity @ 0.9V [A mg_{Pt}^{-1}]	Specific activity @ 0.9V [μAcm_{Pt}^{-2}]
Pt	-	-	-	-	63	0.104	166
$Pt_{25}Ni_{75}$	$Pt_{18}Ni_{82}$	$Pt_{38}Ni_{62}$	$Pt_{82}Ni_{18}$	$Pt_{77}Ni_{23}$	111	0.275	248
$Pt_{20}Ni_{60}Cu_{20}$	$Pt_{19}Ni_{56}Cu_{25}$	$Pt_{38}Ni_{40}Cu_{22}$	$Pt_{82}Ni_{15}Cu_{3}$	$Pt_{48}Ni_{48}Cu_{4}$	116	0.473	406
$Pt_{20}Ni_{60}Co_{20}$	$Pt_{14}Ni_{65}Co_{21}$	$Pt_{41}Ni_{37}Co_{22}$	$Pt_{86}Ni_{11}Co_{3}$	$Pt_{45}Ni_{49}Co_{6}$	145	0.472	326
$Pt_{20}Ni_{60}Fe_{20}$	$Pt_{20}Ni_{60}Fe_{20}$	-	-	-	65	0.289	447
$Pt_{20}Ni_{60}Cr_{20}$	$Pt_{14}Ni_{49}Cr_{37}$	-	$Pt_{75}Ni_{3}Cr_{22}$	-	92	0.366	396

Table 3: *Comparison of bulk and surface composition as well as fuel cell performance parameters of dealloyed ternary Pt-Ni-M catalysts compared to the $PtNi_3$ and a state-of-art Pt catalyst. Reproduced from ref. (26)*

8. Conclusions

Dealloyed Pt alloy nanoparticles are a highly promising class of electrocatalysts for the electroreduction of molecular oxygen (ORR) at cathodes of PEMFC.

The active phase of the electrocatalysts is prepared by selective dissolution of non noble atoms from nanoparticle precursor. This can be achieved by electrochemical cycling as well as via a facile acid leaching wash requiring simple experimental procedures.

The long term stability of dealloyed Pt electrocatalysts has been a research focus and great progress has been achieved recently, in particular through the preparation of highly size-controlled alloy precursor particle catalysts. Very recent reports demonstrated that dealloyed Pt-Ni ORR catalysts successfully meet the 2017 activity and stability targets set by the Department of Energy's Hydrogen Fuel Cell Program, involving 30,000 potential cycles while maintaining a mass based activity above 0.44 A/mg(Pt) at 900 mV cell voltage.[(45)]

Current issues in dealloyed ORR catalysts involve the impact of the dealloying procedure on the structure of the membrane-electrode-assembly at the meso- and macro scale (swelling, rupture, deformation, residual metal ion concentration in membrane and anode). Similarly, the performance of dealloyed Cathode catalyst in air and low humidity conditions has to be investigated in more detail.

Overall, aside from being a promising cathode catalyst for single MEAs and Fuel cell Stacks, dealloyed ORR Pt core-shell catalysts, in their as-prepared or dealloyed form, lend themselves excellently to further applied or fundamental fuel cell catalysis research. Thanks to the development of industrial scale-up methods, a number of dealloyed Pt ORR catalysts have now become available commercially in larger quantities for industrial or academic fuel cell developers and fundamental and applied academic researchers alike.

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Strem Chemicals Chemist Finds New Way to Drive to Work

Dr. Antony Wright. Regulatory and Quality Control Consultant

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antony@strem.com

Antony Wright, a chemist at Strem for more than a decade, is the proud owner of a Tesla model S electric car. He reports that this is a direct consequence of his keen interest following developments in lithium battery and solar energy chemistry over the last 30 years. Antony came to Strem after a career studying the chemistry of elemental silicon as used in the silicones and polycrystalline silicon semiconductor industry. In 2008 he bought a Kalkhoff electric assist bike, outfitted with a lithium ion battery, so he could keep up with his much younger bike club friends. He also pedals the 16 mile round trip to work most days above freezing. Interestingly, after 5 years of hard use the original battery still has 80% of its capacity, and this got him thinking about how he and others could combine battery power with solar energy to reduce the world's dependence on petroleum. In 2011, he put in a reservation for a Tesla model S and installed a 40 panel ground mount solar array at his home, generating enough nominal power at 10Kw on a bright sunny day to balance the charging requirements of the Tesla at an energy storage rate equivalent to 30 miles driving range per hour of optimum sunlight. Since then the Tesla has shown up in the Strem employee parking lot and Antony has even figured out how to mount the electric bike in the cargo bay of the car to attend bike club events with windshield wiper fluid the only consumable fluid used to get there.

The chemicals Strem has provided to the research community have assisted in the development of modern energy systems. Antony notes that the Tesla automobile has some unique features from a chemist's point of view. From Faraday's constant and a 3.5 v assumed output, an 85 kWh Tesla Battery must contain at least $85KwHr/13.5Kwhr*Kg^{-1}$ = 6.3 Kg of lithium metal. This large amount of highly reactive metal is safely put in the hands of the consumer through the computer management of about 7000 Panasonic 2.5 inch x ¾ inch cylindrical laptop style lithium ion batteries installed under the floor of the car.

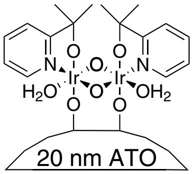
Each battery consists of a laminate of lithium metal graphite intercalation structure as the negative electrode and a positive electrode which functions as a lithium ion storage reservoir in the form of ionic lithium cations embedded in an anionic nickel cobalt aluminum oxide matrix. During charging, the nickel is oxidized from Ni+2 to Ni+3 and a lithium cation is ejected into the electrolyte, replacing one which is reduced to lithium metal at the negative electrode. The two electrodes are separated by a porous polymer membrane, only about 25 micron (μM) thick. To form a single battery cell, a three layer battery laminate is wound as a cylindrical spool about 2.5 inches wide and at least 3 feet long (90 sq in), sealed in a cylindrical can, with a non-aqueous electrolyte consisting of lithium hexafluorophosphate dissolved in a polar liquid organic solvent, commonly a blend of ethylene, methyl, and ethyl carbonates.

In the Tesla, then, 7000 such batteries together contain 7000 x 90/144 = 4375 total square feet of electrolytic cell. One can imagine this would be equivalent to a single cell laminate covering the entire floor area of a large home with the electrochemistry of two gigantic electrodes separated by only 25 μM. While the thin film laminate design compensates for the approximately 10 x lower electrical conductivity of organic vs. aqueous electrolyte used in the old lead acid batteries, Tesla must manage this delicate construction in a way that ensures, as much as possible, that every square millimeter of every laminate is in the same state of charge as every other square millimeter anywhere else in the battery pack, whether the car has been driven 10 of 240 miles, a typical range achieved in practice. The homogeneous state of charge is necessary to help prevent local overcharging and battery lifetime losses. Much of Tesla's technology is making this happen with sophisticated computer control of each individual cell, and careful battery construction engineering by Panasonic.

Chemicals available from Strem to assist in lithium battery development can be found in our ***Materials for Battery Applications*** section on pages 22-27.

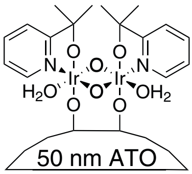
IRIDIUM (Compounds)

77-0030 **Antimony Tin Oxide/Iridium Het-WOC core/shell nanopowder, 20 nm (conductive and acid-stable)** 250mg 1g
blue pwdr.
Note: Sold under license from Catalytic Innovations, LLC for research purposes only. US Patent Publication No. US20150021194 A1.



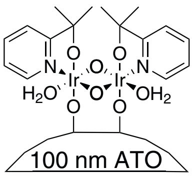
ATO Composition: 90% SnO_2, 10% Sb_2O_3 (w/w)
BET Surface Area: 50 – 60 m^2/g
Resistivity: 0.3 – 0.7 Ω•cm

77-0035 **Antimony Tin Oxide/Iridium Het-WOC core/shell nanopowder, 50 nm (conductive and acid-stable)** 250mg 1g
blue pwdr.
Note: Sold under license from Catalytic Innovations, LLC for research purposes only. US Patent Publication No. US20150021194 A1.

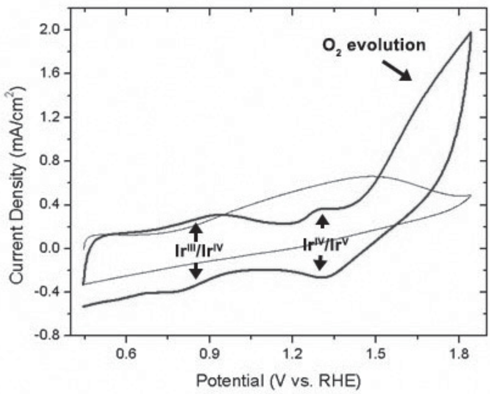


ATO Composition: 90% SnO_2, 10% Sb_2O_3 (w/w)
BET Surface Area: 40 – 50 m^2/g
Resistivity: 0.05 – 0.08 Ω•cm

77-0040 **Antimony Tin Oxide/Iridium Het-WOC core/shell nanopowder, 100 nm (conductive and acid-stable)** 250mg 1g
blue pwdr.
Note: Sold under license from Catalytic Innovations, LLC for research purposes only. US Patent Publication No. US20150021194 A1.



ATO Composition: 90% SnO_2, 10% Sb_2O_3 (w/w)
BET Surface Area: 5 – 10 m^2/g
Resistivity: 0.05 – 0.08 Ω•cm

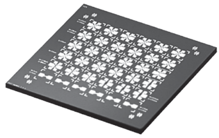


Cyclic voltammogram of 50 nm ATO/het-WOC core/shell nanopowder operating in a test electrolyzer (built-in Hg/$HgSO_4$ reference) for oxygen evolution (black) compared to a bare 50 nm ATO control (grey). Redox features of the molecular iridium species are present, as well as the catalytic wave for oxygen evolution. Activity persists for over 90 days.

GRAPHENE

06-2555 NEW

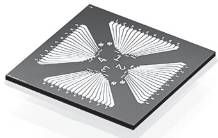
Graphene Field-Effect Transistor (GFET) Chip - Grid pattern *(1034343-98-0)*
Chip
Note: Storage of the chips in a low humidity environment (N2 cabinet, desiccator, or vacuum) is highly recommended.



1pc

06-2560 NEW

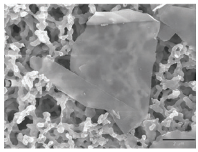
Graphene Field-Effect Transistor (GFET) Chip - Quadrant pattern *(1034343-98-0)*
Chip
Note: Storage of the chips in a low humidity environment (N2 cabinet, desiccator, or vacuum) is highly recommended.



1pc

06-0210

Graphene nanoplatelets (6-8 nm thick x 5 microns wide)
C; black platelet



Note: Graphene nanoplatelets are unique nanoparticles consisting of short stacks of graphene sheets having a platelet shape. They have an average thickness of approximately 6 - 8 nanometers and a typical surface area of 120 to 150 m^2/g. The unique size and platelet morphology of the graphene nanoplatelets makes these particles especially effective at providing barrier properties and improving mechanical properties, while their pure graphitic composition makes them excellent electrical and thermal conductors.

25g
100g

Technical Note:
1. For detailed technical note visit strem.com

06-0215

Graphene nanoplatelets (6-8 nm thick x 15 microns wide)
(1034343-98-0)
C; black platelet

25g
100g

Technical Note:
1. See 06-0210 (page 14)

06-0220

Graphene nanoplatelets (6-8 nm thick x 25 microns wide)
(1034343-98-0)
C; black platelet

25g
100g

Technical Note:
1. See 06-0210 (page 14)

06-0225

Graphene nanoplatelets aggregates (sub-micron particles, surface area 300m^2/g)
(1034343-98-0)
black platelet
Note: Graphene nanoplatelet aggregates are unique nanoparticles consisting of short stacks of graphene sheets having a platelet shape. They typically consist of aggregates of sub-micron platelets that have a particle diameter of less than 2 microns and a typical particle thickness of a few nanometers, depending on the surface area.

The unique size and platelet morphology of the graphene nanoplatelets makes these particles especially effective at providing barrier properties and improving mechanical properties, while their pure graphitic composition makes them excellent electrical and thermal conductors.

25g
100g

Technical Note:
1. For detailed technical note visit strem.com

06-0230

Graphene nanoplatelets aggregates (sub-micron particles, surface area 500m^2/g)
(1034343-98-0)
black platelet

25g
100g

Technical Note:
1. See 06-0225 (page 14)

06-0235

Graphene nanoplatelets aggregates (sub-micron particles, surface area 750m^2/g)
(1034343-98-0)
black platelet

25g
100g

Technical Note:
1. See 06-0225 (page 14)

06-2545 **Graphene oxide (4mg/ml water dispersion)** *(1034343-98-0)* 50ml
yellow-brown liq. dispersion 250ml

Physical Properties:
Form: Dispersion of graphene oxide sheets; *Sheet dimension*: Variable; *Color*: Yellow-brown; *Dispersibility*: Polar solvents; *Solvent*: Water; *pH*: 2.2-2.5; *Concentration*: 4 mg/mL; *Monolayer content (measured in 0.5 mg/mL)*: >95%*
*Note: 4 mg/mL tends to agglomerate the GO flakes and dilution followed by slight sonication is required in order to obtain a higher percentage of monolayer flakes
Elemental Analysis: (sample preparation: 2g of 4 wt% GO in water were dried under vacuum at 60°C overnight)
Carbon: 49-56%; *Hydrogen*: 0-1%; *Nitrogen*: 0-1%; *Oxygen*: 41-50%; *Sulfur*: 0-2%
Quality Control:
Amount of residue on evaporation
pH control
Elemental analysis
Applications: Graphene/polymer composite materials, batteries, biomedical, solar cells, supercapacitors, support for metallic catalysts, low permeability materials, biosensors, multifunctional materials, graphene research

References:

1. *J. Mater. Chem.*, **2011**, *21*, 9762.
2. *Environ. Sci. Technol.*, **2013**, *47*, 3715.
3. *Phys. Chem. Chem. Phys.*, **2013**, *15*, 2321.

06-2530 **Graphene oxide (4mg/ml water dispersion) - low Mn.** *(1034343-98-0)* 100ml
NEW C; brown liq. 500ml
Note: Diameter: 5-30 micron flakes.

06-2550 **Graphene oxide, reduced** *(1034343-98-0)* 250mg
black pwdr. 1g

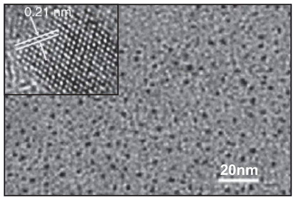
Physical Properties:
Form: powder; *Reduction method*: chemically reduced; *Sheet dimension*: variable; *Color*: black; *Solubility*: insoluble; *Dispersability*: <0.1 mg/mL in NMP, DMF, DMSO; *Humidity (Karl Fisher, TGA)*: 3.7-4.2%; *Electrical conductivity*: 666,7 S/m (measured in a 20 nm film thickness); *BET surface area*: 422.69 - 499.85 m^2/g; *Density*: 1.91 g/cm^3
Elemental Analysis: (sample preparation: 2g of 4 wt% GO in water were dried under vacuum at 60°C overnight)
Carbon: 77-87%; *Hydrogen*: 0-1%; *Nitrogen*: 0-1%; *Oxygen*: 13-22%; *Sulfur*: 0%
Quality Control: Elemental analysis
Applications: Batteries, biomedical, solar cells, supercapacitors, printable graphene electronics, graphene research

References:

1. *Nano Letters*, **2010**, *10*, 92.
2. *J. Phys. Chem. Lett.*, **2013**, *4*, 1347.

06-0330 **Graphene Quantum Dots (GQDs), Aqua-Green Luminescent** *(1034343-98-0)* 100mg
C; dark red-brown pwdr.
light sensitive, (store cold)
Note: Particle diameter: <5 nm. Sold in collaboration with Dotz Nano Ltd. for research purposes only. Suggested use within 6 months of purchase. Do not freeze. Store in DARK.

Suggested Applications:



Graphene quantum dots (GQDs), sheets of few-layered graphene and lateral dimensions smaller than 100nm possess strong quantum confinement and edge effects. Thus, they possess unique physical properties such as strong photoluminescence, which can be tailored for specific applications by controlling their size, shape, defects and functionality.

In contrast to classic QDs, such as metal or silicon quantum dots, GQDs are biocompatible, photostable and inherit superior thermal, electrical and mechanical properties from the graphene. These features can greatly contribute to various state-of-the-art applications: optical brighteners, taggants for security applications[1], bioimaging markers[2], fluorescent polymers[3], antibacterial[4], antibiofouling[5], and disinfection systems[6], heavy metals[7], humidity and pressure[8] sensors, batteries[9], flash memory devices[10], photovoltaic devices[11] and light-emitting diodes[12].

Item #	Photoluminescence			
	QY+ *	λ_{max} *	Max emission	FWHM *
06-0330 / 06-0332	>17%	485 nm	525 nm	70 nm
06-0334 / 06-0336	>65%	350 nm	445 nm	65 nm
06-0340	>25%	420 nm	490 nm	80 nm
Abbreviations				
QY+	Quantum Yield			
λ_{max}	Maximum excitation wavelength			
FWHM	Full width at half maximum			

References:
1. *Angew. Chem. Int. Ed.*, **2012**, *51*, 12215
2. *Part. Part. Syst. Charact*. **2015**, *32*, 515
3. *ACS Appl. Mater. Interfaces*, **2015**, *7*, 26063
4. *ACS Appl. Mater. Interfaces*, **2016**, *8*, 10761
5. *Scientific Reports*, **2016**, *6*, 20142
6. *ACS Nano*, **2014**, *8*, 6202
7. *Electrochim. Acta*, **2015**, *172*, 7
8. *Nano Lett.*, **2013**, *13*, 1757
9. *Nano Lett.*, **2015**, *15*, 565
10. *Nanotechnology,* **2014**, *25*, 255203
11. *Angew. Chem. Int. Ed.*, **2010**, *49*, 3014
12. *J. Mater. Sci.* **2013**, *48*, 2352

06-0332 **Graphene Quantum Dots (GQDs) in water, Aqua-Green Luminescent** *(1034343-98-0)* 100ml
C; cloudy orange liq.
light sensitive, (store cold)
Note: Particle diameter: <5 nm. Concentration: 1 mg/ml. Sold in collaboration with Dotz Nano Ltd. for research purposes only. Suggested use within 6 months of purchase. Do not freeze. Store in DARK.

Technical Note:
1. See 06-0330 (page 16)

06-0334 **Graphene Quantum Dots (GQDs), Blue Luminescent** *(1034343-98-0)* 100mg
C; dark brown pwdr.
light sensitive, (store cold)
Note: Particle diameter: <5 nm. Sold in collaboration with Dotz Nano Ltd. for research purposes only. Suggested use within 6 months of purchase. Do not freeze. Store in DARK.

Technical Note:
1. See 06-0330 (page 16)

06-0336 **Graphene Quantum Dots (GQDs) in water, Blue Luminescent** *(1034343-98-0)* 100ml
C; cloudy colorless liq.
light sensitive, (store cold)
Note: Particle diameter: <5 nm. Concentration: 1 mg/ml. Sold in collaboration with Dotz Nano Ltd. for research purposes only. Suggested use within 6 months of purchase. Do not freeze. Store in DARK.

Technical Note:

1. See 06-0330 (page 16)

06-0340 **Graphene Quantum Dots (GQDs) in water, Cyan Luminescent** *(1034343-98-0)* 100ml
C; cloudy brown liq.
light sensitive, (store cold)
Note: Particle diameter: <5 nm. Concentration: 1 mg/ml. Sold in collaboration with Dotz Nano Ltd. for research purposes only. Suggested use within 6 months of purchase. Do not freeze. Store in DARK.

Technical Note:

1. See 06-0330 (page 16)

06-2510 **Monolayer Graphene on Cu (10 mm x 10 mm)** *(1034343-98-0)* 4pcs
C; FW: 12.011; wafer

Physical Properties:
Growth Method: Chemical Vapor Deposition (CVD synthesis); *Appearance*: Transparent; *Transparency*: >97%; *Coverage*: 98%; *Layers*: 1; *Thickness (theoretical)*: 0.345 nm; *FET Electron Mobility on Al_2O_3*: 2000 cm²/Vs; *FET Electron Mobility on SiO_2*: 4000 cm²/Vs; *Sheet Resistance on SiO_2/Si*: 410-490 Ω/sq (1 cm x 1 cm); *Grain size*: Up to 10 μm
Substrate Cu foil:
Thickness: 18 μm
Pretreated for easier bottom layer removal: Monolayer graphene on the back side of Copper is partially removed, but not completely, so an additional treatment like RIE is needed before transfer to eliminate the bottom layer totally
Applications: Flexible batteries, electronics, aerospace, MEMS and NEMS, Microactuators, Conductive coatings
Quality Control: Raman Spectroscopy and Optical Microscopy
References:

1. *J. Electrochem. Soc.*, **2012**, *159*, A752.
2. *J. Mater. Chem. A.*, **2013**, *1*, 3177.

06-2518 **Monolayer Graphene on Cu (60 mm x 40 mm)** *(1034343-98-0)* 1pc
C; FW: 12.011; wafer

Physical Properties:
Growth Method: Chemical Vapor Deposition (CVD synthesis); *Appearance*: Transparent; *Transparency*: >97%; *Coverage*: 95%; *Layers*: 1; *Thickness (theoretical)*: 0.345 nm; *FET Electron Mobility on Al_2O_3*: 2000 cm²/Vs; *FET Electron Mobility on SiO_2*: 4000 cm²/Vs; *Sheet Resistance on SiO_2/Si*: 410-490 Ω/sq (1 cm x 1 cm); *Grain size*: Up to 10 μm
Substrate Cu foil:
Thickness: 18 μm
Pretreated for easier bottom layer removal: Monolayer graphene on the back side of Copper is partially removed, but not completely, so an additional treatment like RIE is needed before transfer to eliminate the bottom layer totally
Applications: Flexible batteries, electronics, aerospace, MEMS and NEMS, Microactuators, Conductive coatings
Quality control: Raman Spectroscopy and Optical Microscopy
References:

1. *J. Electrochem. Soc.*, **2012**, *159*, A752.
2. *J. Mater. Chem. A.*, **2013**, *1*, 3177.

06-2523 **Monolayer Graphene on Cu with PMMA coating (60mm x 40mm)** *(1034343-98-0)* 1pc
C; FW: 12.011; wafer

Physical Properties:
Growth Method: Chemical Vapor Deposition (CVD synthesis); *Appearance*: Transparent; *Transparency*: >97%; *Coverage*: 95%; *Layers*: 1; *Thickness (theoretical)*: 0.345 nm; *FET Electron Mobility on Al_2O_3*: 2000 cm²/Vs; *FET Electron Mobility on SiO_2*: 4000 cm²/Vs; *Sheet Resistance on SiO_2/Si*: 410-490 Ω/sq (1 cm x 1 cm); *Grain size*: Up to 10 μm
Substrate Cu foil:
Thickness: 18 μm
Pretreated for easier bottom layer removal: Monolayer graphene on the back side of Copper is partially removed, but not completely, so an additional treatment like RIE is needed before transfer to eliminate the bottom layer totally
Applications: Flexible batteries, electronics, aerospace, MEMS and NEMS, Microactuators, Conductive coatings
Quality control: Raman Spectroscopy and Optical Microscopy
References:

1. *J. Electrochem. Soc.*, **2012**, *159*, A752.
2. *J. Mater. Chem. A.*, **2013**, *1*, 3177.

06-2534 **Monolayer Graphene on SiO_2/Si (10mm x 10mm)** *(1034343-98-0)* 4pc
C; wafer

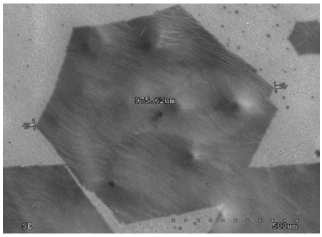
Physical Properties:
Growth Method: Chemical Vapor Deposition (CVD synthesis); *Appearance*: Transparent; *Transparency*: >97%; *Coverage*: 95%; *Layers*: 1; *Thickness (theoretical)*: 0.345 nm; *FET Electron Mobility on Al_2O_3*: 2000 cm^2/Vs; *FET Electron Mobility on SiO_2*: 4000 cm^2/Vs; *Sheet Resistance on SiO_2/Si*: 410-490 Ω/sq (1 cm x 1 cm); *Grain size*: Up to 10 μm
Substrate Cu foil:
Dry Oxide Thickness: 285-315 nm; *Type/Dopant*: P/Bor; *Orientation*: <100>; *Resistivity*: <0.005 Ohm·cm; *Thickness*: 505-545 μm; *Front surface*: single side polished; *Back surface*: etched; *Particles*: <10@0.3 μm
Applications: Flexible batteries, electronics, aerospace, MEMS and NEMS, Microactuators, Conductive coatings
Quality control: Raman Spectroscopy and Optical Microscopy
References:

1. *J. Electrochem. Soc.,* **2012**, *159*, A752
2. *J. Mater. Chem. A.,* **2013**, *1*, 3177

06-0365 NEW **Monolayer High Strength Metallurgical Graphene, HSMG®, on GLASS (10x10mm)** 1pc
(1034343-98-0)
C; FW: 12.011; Colorless solid
Note: HSMG® Sold under license for research purposes only.
U.S. Patent no. 9,284,640 B2.

PRODUCT DATA	
GROWTH METHOD	Metallurgical graphene growth on liquid metal
STANDARD SUBSTRATES	PMMA, Si/SiO_2, quartz
TRANSFER AVAILABILITY	Transfer on custom substrates available upon request
QUALITY CONTROL	Raman spectroscopy Optical microscopy SEM microscopy
FORM	Graphene film
GRAIN SIZE	Up to 1mm
COVERAGE*	>95%
OPTICAL TRANSMITTANCE*	>97% *(measured on quartz with UV-Vis method)*
THICKNESS (THEORETICAL)	0.345 nm
AVERAGE SHEET RESISTANCE*	<250 Ω/cm^2 *(measured on Si/SiO_2 with van der Pauw method)*

*values confirmed by EIT+ Wroclaw Research Centre independent product evaluation study



SEM image: **Evaluation of graphene grain size during growth process**

Absorption and incorporation of carbon atoms into the crystal structure of the copper matrix occurs during the carburization process. Maximum carbon content is significantly lower for liquid copper matrix than for solid state matrix, therefore, after heating above the melting point, the metal matrix becomes supersaturated with carbon atoms. **HSMG® growth is based on the controlled carbon precipitation from the liquid metal matrix.**

The growth process originates with nucleation of single hexagonal flakes on the metallic substrate. Liquid matrix enables grain rotation and rearrangement during nucleation process which results in larger grain sizes and improved graphene properties. This process is fully controlled and enables the production of graphene sheets with specified number of layers.

06-0345 NEW **Monolayer High Strength Metallurgical Graphene, HSMG®, on PMMA (10x10 mm)** 1pc
(1034343-98-0)
C; FW: 12.011; Colorless solid
Note: HSMG® Sold under license for research purposes only.
U.S. Patent no. 9,284,640 B2.

06-0355 NEW **Monolayer High Strength Metallurgical Graphene, HSMG®, on PMMA (25x25mm)** 1pc
(1034343-98-0)
C; FW: 12.011; Colorless solid
Note: HSMG® Sold under license for research purposes only.
U.S. Patent no. 9,284,640 B2.

06-0360 NEW **Monolayer High Strength Metallurgical Graphene, HSMG®, on PMMA (50x50mm)** 1pc
(1034343-98-0)
C; FW: 12.011; Colorless solid
Note: HSMG® Sold under license for research purposes only.
U.S. Patent no. 9,284,640 B2.

KITS - Graphene Quantum Dots (GQDs) Master Kit

96-7410 **Graphene Quantum Dots (GQDs) Master Kit**
Sold in collaboration with Dotz Nano Ltd. for research purposes only.
Suggested use within 6 months of purchase. Do not freeze. Store in DARK.
Components also available for individual sale. Contains the following:

06-0330	Graphene Quantum Dots (GQDs), Aqua-Green Luminescent *(1034343-98-0)*	100mg	See page 16
06-0332	Graphene Quantum Dots (GQDs) in water, Aqua-Green Luminescent *(1034343-98-0)*	100ml	See page 16
06-0334	Graphene Quantum Dots (GQDs), Blue Luminescent *(1034343-98-0)*	100mg	See page 16
06-0336	Graphene Quantum Dots (GQDs) in water, Blue Luminescent *(1034343-98-0)*	100ml	See page 17
06-0340	Graphene Quantum Dots (GQDs) in water, Cyan Luminescent *(1034343-98-0)*	100ml	See page 17

Item #	Photoluminescence			
	QY+ *	λ max *	Max emission	FWHM *
06-0330 / 06-0332	>17%	485 nm	525 nm	70 nm
06-0334 / 06-0336	>65%	350 nm	445 nm	65 nm
06-0340	>25%	420 nm	490 nm	80 nm

Particle diameter: <5 nm
Topographic height: 1.0 - 2.0 nm
Concentration: 1mg/ml (for liquid items)

Abbreviations: QY+ = *Quantum Yield*; λ max = *Maximum excitation wavelength*; FWHM = *Full width at half maximum*

KITS - Graphene Quantum Dots (GQDs) Mini Kit (Powders)

96-7425 **Graphene Quantum Dots (GQDs) Mini Kit (Powders)**
Sold in collaboration with Dotz Nano Ltd. for research purposes only.
Suggested use within 6 months of purchase. Do not freeze. Store in DARK.
Components also available for individual sale. Contains the following:

06-0330	Graphene Quantum Dots (GQDs), Aqua-Green Luminescent *(1034343-98-0)*	100mg	See page 16
06-0334	Graphene Quantum Dots (GQDs), Blue Luminescent *(1034343-98-0)*	100mg	See page 16

See table listed under 96-7410 (above) for individual product specifications.

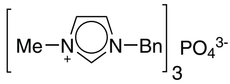
KITS - Graphene Quantum Dots (GQDs) Mini Kit (Liquids)

96-7420 **Graphene Quantum Dots in water (GQDs) Mini Kit (Liquids)**
Sold in collaboration with Dotz Nano Ltd. for research purposes only.
Suggested use within 6 months of purchase. Do not freeze. Store in DARK.
Components also available for individual sale. Contains the following:

06-0332	Graphene Quantum Dots (GQDs) in water, Aqua-Green Luminescent *(1034343-98-0)*	100ml	See page 16
06-0336	Graphene Quantum Dots (GQDs) in water, Blue Luminescent *(1034343-98-0)*	100ml	See page 17
06-0340	Graphene Quantum Dots (GQDs) in water, Cyan Luminescent *(1034343-98-0)*	100ml	See page 17

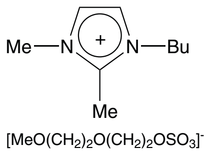
See table listed under 96-7410 (above) for individual product specifications.

07-0090 **1-Benzyl-3-methylimidazolium phosphate, 99%**
$[C_{11}H_{13}N_2]_3PO_4$; FW: 614.68; clear, brown liq.



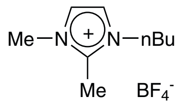
5g

07-0050 **1-Butyl-2,3-dimethylimidazolium diethyleneglycolmonomethylether sulfate, 98% [BDiMIM] [MDEGSO$_4$]** *(108203-89-0)*
$[C_9H_{17}N_2]^+[CH_3O(CH_2)_2O(CH_2)_2OSO_3]^-$; FW: 352.45; orange-brown liq.



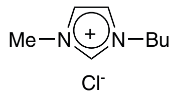
5g

07-0075 **1-Butyl-2,3-dimethylimidazolium tetrafluoroborate, 98% [BDiMIM] [BF$_4$]** *(402846-78-0)*
$[C_9H_{17}N_2]^+BF_4^-$; FW: 240.05; pale yellow liq.; d. 1.198



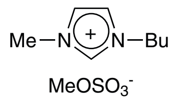
5g

07-0100 **1-Butyl-3-methylimidazolium chloride, 98% [BMIM]Cl** *(79917-90-1)*
$[C_8H_{15}N_2]^+Cl^-$; FW: 174.67; white to off-white solid; m.p. 65°
hygroscopic
Note: BMIM Ionic Liquid Kit 2 component.



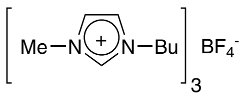
10g

07-0140 **1-Butyl-3-methylimidazolium methanesulfonate, 98% [BMIM] [MeSO$_4$]** *(401788-98-5)*
$[C_8H_{15}N_2]^+[CH_3OSO_3]^-$; FW: 250.32; yellow liq.; d. 1.21
hygroscopic
Note: BMIM Ionic Liquid Kit 2 component.



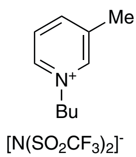
5g

07-0170 **1-Butyl-3-methylimidazolium tetrafluoroborate, 98% [BMIM] [BF$_4$]** *(174501-65-6)*
$[C_8H_{15}N_2]^+BF_4^-$; FW: 226.03; yellow liq.; m.p. -75°; d. 1.21
hygroscopic
Note: BMIM Ionic Liquid Kit 2 component.



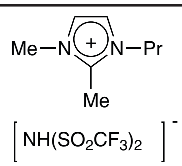
5g

07-0180 **N-Butyl-3-methylpyridinium bis(trifluoromethylsulfonyl) imide, 99% [BMPIm]** *(344790-86-9)*
$[C_{11}H_{16}N]^+[N(SO_2CF_3)_2]^-$; FW: 442.40; colorless to pale yellow liq.; d. 1.40
Note: Product protected by U.S. Patent 5,827,602 assigned to Covalent Associates, Inc.
Hydrophobic (water-immiscible) Ionic Liquid Kit 1 component.



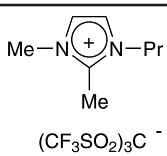
1g
5g

07-0465 **1,2-Dimethyl-3-propylimidazolium bis(trifluoromethylsulfonyl)imide, 99% [DMPIIm]** *(169051-76-7)*
$[C_8H_{15}N_2]^+[N(SO_2CF_3)_2]^-$; FW: 419.37; colorless to pale yellow liq.; d. 1.47
Note: Product protected by U.S. Patent 5,827,602 assigned to Covalent Associates, Inc. Hydrophobic (water-immiscible) Ionic Liquid Kit 1 component.



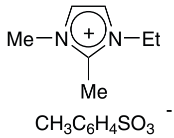
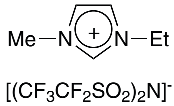
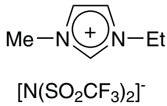
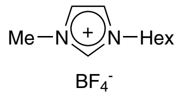
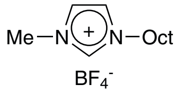
1g
5g

07-0470 **1,2-Dimethyl-3-propylimidazolium tris(trifluoromethylsulfonyl)methide, 99% [DMPIMe]** *(169051-77-8)*
$[C_8H_{15}N_2]^+[C(SO_2CF_3)_3]^-$; FW: 550.44; colorless to pale yellow liq.; d. 1.52
Note: Product protected by U.S. Patent 5,827,602 assigned to Covalent Associates, Inc. Hydrophobic (water-immiscible) Ionic Liquid Kit 1 component.



500mg
2g

IONIC LIQUIDS

07-0535	**1-Ethyl-2,3-dimethylimidazolium tosylate, 98%** **[EDiMIM] [TOS]** *(783321-71-1)* $[C_7H_{13}N_2]$+$[CH_3C_6H_4SO_3]$-; FW: 296.38; white to off-white pwdr.		5g
07-0578	**1-Ethyl-3-methylimidazolium bis(pentafluoroethylsulfonyl) imide, 99% [EMIBeti]** *(216299-76-2)* $[C_6H_{11}N_2]^+[N(SO_2CF_2CF_3)_2]^-$; FW: 491.33; colorless to pale yellow liq.; d. 1.57 Note: Product protected by U.S. Patent 5,827,602 assigned to Covalent Associates, Inc. Hydrophobic (water-immiscible) Ionic Liquid Kit 1 component.		500mg 2g
07-0579	**1-Ethyl-3-methylimidazolium bis(trifluoromethylsulfonyl) imide, 99% [EMIIm]** *(174899-82-2)* $[C_6H_{11}N_2]^+[N(SO_2CF_3)_2]^-$; FW: 391.31; colorless to pale yellow liq.; d. 1.53 Note: Product protected by U.S. Patent 5,827,602 assigned to Covalent Associates, Inc. Hydrophobic (water-immiscible) Ionic Liquid Kit 1 component.		1g 5g
07-0968	**1-Hexyl-3-methylimidazolium tetrafluoroborate, 98%** **[HMIM] [BF_4]** *(244193-50-8)* $[C_{10}H_{19}N_2]^+BF_4^-$; FW: 254.08; yellow liq.; m.p. -81°; d. 1.149 *hygroscopic*		5g
07-1264	**1-Methyl-3-octylimidazolium tetrafluoroborate, 98%** **[OMIM] [BF_4]** *(244193-52-0)* $[C_{12}H_{23}N_2]^+BF_4^-$; FW: 282.13; yellow liq.; m.p. -88°; d. 1.12 *hygroscopic*		5g

MATERIALS FOR BATTERY APPLICATIONS

ALUMINUM (Compounds)

93-1350	**Aluminum sulfate octadecahydrate, 98+% (ACS)** *(7784-31-8)* $Al_2(SO_4)_3\cdot18H_2O$; FW: 342.15 (666.41); colorless xtl.; m.p. 86.5° dec.; d. 1.69 *moisture sensitive*	500g 2kg

CARBON (Elemental Forms)

06-0720	**Carbon nanotubes, multi-walled, arc-produced (diameter = 2-50nm, length = >2 microns) (55-65wt% nanotubes)** *(308068-56-6)* black pwdr.	250mg 1g

Technical Note:

1. Arc-produced, multi-walled carbon nanotubes contain 55-65 wt% nanotubes and 35-45wt% graphite nanoparticles. The tubes have a diameter distribution of 2-50 nm, and a typical length of >2 microns (straight tubes). The chemical composition is 100% carbon, with no metal impurities. Because the nanotubes are grown at very high temperatures (3000-4000°C), the product contain far less defects than nanotubes produced by other methods. The nanotubes are stable in air up to 700°C.

COBALT (Compounds)

93-2749	**Cobalt(II) sulfate heptahydrate, 98+%** *(10026-24-1)* $CoSO_4\cdot7H_2O$; FW: 155.00 (281.10); pink to red xtl.; m.p. 96.8°; d. 1.948	100g 500g
93-2750	**Cobalt(II) sulfate heptahydrate (99.999%-Co) PURATREM** *(10026-24-1)* $CoSO_4\cdot7H_2O$; FW: 155.00 (281.10); pink to red xtl.; m.p. 96.8°; d. 1.948	10g 50g

LITHIUM (Elemental Forms)

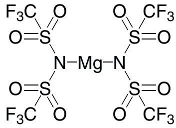
03-0375 HAZ	**Lithium granules (99+%)** *(7439-93-2)* Li; FW: 6.94; 2.5mm granules; m.p. 179°; b.p. 1317°; d. 0.534 *air sensitive, moisture sensitive*	50g 250g
93-0369 HAZ	**Lithium ribbon (99.8%)** *(7439-93-2)* Li; FW: 6.94; 100 mm wide x 1.5 mm thick; m.p. 179°; b.p. 1317°; d. 0.534 *air sensitive, moisture sensitive*	25g 100g
93-0359 HAZ	**Lithium rod (99.8%)** *(7439-93-2)* Li; FW: 6.94; 1.27 cm dia. (packed in mineral oil) (~0.67g/cm); m.p. 179°; b.p. 1317°; d. 0.534 *air sensitive, moisture sensitive*	50g 250g

LITHIUM (Compounds)

93-0325 HAZ	**Lithium hexafluorophosphate, 99+%** *(21324-40-3)* $LiPF_6$; FW: 151.92; white to off-white pwdr. *hygroscopic*	5g 25g
03-0325 HAZ	**Lithium hexafluorophosphate (99.9+%-Li)** *(21324-40-3)* $LiPF_6$; FW: 151.92; white xtl. *hygroscopic*	10g 50g 250g
93-0330 HAZ	**Lithium hydroxide, anhydrous, 95%** *(1310-65-2)* LiOH; FW: 23.95; white pwdr.; m.p. 450°; b.p. 925°; d. 1.46 *hygroscopic*	50g 250g
93-0329 HAZ	**Lithium hydroxide monohydrate, min. 98%** *(1310-66-3)* $LiOH\cdot H_2O$; FW: 23.95 (41.96); white pwdr. *hygroscopic*	500g 2kg
93-0356 HAZ	**Lithium tetrafluoroborate, 98%** *(14283-07-9)* $LiBF_4$; FW: 93.75; white pwdr.; m.p. dec. *hygroscopic*	10g 50g
03-5001	**2,2,6,6-Tetramethyl-3,5-heptanedionato lithium, 98+% [Li(TMHD)]** *(22441-13-0)* $LiC_{11}H_{19}O_2$; FW: 190.24; white pwdr.; m.p. 265-268°; b.p. dec. 295°	1g 5g 25g

MAGNESIUM (Compounds)

12-1200<s=An-chor 4A6826> **Magnesium bis(trifluoromethylsulfonyl)imide, min. 97%** *(133395-16-1)* — 1g, 5g
$Mg[(CF_3SO_2)_2N]_2$; FW: 584.60; white pwdr.
moisture sensitive



Technical Notes:
1. For detailed technical note visit strem.com.

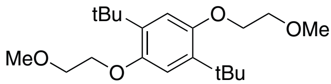
NICKEL (Compounds)

93-2839 **Nickel(II) sulfate hexahydrate, 98+% (ACS)** *(10101-97-0)* — 500g, 2kg
$NiSO_4 \cdot 6H_2O$; FW: 154.78 (262.86); green xtl.; d. 2.07

93-2856 **Nickel(II) sulfate hexahydrate (99.99%-Ni) PURATREM** *(10101-97-0)* — 25g, 100g
$NiSO_4 \cdot 6H_2O$; FW: 154.78 (262.86); green xtl.; d. 2.07

OXYGEN (Compounds)

08-0215 **1,4-Di-t-butyl-2,5-bis(2-methoxyethoxy)benzene, 99+% Redox shuttle ANL-RS2** *(1350770-63-6)* — 1g, 5g
$C_{20}H_{34}O_4$; FW: 338.48; white to off-white pwdr.; m.p. 69-70°
air sensitive, moisture sensitive
Note: U.S. Patent: 8,609,287.
European Patent App.: 11787270.5.
Chinese Patent App.: 11/80014192.6



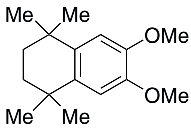
Redox Shuttles for Lithium Ion Batteries
1. Provides a long term intrinsic overcharge protection of lithium-ion batteries.
2. Maintains the safe operation of lithium-ion batteries.
3. Highly-soluble in conventional non-aqueous, carbonate based electrolytes.
4. Increases battery long-term stability and oxidation potential.

Electrochemical Properties:
1. ANL-RS2 (abbreviated DBBB) redox shuttle, compared to other dimethoxybenzene-based shuttles, has demonstrated improved solubility in carbonate-based electrolytes. DBBB displays a reversible redox potential at 3.9 V [1]
2. In comparison to a variety of quinoxaline-based species, DBBB exhibits reversible single electron transfer at 4 V vs. Li/Li+. Quinoxaline and its derivatives demonstrate two redox events between 4-3 V vs. Li/Li+ [2]
3. DBBB enriched electrolyte was demonstrated as an effective protection against overcharge abuse in 18650 format $LiFePO_4$ based lithium ion batteries [3]
4. Due to excellent solubility in carbonate-based electrolytes and improved electrolyte conductivity, DBBB is compatible with modest battery technologies. [4-5]

References:

1. *Energy Environ. Sci.,* **2012**, *5*, 8204.
2. *Adv. Energy Mater.,* **2012**, *2*, 1390
3. *J. Power Sources,* **2014**, *247*, 1011
4. *J. Electrochem. Soc.,* **2014**, *161*, A1905
5. *J. Electrochem. Soc.,* **2016**, *163*, A1.

08-0220 **6,7-Dimethoxy-1,1,4,4-tetramethyl-1,2,3,4-tetrahydronaphthalene, 99+% Redox shuttle ANL-RS21** *(22825-00-9)* — 1g, 5g
$C_{16}H_{24}O_2$; FW: 248.36; off-white solid
air sensitive, moisture sensitive
Note: U.S. Patent: 13/457,239.



Redox Shuttles for Lithium Ion Batteries
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4. Increases battery long-term stability and oxidation potential.

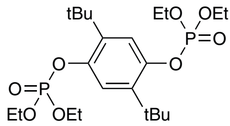
Electrochemical Properties:
1. ANL-RS21 5 mM exhibits a redox potential of about 4.05V, in electrolytes (1.2 M $LiPF_6$ in 3:7 wt/wt mixtures of EC/EMC. [1]
2. The redox shuttle in aprotic solvents can be used from -30° C to 70° C and are stable in the electrochemical window in which the cell electrodes and redox shuttle operates. ANL-RS21 undergoes reversible electrochemical oxidation to form stable cation-radical salts. [2]

References:

1. *US* **2013** *0288137* A1
2. *Org. Lett.,* **2009**, *11*, 2253

PHOSPHORUS (Compounds)

15-1375 **2,5-Di-t-butyl-1,4-phenylene tetraethyl bis(phosphonate), 99+% Redox shuttle ANL-RS6**
(1350767-15-5)
$C_{22}H_{40}O_8P_2$; FW: 494.50; white solid
air sensitive, moisture sensitive
Note: U.S. Patents: 8,969,625



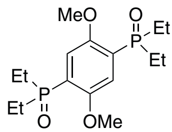
500mg
2g

Redox Shuttles for Lithium Ion Batteries
1. Provides a long term intrinsic overcharge protection of lithium-ion batteries.
2. Maintains the safe operation of lithium-ion batteries.
3. Highly-soluble in conventional non-aqueous, carbonate based electrolytes.
4. Increases battery long-term stability and oxidation potential.

Electrochemical Properties
1. ANL-RS6 (10 mM) exhibits a reversible redox potential of about 4.8V vs Li/Li^+ (1.2 M $LiPF_6$ in 3:7 wt/wt mixtures of ethylene carbonate and ethyl methyl carbonate.[1]
2. In cell tests using $LiMn_2O_4$ and $Li_{1.2}Ni_{0.15}Co_{0.1}Mn_{0.55}O_2$ as the cathode materials, overcharge protection was provided at 4.75 V vs. Li/Li^+[1].

References:
1. *Energy Environ. Sci.,* **2011**, *4*, 2858

15-1372 **(2,5-Dimethoxy-1,4-phenylene)bis(diethylphosphine oxide), 99+% Redox shuttle ANL-RS51**
(1802015-49-1)
$C_{16}H_{28}O_4P_2$; FW: 346.34; white solid
air sensitive, moisture sensitive
Note: U.S. Patent: 14/171,556.



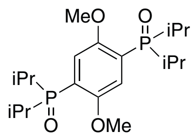
500mg
2g

Redox Shuttles for Lithium Ion Batteries
1. Provides a long term intrinsic overcharge protection of lithium-ion batteries.
2. Maintains the safe operation of lithium-ion batteries.
3. Highly-soluble in conventional non-aqueous, carbonate based electrolytes.
4. Increases battery long-term stability and oxidation potential.

Electrochemical Properties
1. ANL-RS51 exhibits a reversible redox potential of about 4.6V vs Li/Li+ (1.2 M $LiPF_6$ in 3:7 wt/wt mixture of ethylene carbonate and ethyl methyl carbonate).

References:
1. US 20150221982 A1 6, Aug, 2015

15-1365 **(2,5-Dimethoxy-1,4-phenylene)bis(di-i-propylphosphine oxide), 99+% Redox shuttle ANL-RS5** *(1426397-81-0)*
$C_{20}H_{36}O_4P_2$; FW: 402.45; white pwdr.
air sensitive, moisture sensitive
Note: U.S. Patent: 14/171,556.



250mg
1g

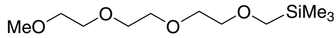
Redox Shuttles for Lithium Ion Batteries
1. Provides a long term intrinsic overcharge protection of lithium-ion batteries.
2. Maintains the safe operation of lithium-ion batteries.
3. Highly-soluble in conventional non-aqueous, carbonate based electrolytes.
4. Increases battery long-term stability and oxidation potential.

Electrochemical Properties:
1. ANL-RS5 (abbreviated BPDB) exhibits a reversible redox potential of about 4.5V vs Li/Li^+ (1.2 M $LiPF_6$ in 3:7 wt/wt mixture of ethylene carbonate and ethyl methyl carbonate) [1]
2. Provides stable overcharge protection for 4V MCMB (mesocarbon microbead)/LMO ($LiMn_2O_4$) cells delivering 95 cycles of 100% overcharge at room temperature [1]

References:
1. *J. Mater. Chem., A,* **2015**, *3*, 10710.

SILICON (Compounds)

14-1946 **2,2-Dimethyl-4,7,10,13-tetraoxa-2-silatetradecane, 99+%** 1g
Electrolyte Solvent ANL-1S1M3 *(864079-63-0)* 5g
$C_{11}H_{26}O_4Si$; FW: 250.41; colorless liq.
air sensitive, moisture sensitive
Note: Use for batteries for medical devices expressly excluded. U.S. Patent: 8,076,032

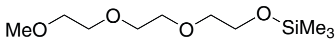


Organosilicon Electrolytes for Lithium Ion Batteries
1. Silicon based electrolytes with polyethylene glycol oligomers improve thermal and electrochemical stability of lithium-ion batteries.
2. Increases battery long-term stability.
3. Are less flammable as conventional organic carbonate-based solvents and maintain the safe operation of batteries.
4. Improves conductivity and kinetics of the lithium salts;

Electrochemical and Physical Properties:
1. **Viscosity** 2.0 cP at 25°C; **Conductivity** of 0.8M LiBOB electrolyte: 1.29 x 10^{-3} S cm^{-1} at 25°C. **Boiling point** 245°C; **Glass transition temperature** -110°C. [1, 2]
2. Soluble electrolytic lithium salts: LiBOB, $LiPF_6$ (03-0325), and LiTFSI
3. ANL-1S1M3 is non-hydrolyzable and less flammable than their alkoxysilane counterparts [2].
4. ANL-1S1M3 electrolyte cell test demonstrated good cycling performance in lithium-ion batteries, with a charge and discharge rate of C/5, cycled between 3.0 and 4.2 V at room temperature with only 9% capacity loss over 200 cycles. [2]

References:
1. *Electrochem. Commun.,* **2006**, *8*, 429
2. *J. Mater. Chem.,* **2010**, *20*, 8224

14-1930 **2,2-Dimethyl-3,6,9,12-tetroxa-2-silatridecane, 99+%** 1g
Electrolyte Solvent ANL-1NM3 *(864079-62-9)* 5g
$C_{10}H_{24}O_4Si$; FW: 236.38; colorless liq.
Note: Use for batteries for medical devices expressly excluded. U.S. Patent: 8,076,032



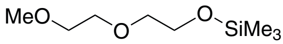
Organosilicon Electrolytes for Lithium Ion Batteries
1. Silicon based electrolytes with polyethylene glycol oligomers improve thermal and electrochemical stability of lithium-ion batteries
2. Increases battery long-term stability.
3. Are less flammable than conventional organic carbonate-based solvents and maintain the safe operation of batteries.
4. Improves conductivity and kinetics of the lithium salts;

Electrochemical and Physical Properties:
1. **Viscosity:** 1.4 cP at 25°C, doped with 0.8M LiBOB electrolyte 1.9 cP at 25°C; <b Conductivity: of 0.8M LiBOB doped electrolyte: 1.18 x 10^{-3}S cm^{-1} at 25°C; **Thermally stable** up to 400°C. **Boiling point** 233-234°C; **Glass transition temperature** -116°C [1, 2].
2. Soluble electrolytic lithium salts: LiBOB, $LiPF_6$ (03-0325), $LiBF_4$ (03-0325 Strem product - not battery grade) and LiTFSI
3. ANL-1NM3 electrolytes show excellent charge/discharge cycling behavior in lithium-ion cells. Silane-based electrolytes with certain lithium salts are stable to 4.4 V [1]
4. Compared to other trimethylsilylated polyethyleneoxide oligomers (see also ANL-1NM2; product # 14-1925) with two and three ethylene oxide units, these electrolytic blends are advantageous for the conductivity and kinetics of the lithium salts. [2] In some cases, ANL-1NM3 is more preferable because of the higher boiling point (233-234°C vs 190-191°C of ANL-1NM2) and a lower viscosity.
5. ANL-1NM3 doped with Lithium salts exhibit high ionic conductivity (more than 10^{-3}S cm^{-1}) at room temperature. Lithium bis(oxalate)borate (LiBOB) salt blended silicon electrolyte is showing most stable and higher electrochemical performance.[3-5] In addition silylated electrolytes show much better electrochemical stability than carbon and germanium analogues.[6]
6. Organosilicon electrolyte helps to enhance the transport properties of other electrolytes [7], shows excellent thermal and electrochemical stability [8] and also applicable for Li-air batteries. [9]

References:
1. *Electrochem. Commun.,* **2006**, *8*, 429
2. *Phys. Chem. C,* **2008**, *112*, 2210
3. *J. Power Sources,* **2011**, *196*, 2255
4. *J. Power Sources,* **2011**, *196*, 8301
5. *J. Phys. Chem. C,* **2011**, *115*, 24013
6. *J. Mater. Chem.,* **2008**, *18*, 3713
7. *J. Phys. Chem. C,* **2010**, *114*, 20569
8. *J. Power Sources,* **2013**, *241*, 311
9. *J. Phys. Chem. C,* **2011**, *115*, 25535

SILICON (Compounds)

14-1925 **2,2-Dimethyl-3,6,9-trioxa-2-siladecane, 99+% Electrolyte Solvent ANL-1NM2** *(62199-57-9)* 500mg 2g
$C_8H_{20}O_3Si$; FW: 192.33; colorless liq.
air sensitive, moisture sensitive
Note: U.S. Patent: 8,475,688

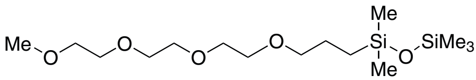


Organosilicon Electrolytes for Lithium Ion Batteries
1. Silicon based electrolytes with polyethylene glycol oligomers improve thermal and electrochemical stability of lithium-ion batteries.
2. Increases battery long-term stability
3. Are less flammable than conventional organic carbonate-based solvents and maintain the safe operation of batteries
4. Improves conductivity and kinetics of the lithium salts

Electrochemical and Physical Properties
1. **Viscosity:** 0.9 cP at 25°C; **Conductivity:** 1.2 x 10^{-3} S cm^{-1} at 25° (1.0 M LiTFSI); **Boiling point:** 190-191°C; **Glass transition temperature:** -129°C. [1-3]
2. Soluble electrolytic lithium salt LiTFSI; Less soluble LiBOB.
3. Silylated electrolytes show much better electrochemical stability than its carbon and germanium analogues.[3]
4. Compares well with other trimethylsilylated polyethyleneoxide oligomers, with longer chain lengths (see also ANL-1NM3; product # 14-1930). Ethylene oxide units in certain electrolytic blends are advantageous improving the conductivity and kinetics of the lithium salts.[3-4]

References:
1. *Electrochem. Commun.,* **2006**, *8*, 429
2. *J. Phys. Chem. C,* **2008**, *112*, 2210
3. *J. Mater. Chem.,* **2008**, *18*, 3713
4. *J. Power Sources,* **2014**, *272*, 190

14-1943 **2,2,4,4-Tetramethyl-3,8,11,14,17-pentaoxa-2,4-disilaoctadecane, 99+% Electrolyte solvent ANL-2SM3** *(855996-83-7)* 5g 25g
$C_{15}H_{36}O_5Si_2$; FW: 352.61; colorless liq.
Note: Use for batteries for medical devices expressly excluded.
U.S. Patent: 8,076,031 B1; 14/266,052.



Organosilicon Electrolytes for Lithium Ion Batteries
1. Silicon based electrolytes with polyethylene glycol oligomers improve thermal and electrochemical stability of lithium-ion batteries.
2. Increases battery long-term stability.
3. Are less flammable than conventional organic carbonate-based solvents and maintain the safe operation of batteries.
4. Improves conductivity and kinetics of the lithium salts.

Electrochemical and Physical Properties:
1. Disiloxane liquid electrolyte ANL-2SM3 exhibits electrochemical stability, high thermal stability, and low viscosity.- **Viscosity** 3.8 cP at 25ºC; **The conductivity and viscosity** of ANL-2SM3-based electrolyte are 3.65x10^{-4} Scm^{-1} and 18 cP at 25ºC [1,2] Charged cathode material is more thermally stable in the siloxane-based electrolyte than in the carbonate-based electrolyte.[1] **Boiling point** 269-271ºC; **Glass transition temperature** -103.0ºC
2. Soluble electrolytic lithium salts: LiBOB, $LiPF_6$, ANL2SM3, and LiTFSIANL-2SM3 is compatible with nanostructured material-based electrodes.[3]
3. Disiloxane/LiBOB or Disiloxane /$LiPF_6$ electrolytes show conductivities up to 6.2x10^{-4} Scm^{-1} at room temperature. Disiloxane electrolytes doped with 0.8MLiBOB are stable to 4.7 V. The LiBOB/disiloxane combinations were found to be good electrolytes for lithium-ion cells.[4]

References:
1. *J. Power Sources,* **2006**, *160*, 645
2. *J. Power Sources,* **2006**, *160*, 1355
3. *Chem. Mater.,* **2007**, *19*, 5734
4. *J. Power Sources,* **2010**, *195*, 6062

MATERIALS FOR BATTERY APPLICATIONS

SODIUM (Compounds)

11-1146	**Sodium hexafluorophosphate 99% (99.99%-Na) PURATREM** *(21324-39-0)* F_6NaP; FW: 167.95; white pwdr.; d. 2.37 *air sensitive, moisture sensitive, hygroscopic*	2g 10g
11-1147 NEW HAZ	**Sodium hexafluorophosphate 99% (99.99%-Na) PURATREM (<10ppm H_2O)** *(21324-39-0)* F_6NaP; FW: 167.95; white pwdr. *air sensitive, moisture sensitive, hygroscopic* Note: Suitable for battery applications	1g 5g

TANTALUM (Compounds)

93-7303 amp HAZ	**Tantalum(V) ethoxide (99.99+%-Ta) PURATREM** *(6074-84-6)* $Ta(OC_2H_5)_5$; FW: 406.26; colorless to yellow liq.; m.p. 21°; b.p. 145°/0.1 mm; f.p. 87°F; d. 1.56 *moisture sensitive*	10g 50g 5 x 50g
73-1080 amp HAZ	**Tantalum(V) ethoxide (99.9999%-Ta) PURATREM** *(6074-84-6)* $Ta(OC_2H_5)_5$; FW: 406.26; yellow liq.; m.p. 21°; b.p. 145°/0.1mm; f.p. 87°F; d. 1.56 *moisture sensitive* Note: Limited quantities available.	1g

TITANIUM (Compounds)

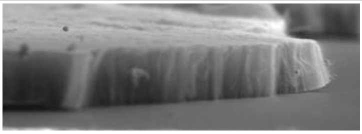
93-2220 HAZ	**Titanium(IV) sulfide (99.8%-Ti)** *(12039-13-3)* TiS_2; FW: 112.03; -200 mesh yellow to brown pwdr.; d. 3.22 *moisture sensitive*	1g 5g 25g

CARBON (Elemental Forms)

06-0025 **Acetylene carbon black (100% compressed)** *(1333-86-4)* 250g, 1kg
C; FW: 12.011; black pwdr. (avg. particle size 0.042 microns);
SA: 80m^2/g; m.p. 3652-3697° (subl.); b.p. 4200°; d. bulk 0.21g/cm^3

06-0026 **Acetylene carbon black (50% compressed)** *(1333-86-4)* 250g, 1kg
C; FW: 12.011; black pwdr. (avg. particle size 0.042 microns);
SA: 80m^2/g; m.p. 3652-3697° (subl.); b.p. 4200°; d. bulk 0.10/g/cm^3

06-0440 **Carbon nanotube array, multi-walled, on quartz (diameter= 100nm, length=30 microns)** *(308068-56-6)* 1pc
black microfibers



Technical Note:

1. Arrays grown on 10x10x1mm quartz substrate using a single source CVD process that yields vertically aligned MWNTs (< 1% catalyst impurity). Arrays are 30μm tall (± 3μm) and are composed of MWNTs 100nm in diameter (± 10nm). Arrays up to 150μm an be provided on request.

06-0470 **Carbon nanotubes, multi-walled (diameter = ~140nm, length = ~7 microns) (>90% nanotubes)** *(308068-56-6)* 1g, 5g
black pwdr.

Technical Note:

1. Produced by chemical vapor deposition. Typical metal content is <0.1%.

06-0475 **Carbon nanotubes, multi-walled (diameter = ~20-25nm, length = ~1-5 microns) (85% nanotubes)** *(308068-56-6)* 250mg, 1g
black pwdr.

Technical Note:

1. Produced by chemical vapor deposition. Typical metal content is 4-5 wt %.

06-0720 **Carbon nanotubes, multi-walled, arc-produced (diameter = 2-50nm, length = >2 microns) (55-65wt% nanotubes)** *(308068-56-6)* 250mg, 1g
black pwdr.

Technical Note:

1. Arc-produced, multi-walled carbon nanotubes contain 55-65 wt% nanotubes and 35-45wt% graphite nanoparticles. The tubes have a diameter distribution of 2-50 nm, and a typical length of >2 microns (straight tubes). The chemical composition is 100% carbon, with no metal impurities. Because the nanotubes are grown at very high temperatures (3000-4000°C), the product contain far less defects than nanotubes produced by other methods. The nanotubes are stable in air up to 700°C.

06-0504 **Carbon nanotubes, multi-walled, as produced cathode deposit** *(308068-56-6)* 1g, 5g
pieces

06-0505 **Carbon nanotubes, multi-walled, core material** *(308068-56-6)* 1g, 5g
pieces (20-40% nanotubes)

06-0506 **Carbon nanotubes, multi-walled, ground core material** *(308068-56-6)* 250mg, 1g, 5g
-270 mesh pwdr. (20-40%nanotubes)

06-0508 **Carbon nanotubes, single-walled/double-walled, 90%** *(308068-56-6)* 250mg, 1g
pwdr.

Technical Note:

1. This product is nanotubes, single-walled/double-walled, 90%. The tubes are 1-2nm in diameter with lengths of 5-30 microns. Ash is <1.5wt%.

93-0601 **Carbon powder (99+%)** *(7440-44-0)* 250g, 1kg
C; FW: 12.011; -325 mesh pwdr.; m.p. 3652-3697° (subl.); b.p. 4200°;
d. 1.8-2.1 (amorphous)

93-0602 **Carbon powder (99.999%)** *(7440-44-0)* 5g, 25g
C; FW: 12.011; -200 mesh pwdr.; m.p. 3652-3697° (subl.); b.p. 4200°;
d. 1.8-2.1 (amorphous)

93-0605 **Carbon rods (99.999%)** *(7440-44-0)* 1rod, 5rods
C; FW: 12.011; 3mm dia. x 30cm; m.p. 3652-3697° (subl.); b.p. 4200°;
d. 1.8-2.1 (amorphous)

MATERIALS FOR ENERGY STORAGE

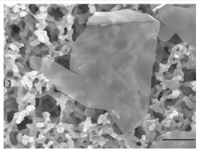
CARBON (Elemental Forms)

93-0608 **Carbon sheet (99.8%)** *(7440-44-0)* — 30 x 15cm; 150 x 15cm
C; FW: 12.011; 0.25 mm thick x 15 cm wide; m.p. 3652-3697° (subl.); b.p. 4200°; d. 1.8-2.1 (amorphous)

93-0607 **Carbon sheet (99.8%)** *(7440-44-0)* — 30 x 15cm; 150 x 15cm
C; FW: 12.011; 0.127 mm thick x 15 cm wide; m.p. 3652-3697° (subl.); b.p. 4200°; d. 1.8-2.1 (amorphous)

93-0609 **Carbon yarn (99.9%)** *(7440-44-0)* — 5m; 25m
C; FW: 12.011; ~0.6mm dia.; m.p. 3652-3697° (subl.); b.p. 4200°; d. 1.8-2.1 (amorphous)

06-0210 **Graphene nanoplatelets (6-8 nm thick x 5 microns wide)** *(1034343-98-0)* — 25g; 100g
C; black platelet
Note: See (page 14)



Technical Note:
1. For detailed technical note visit strem.com

06-0215 **Graphene nanoplatelets (6-8 nm thick x 15 microns wide)** *(1034343-98-0)* — 25g; 100g
C; black platelet
Technical Note:
1. See 06-0210 (page 14)

06-0220 **Graphene nanoplatelets (6-8 nm thick x 25 microns wide)** *(1034343-98-0)* — 25g; 100g
C; black platelet
Technical Note:
1. See 06-0210 (page 14)

06-0225 **Graphene nanoplatelets aggregates (sub-micron particles, surface area 300m^2/g)** *(1034343-98-0)* — 25g; 100g
black platelet
Note: See (page 14)
Technical Note:
1. For detailed technical note visit strem.com

06-0230 **Graphene nanoplatelets aggregates (sub-micron particles, surface area 500m^2/g)** *(1034343-98-0)* — 25g; 100g
black platelet
Technical Note:
1. See 06-0225 (page 14)

06-0235 **Graphene nanoplatelets aggregates (sub-micron particles, surface area 750m^2/g)** *(1034343-98-0)* — 25g; 100g
black platelet
Technical Note:
1. See 06-0225 (page 14)

COBALT (Compounds)

93-2741 **Cobalt(II) hydroxide (97%-Co)** *(21041-93-0)* — 50g; 250g
$Co(OH)_2$; FW: 92.96; pink pwdr.; m.p. dec.; d. 3.597

93-2712 **Cobalt(II,III) oxide, 99.5%** *(1308-06-1)* — 25g; 100g; 500g
Co_3O_4; FW: 240.80; black pwdr.

27-0490 **Cobalt(II,III) oxide (99.9985%-Co) PURATREM** *(1308-06-1)* — 5g; 25g
Co_3O_4; FW: 240.80; gray to black pwdr.

93-0386 **Lithium cobalt(III) oxide, min. 98%** *(12190-79-3)*
See page 30

COPPER (Compounds)

93-2943	**Copper(II) oxide, min. 97% (99+%-Cu)** *(1317-38-0)* CuO; FW: 79.54; black pwdr.; m.p. 1362°; d. 6.3-6.49	100g 500g
29-2945	**Copper(II) oxide (99.5+%-Cu)** *(1317-38-0)* CuO; FW: 79.54; black pwdr.; m.p. 1362°; d. 6.3-6.49	100g 500g
29-0590	**Copper(II) oxide (99.995%-Cu) PURATREM** *(1317-38-0)* CuO; FW: 79.55; 80-100 mesh black pwdr.; m.p. 1362°; d. 6.3-6.49	10g 50g

IRON (Compounds)

93-2616	**Iron(II,III) oxide, black (Magnetite), min. 95%** *(1317-61-9)* Fe_3O_4; FW: 231.54; black pwdr.; m.p. 1538° dec.; d. 5.18	500g 2kg
26-2750	**Iron(III) oxide (99.995%-Fe) PURATREM** *(1309-37-1)* Fe_2O_3; FW: 159.69; red to brown pwdr.; m.p. 1565°	10g 50g
93-2618	**Iron(III) oxide monohydrate, yellow (99.9+%-Fe)** *(51274-00-1)* $Fe_2O_3 \cdot H_2O$; FW: 159.69 (177.71); yellow pwdr.	1kg 5kg
93-2617	**Iron(III) oxide, red (Hematite) (99.8%-Fe)** *(1317-60-8)* Fe_2O_3; FW: 159.69; red pwdr.	250g 1kg 5kg
26-2860	**Iron(III) i-propoxide (99.9+%-Fe)** *(14995-22-3)* $Fe(OC_3H_7)_3$; FW: 233.12; brown to black solid *moisture sensitive*	25g

LITHIUM (Elemental Forms)

03-0375 HAZ	**Lithium granules (99+%)** *(7439-93-2)* Li; FW: 6.94; 2.5mm granules; m.p. 179°; b.p. 1317°; d. 0.534 *air sensitive, moisture sensitive*	50g 250g
93-0369 HAZ	**Lithium ribbon (99.8%)** *(7439-93-2)* Li; FW: 6.94; 100 mm wide x 1.5 mm thick; m.p. 179°; b.p. 1317°; d. 0.534 *air sensitive, moisture sensitive*	25g 100g
93-0359 HAZ	**Lithium rod (99.8%)** *(7439-93-2)* Li; FW: 6.94; 1.27 cm dia. (packed in mineral oil) (~0.67g/cm); m.p. 179°; b.p. 1317°; d. 0.534 *air sensitive, moisture sensitive*	50g 250g

LITHIUM (Compounds)

93-0386	**Lithium cobalt(III) oxide, min. 98%** *(12190-79-3)* $LiCoO_2$; FW: 97.87; dark gray pwdr.	50g 250g
93-0383	**Lithium dihydrogen phosphate, 97%** *(13453-80-0)* LiH_2PO_4; FW: 103.93; white pwdr.; d. 2.461	100g 500g
03-1250	**Lithium hexafluoroarsenate(V) (99.9+%-As)** *(29935-35-1)* $LiAsF_6$; FW: 195.85; white pwdr. *hygroscopic*	5g 25g
03-0343 HAZ	**Lithium oxide, min. 95% (99.5%-Li)** *(12057-24-8)* Li_2O; FW: 29.88; white pwdr.; m.p. 1427°; d. 2.013 *moisture sensitive*	25g 100g
03-2000	**Lithium trifluoromethanesulfonate, 99% (Lithium triflate)** *(33454-82-9)* $LiCF_3SO_3$; FW: 156.01; white pwdr. *hygroscopic*	10g 50g

MANGANESE (Compounds)

93-2510 HAZ	**Manganese(IV) oxide, 99+%** *(1313-13-9)* MnO_2; FW: 86.94; black xtl.; m.p. 535° dec.; d. 5.026	100g 500g
25-1380 HAZ	**Manganese(IV) oxide (99.995%-Mn) PURATREM** *(1313-13-9)* MnO_2; FW: 86.94; black, random pieces; m.p. 535° dec.; d. 5.026	10g 50g
25-1360 HAZ	**Manganese(IV) oxide, activated** *(1313-13-9)* MnO_2; FW: 86.94; brown to black pwdr.; m.p. 535° dec.; d. 5.026	50g 250g

MOLYBDENUM (Compounds)

93-4246	**Molybdenum(IV) oxide, 99%** *(18868-43-4)* MoO_2; FW: 127.95; purple pwdr.; d. 6.47	10g 50g
93-4215	**Molybdenum(VI) oxide, 99.5+%** *(1313-27-5)* MoO_3; FW: 143.95; pale green pwdr.; m.p. 795°; b.p. subl.; d. 4.69	50g 250g
42-1475	**Molybdenum(VI) oxide (99.998%-Mo) PURATREM** *(1313-27-5)* MoO_3; FW: 143.95; pale green pwdr.; m.p. 795°; b.p. subl.; d. 4.69	10g 50g
42-1476	**Molybdenum(VI) oxide (99.999%-Mo) PURATREM** *(1313-27-5)* MoO_3; FW: 143.95; pale green pwdr.; m.p. 795°; b.p. subl.; d. 4.69	10g 50g
93-4209 HAZ	**Molybdenum(VI) tetrachloride oxide, min. 97%** *(13814-75-0)* $MoOCl_4$; FW: 253.78; green pwdr.; m.p. 100-101° *air sensitive, moisture sensitive, (store cold)*	5g 25g

NICKEL (Compounds)

93-2833	**Nickel(II) oxide (99.99%-Ni) PURATREM** *(1313-99-1)* NiO; FW: 74.71; green pwdr.; m.p. 1990°; d. 6.67	25g 100g
28-1475	**Nickel(II) oxide (99.998%-Ni) PURATREM** *(1313-99-1)* NiO; FW: 74.71; greenish-black pwdr.; m.p. 1990°; d. 6.67	10g 50g
93-2861	**Nickel(II) oxide, black (99.9+%)** *(1313-99-1)* NiO; FW: 74.71; -325 mesh black pwdr.; m.p. 1990°; d. 6.67	100g 500g
93-2832	**Nickel(II) oxide, green, 99%** *(1313-99-1)* NiO; FW: 74.71; -325 mesh green pwdr.; m.p. 1990°; d. 6.67	50g 250g

RUTHENIUM (Compounds)

44-1977	**Ruthenium(IV) oxide, anhydrous (99.9+%-Ru)** *(12036-10-1)* RuO_2; FW: 133.07; black pwdr.; m.p. dec.; d. 6.97	1g 5g

TIN (Compounds)

93-5026	**Tin(IV) oxide (99.9%-Sn)** *(18282-10-5)* SnO_2; FW: 150.69; white pwdr.; m.p. 1630°; d. 7.0	100g 500g
50-2500	**Tin(IV) oxide (99.998%-Sn) PURATREM** *(18282-10-5)* SnO_2; FW: 150.69; -22 mesh off-white pwdr.; m.p. 1630°; d. 7.0	5g 25g

TITANIUM (Compounds)

93-2206	**Titanium(IV) oxide, 99+%** *(13463-67-7)* TiO_2; FW: 79.90; 1.0-1.3 micron white pwdr.; m.p. 1830-1850°; b.p. 2500-3000°; d. 4.26	250g 1kg
93-2207	**Titanium(IV) oxide (99.99+%-Ti) PURATREM** *(13463-67-7)* TiO_2; FW: 79.90; white pwdr.; m.p. 1830-1850°; b.p. 2500-3000°; d. 4.26	25g 100g
93-2225	**Titanium(IV) oxide bis(acetylacetonate), min. 95%** *(14024-64-7)* $TiO(CH_3COCHCOCH_3)_2$; FW: 262.12; yellow pwdr.; m.p. 184° dec.	5g 25g 100g

TITANIUM (Compounds)

22-1400	**Titanium(IV) oxide nanopowder Anatase** *(1317-80-2)* TiO_2; FW: 79.90; white pwdr.	5g 25g

Specific Surface Area (BET): ≥500 m²/g; **True Density:** 3.7 g/cc; **Crystallite Size:** Amorphous; **Mean Aggregate Size**: 5 μm; **Average Pore Diameter:** 32Å; **Loss on Ignition:** ≤12%; **Total Pore Volume:** ≥0.4 cc/g; **Moisture Content:** ≤4%; **Bulk Density:** 0.6 g/cc; **Ti Content (Based on Metal):**> 99.999%

93-2208	**Titanium(IV) oxide, sintered lumps, 99.5%** *(13463-67-7)* TiO_2; FW: 79.90; white lump; m.p. 1830-1850°; b.p. 2500-3000°; d. 4.26	25g 100g

TUNGSTEN (Compounds)

74-7430	**Tungsten(IV) oxide (99.9%-W)** *(12036-22-5)* WO_2; FW: 215.85; brown pwdr.; m.p. 1500-1600°; d. 12.11	10g 50g
74-7435	**Tungsten(IV) oxide (99.9+%-W) (WO2.9 Blue Sub-oxide)** *(12037-58-0)* $WO_{2\cdot75}$-$_{2\cdot90}$; FW: 215.85; blue pwdr.	10g 50g
93-7427	**Tungsten(VI) oxide (min. 99.8%-W)** *(1314-35-8)* WO_3; FW: 231.85; yellowish-green pwdr.; m.p. 1473°; d. 7.16	100g 500g
74-3105	**Tungsten(VI) oxide (99.995%-W) PURATREM** *(1314-35-8)* WO_3; FW: 231.85; yellow pwdr.; m.p. 1473°; d. 7.16	10g 50g
93-7411	**Tungsten(VI) oxide, sintered lumps (99.99%-W) PURATREM** *(1314-35-8)* WO_3; FW: 231.85; yellowish-green pieces; m.p. 1473°; d. 7.16	10g 50g

VANADIUM (Compounds)

93-2306 HAZ	**Vanadium(V) oxide, 98%** *(1314-62-1)* V_2O_5; FW: 181.88; orange to brown pwdr.; m.p. 690°; b.p. 1750° dec.; d. 3.357	100g 500g
93-2321 HAZ	**Vanadium(V) oxide, 99.5%** *(1314-62-1)* V_2O_5; FW: 181.88; -60 mesh orange to brown pwdr.; m.p. 690°; b.p. 1750° dec.; d. 3.357	100g 500g
93-2337 HAZ	**Vanadium(V) oxide (99.99%-V) PURATREM** *(1314-62-1)* V_2O_5; FW: 181.88; -22 mesh orange pwdr.; m.p. 690°; b.p. 1750° dec.; d. 3.357	5g 25g

ZINC (Compounds)

93-3017	**Zinc oxide, 99.7%** *(1314-13-2)* ZnO; FW: 81.37; white pwdr. (mean partical size 0.31 microns); m.p. 1975°; d. 5.606	500g 2kg
93-3016	**Zinc oxide (99.999%-Zn) PURATREM** *(1314-13-2)* ZnO; FW: 81.37; white pwdr.; m.p. 1975°; d. 5.606	10g 50g
93-3039	**Zinc oxide, sintered tablets (99.9%-Zn)** *(1314-13-2)* ZnO; FW: 81.37; ~10-12mm dia. x 4-5mm thick (~2.3g ea.); m.p. 1975°; d. 5.606	25g 100g

AMMONIUM (Compounds)

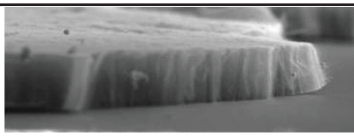
93-7801 HAZ — **Ammonium hexachloroplatinate(IV), 99%** *(16919-58-7)* — 1g, 5g
$(NH_4)_2PtCl_6$; FW: 443.89; yellow pwdr.; m.p. dec.; d. 3.065
hygroscopic

CARBON (Elemental Forms)

06-0100 — **Activated carbon** *(7440-44-0)* — 300g, 1kg
C; FW: 12.011; black pwdr.; SA: 1300-1400 m²/g; m.p. 3652-3697° (subl.); b.p. 4200°; d. 1.8-2.1 (amorphous)

06-0050 — **Activated carbon** *(7440-44-0)* — 500g, 2kg
C; FW: 12.011; 4 x 10 mesh black gran.; SA: 1000 m²/g; m.p. 3652-3697° (subl.); b.p. 4200°; d. 1.8-2.1 (amorphous)

06-0440 — **Carbon nanotube array, multi-walled, on quartz (diameter= 100nm, length=30 microns)** *(308068-56-6)* — 1pc
black microfibers



Technical Note:
1. See (page 28)

06-0470 — **Carbon nanotubes, multi-walled (diameter = ~140nm, length = ~7 microns) (>90% nanotubes)** *(308068-56-6)* — 1g, 5g
black pwdr.
Technical Note:
1. See (page 28)

06-0475 — **Carbon nanotubes, multi-walled (diameter = ~20-25nm, length = ~1-5 microns) (85% nanotubes)** *(308068-56-6)* — 250mg, 1g
black pwdr.
Technical Note:
1. See (page 28)

06-0720 — **Carbon nanotubes, multi-walled, arc-produced (diameter = 2-50nm, length = >2 microns) (55-65wt% nanotubes)** *(308068-56-6)* — 250mg, 1g
black pwdr.
Technical Note:
1. See (page 22)

06-0504 — **Carbon nanotubes, multi-walled, as produced cathode deposit** *(308068-56-6)* — 1g, 5g
pieces

06-0505 — **Carbon nanotubes, multi-walled, core material** *(308068-56-6)* — 1g, 5g
pieces (20-40% nanotubes)

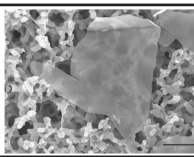
06-0506 — **Carbon nanotubes, multi-walled, ground core material** *(308068-56-6)* — 250mg, 1g, 5g
-270 mesh pwdr. (20-40%nanotubes)

06-0508 — **Carbon nanotubes, single-walled/double-walled, 90%** *(308068-56-6)* — 250mg, 1g
pwdr.
Technical Note:
1. This product is nanotubes, single-walled/double-walled, 90%. The tubes are 1-2nm in diameter with lengths of 5-30 microns. Ash is <1.5wt%.

93-0601 — **Carbon powder (99+%)** *(7440-44-0)* — 250g, 1kg
C; FW: 12.011; -325 mesh pwdr.; m.p. 3652-3697° (subl.); b.p. 4200°; d. 1.8-2.1 (amorphous)

93-0602 — **Carbon powder (99.999%)** *(7440-44-0)* — 5g, 25g
C; FW: 12.011; -200 mesh pwdr.; m.p. 3652-3697° (subl.); b.p. 4200°; d. 1.8-2.1 (amorphous)

06-0210 — **Graphene nanoplatelets (6-8 nm thick x 5 microns wide)** *(1034343-98-0)* — 25g, 100g
C; black platelet
Note: See (page 14)



Technical Note:
1. For detailed technical note visit strem.com

CARBON (Elemental Forms)

06-0215 **Graphene nanoplatelets (6-8 nm thick x 15 microns wide)** *(1034343-98-0)* 25g
C; black platelet 100g

Technical Note:
1. See 06-0210 (page 14)

06-0220 **Graphene nanoplatelets (6-8 nm thick x 25 microns wide)** *(1034343-98-0)* 25g
C; black platelet 100g

Technical Note:
1. See 06-0210 (page 14)

06-0225 **Graphene nanoplatelets aggregates (sub-micron particles, surface area 300m²/g)** 25g
(1034343-98-0) 100g
black platelet
Note: See (page 14)

Technical Note:
1. For detailed technical note visit strem.com

06-0230 **Graphene nanoplatelets aggregates (sub-micron particles, surface area 500m²/g)** 25g
(1034343-98-0) 100g
black platelet

Technical Note:
1. See 06-0225 (page 14)

06-0235 **Graphene nanoplatelets aggregates (sub-micron particles, surface area 750m²/g)** 25g
(1034343-98-0) 100g
black platelet

Technical Note:
1. See 06-0225 (page 14)

COBALT (Compounds)

93-2703 **Cobalt(II) acetylacetonate hydrate** *(123334-29-2)* 50g
$Co(CH_3COCHCOCH_3)_2 \cdot XH_2O$; FW: 257.18; pink pwdr. 250g

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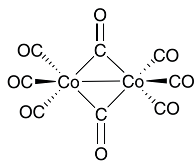
27-0400 **Cobalt carbonyl (Dicobalt octacarbonyl)** 5g
HAZ **(Stabilized with 1-5% hexanes)** *(10210-68-1)* 25g
$Co_2(CO)_8$; FW: 341.95; dark orange xtl.; m.p. 51-52° dec.; 100g
f.p. -9°F (hexane); d. 1.73
air sensitive, (store cold)



Technical Note:
1. For detailed technical note visit strem.com

93-2730 **Cobalt(II) nitrate hexahydrate, 99%** *(10026-22-9)* 100g
HAZ $Co(NO_3)_2 \cdot 6H_2O$; FW: 182.99 (291.05); red xtl.; m.p. 55-56°; d. 1.87 500g

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93-2746 **Cobalt(II) nitrate hexahydrate (99.999%-Co) PURATREM** *(10026-22-9)* 5g
HAZ $Co(NO_3)_2 \cdot 6H_2O$; FW: 182.99 (291.05); red to purple xtl.; m.p. 55-56°; d. 1.87 25g

COPPER (Compounds)

93-2968 **Copper(II) acetylacetonate, 98+%** *(13395-16-9)* 50g
$Cu(CH_3COCHCOCH_3)_2$; FW: 261.77; blue pwdr.; m.p. 284-285° dec.; 250g
b.p. dec. 284° (subl. 78°/0.05mm)

93-2920 **Copper(II) ethylacetoacetate, 99%** *(14284-06-1)* 5g
$Cu(CH_3COCHCOC_2H_5)_2$; FW: 321.82; green to blue pwdr. 25g

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29-2941 **Copper(II) 2-ethylhexanoate (solvent free - 16-19% Cu)** *(149-11-1)* 5g
$Cu[OOCCH(C_2H_5)C_4H_9]_2$; FW: 349.96; blue pwdr. 25g
100g

29-2928 **Copper(II) hexafluoroacetylacetonate, anhydrous, elec. gr.** 1g
(99.99+%-Cu) PURATREM *(14781-45-4)* 5g
$Cu(CF_3COCHCOCF_3)_2$; FW: 477.64; blue xtl.
moisture sensitive

COPPER (Compounds)

29-2929 **Copper(II) hexafluoroacetylacetonate hydrate, elec. gr. (99.99+%-Cu) PURATREM** *(14781-45-4)* — 1g, 5g, 25g
$Cu(CF_3COCHCOCF_3)_2 \cdot XH_2O$; FW: 477.64; green to blue xtl.; m.p. 85-89°; b.p. dec. 220° (subl. 70°/0.05mm)
hygroscopic

93-2939 HAZ **Copper(II) nitrate trihydrate, 99.5%** *(10031-43-3)* — 250g, 1kg
$Cu(NO_3)_2 \cdot 3H_2O$; FW: 187.56 (241.60); blue xtl.; m.p. 114.5°; d. 2.32

93-2940 HAZ **Copper(II) nitrate trihydrate (99.999%-Cu) PURATREM** *(10031-43-3)* — 5g, 25g, 100g
$Cu(NO_3)_2 \cdot 3H_2O$; FW: 187.56 (241.60); blue xtl.; m.p. 114.5°; d. 2.32

NANOMATERIALS (Elemental Forms)

78-0007 HAZ **Platinum, 97% (2-5 nanometers)** *(7440-06-4)* — 250mg, 1g
Pt; black pwdr.
pyrophoric
Note: Made to order. Suggest use within 3 months of receipt. Long term shelf life not established.

References:
1. *J. Mol. Catal.,* **1994**, *86*, 129

78-0405 **Platinum Nanoparticles [PtNP: 2-3 nm (gum Arabic)]** *(7440-06-4)* — 25ml, 100ml
yellowish-brown liq.
(store cold)

Properties: Water soluble; **Size**: 2-3 nm; **Shape**: Sphere; **UV Vis (nm):**405-410 nm; **Specification**: Stable for 60 days Supplied in aqueous media, contains gum arabic stabilizer. Suitable for in vitro use and sensor design applications. Suitable for spin coating, self-assembly and monolayer formation. Potential new Catalysts.

78-0055 HAZ **Platinum/tetra-n-octylammonium chloride colloid, purified (70-85% Pt)** *(7440-06-4)* — 250mg, 1g
$Pt/(C_8H_{17})_4NCl$; 2.8 nm ±0.5 nm; grayish-black pwdr
pyrophoric
Note: Made to order. Suggest use within 3 months of receipt. Long term shelf life not established.

Technical Note:
1. Soluble in THF. Insoluble in toluene, acetone, ether and ethanol.

References:
1. *J. Mol. Catal.,* **1994**, *86*, 129
2. *Eur. J. Inorg. Chem.,* **2001**, 2455.
3. *Synthetic Methods of Organometallic and Inorganic Chemistry*, Vol.10, Chapter 20, p. 209-223, Theime Verlag, NY, 2002.
4. *Catalysis and Electrocatalysis at Nanoparticles Surfaces*, Chapter 10, p. 343, 377, Marcel Dekker, NY, 2003.

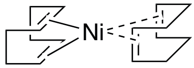
78-0062 HAZ **Platinum-ruthenium/tetra-n-octylammonium chloride colloid (~7 wt% Pt, ~3.5 wt% Ru)** *(7440-06-4)* — 250mg, 1g
$Pt_{50}Ru_{50}/(C_8H_{17})_4NCl$; 1.7 nm ±0.5 nm; waxy, black residue
Note: Made to order. Suggest use within 3 months of receipt. Long term shelf life not established.

Technical Note:
1. Very soluble in THF. Soluble in toluene. Precursor for fuel cell catalysts.

References:
1. *J. Mol. Catal.,* **1994**, *86*, 129
2. *Synthetic Methods of Organometallic and Inorganic Chemistry,* Vol. 10, Chapter 20, p. 209-223, Theime Verlag, NY, 2002.
3. *Catalysis and Electrocatalysis at Nanoparticles Surfaces*, Chapter 10, p. 343-377, Marcel Dekker, NY, 2003.

NICKEL (Compounds)

28-0010 HAZ
Bis(1,5-cyclooctadiene)nickel (0), 98+% *(1295-35-8)*
$(C_8H_{12})_2Ni$; FW: 275.08; yellow xtl.; m.p. 60° dec. (under N_2)
air sensitive, (store cold)
2g, 10g



Technical Notes:
1. For detailed technical note visit strem.com.

93-2821
Nickel(II) hexafluoroacetylacetonate hydrate, 98% *(14949-69-0)*
$Ni(CF_3COCHCOCF_3)_2{\cdot}XH_2O$; FW: 472.81; green xtl.; m.p. 211-213°
1g, 5g

93-2860 HAZ
Nickel(II) nitrate hexahydrate (99.9+%-Ni) *(13478-00-7)*
$Ni(NO_3)_2{\cdot}6H_2O$; FW: 182.72 (290.81); green flake; m.p. 56.7°; d. 2.05
250g, 1kg

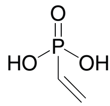
28-1440 HAZ
Nickel(II) nitrate hexahydrate (99.9985%-Ni) PURATREM *(13478-00-7)*
$Ni(NO_3)_2{\cdot}6H_2O$; FW: 182.72 (290.81); green xtl.; m.p. 56.7°; d. 2.05
25g, 100g

93-2833
Nickel(II) oxide (99.99%-Ni) PURATREM *(1313-99-1)*
NiO; FW: 74.71; green pwdr.; m.p. 1990°; d. 6.67
25g, 100g

28-1475
Nickel(II) oxide (99.998%-Ni) PURATREM *(1313-99-1)*
NiO; FW: 74.71; greenish-black pwdr.; m.p. 1990°; d. 6.67
10g, 50g

PHOSPHORUS (Compounds)

15-9155 HAZ
Vinylphosphonic acid, min. 90% *(1746-03-8)*
$CH_2{=}CHP(O)(OH)_2$; FW: 108.00;
colorless to pale-yellow liq.; m.p. 36°
50g, 250g



15-9158 HAZ
Vinylphosphonic acid dimethyl ester, min. 90% *(4645-32-3)*
$CH_2{=}CHP(O)(OCH_3)_2$; FW: 136.10; colorless liq.
(store cold)
50g, 250g

PLATINUM (Elemental Forms)

78-1685 HAZ
Dealloyed Pt-Co core-shell fuel cell catalyst on carbon
PtCo; black solid
100mg

78-1688 HAZ
Dealloyed Pt-Cu core-shell fuel cell catalyst on carbon
PtCu; black solid
100mg

78-0007
Platinum, 97% (2-5 nanometers) *(7440-06-4)*
See page 35

78-1420 HAZ
Platinum black, min. 97% *(7440-06-4)*
Pt; FW: 195.09; black pwdr.; SA: ~24 m^2/g; m.p. 1769°; b.p. 3827°; d. 21.45
250mg, 1g, 5g

78-0405
Platinum Nanoparticles [PtNP: 2-3 nm (gum Arabic)] *(7440-06-4)*
See page 35

78-0055
Platinum/tetra-n-octylammonium chloride colloid, purified (70-85% Pt)
(7440-06-4)
See page 35

PLATINUM (Compounds)

93-7801	**Ammonium hexachloroplatinate(IV), 99%** *(16919-58-7)* *See* page 33	
78-0200 HAZ	**Chloroplatinic acid hexahydrate (38-40% Pt) (99.9%-Pt)** *(18497-13-7)* $H_2PtCl_6 \cdot 6H_2O$; FW: 409.82 (517.92); orange pwdr.; m.p. 60° *light sensitive, hygroscopic, (store cold)*	1g 5g 25g
93-7806	**Dihydrogen hexahydroxyplatinate(IV), 99%** *(51850-20-5)* $H_2Pt(OH)_6$; FW: 299.15; yellow pwdr.	1g 5g
78-0700	**Dimethyl(1,5-cyclooctadiene)platinum(II), 99%** *(12266-92-1)* $(CH_3)_2Pt(C_8H_{12})$; FW: 333.34; white pwdr.	250mg 1g 5g
78-1400	**Platinum(II) acetylacetonate, 98%** *(15170-57-7)* $Pt(CH_3COCHCOCH_3)_2$; FW: 393.31; pale yellow xtl.	1g 5g
78-1429	**Platinum(II) bromide, 98%** *(13455-12-4)* $PtBr_2$; FW: 354.91; brown pwdr.; m.p. 250° dec.; d. 6.65	1g 5g
78-1480 HAZ	**Platinum(II) chloride (99.9%-Pt)** *(10025-65-7)* $PtCl_2$; FW: 266.00; olive-brown pwdr.; m.p. 581° dec.; d. 6.05	250mg 1g 5g
78-1490 HAZ	**Platinum(IV) chloride (99.9%-Pt)** *(13454-96-1)* $PtCl_4$; FW: 336.90; reddish-brown xtl.; m.p. 370° dec.; d. 4.303 *moisture sensitive*	1g 5g
78-1550	**Platinum(II) hexafluoroacetylacetonate, 98% (99.9%-Pt)** *(65353-51-7)* $Pt(CF_3COCHCOCF_3)_2$; FW: 609.22; orange xtl.; m.p. 143-145°; b.p. subl. 65°/0.1mm	500mg 2g
93-7808	**Platinum(II) iodide, min. 98%** *(7790-39-8)* PtI_2; FW: 448.90; black pwdr.; m.p. 360° dec.	1g 5g

POTASSIUM (Compounds)

78-1950	**Potassium hexabromoplatinate(IV), 99%** *(16920-93-7)* *See* page 38	
78-1960	**Potassium hexachloroplatinate(IV), 99%** *(16921-30-5)* *See* page 38	
78-1963	**Potassium hexacyanoplatinate(IV), 99%** *(16920-94-8)* *See* page 38	
78-1967	**Potassium tetrabromoplatinate(II), 99%** *(13826-94-3)* *See* page 38	
78-1970	**Potassium tetrachloroplatinate(II) (99.9%-Pt)** *(10025-99-7)* *See* page 38	
78-1995	**Sodium hexachloroplatinate(IV) hexahydrate, 98+%** *(19583-77-8)* *See* page 38	
93-7810	**Sodium tetrachloroplatinate(II) hydrate** *(207683-21-4)* *See* page 38	
78-2000	**Tetraammineplatinum(II) chloride monohydrate, 99% (99.95%-Pt)** *(13933-32-9)* $[Pt(NH_3)_4]Cl_2 \cdot H_2O$; FW: 334.09 (352.12); white xtl.	1g 5g
78-2005	**Tetraammineplatinum(II) hydroxide hydrate (59% Pt)** *(15651-37-3)* $Pt(NH_3)_4(OH)_2 \cdot XH_2O$; FW: 297.23; white to off-white solid *(store cold)*	1g 5g
78-2010 HAZ	**Tetraammineplatinum(II) nitrate, 99%** *(20634-12-2)* $[Pt(NH_3)_4](NO_3)_2$; FW: 387.22; white to off-white pwdr. *hygroscopic*	250mg 1g 5g
78-2015	**Tetraammineplatinum(II) tetrachloroplatinate(II), 99%** *(13820-46-7)* $[Pt(NH_3)_4][PtCl_4]$; FW: 600.12; green pwdr.	1g 5g
78-1365	**Tris(dibenzylideneacetone)diplatinum(0), min. 98%** *(63782-74-1)* $(C_6H_5CH{=}CHCOCH{=}CHC_6H_5)_3Pt_2$; FW: 1093.03; purple-black solid *air sensitive*	250mg 1g

Technical Notes:

1. For detailed technical note visit strem.com

POTASSIUM (Compounds)

78-1950	**Potassium hexabromoplatinate(IV), 99%** *(16920-93-7)* K_2PtBr_6; FW: 752.72; red to brown pwdr.; m.p. 400° dec.; d. 4.66 *hygroscopic*	1g 5g
78-1960 HAZ	**Potassium hexachloroplatinate(IV), 99%** *(16921-30-5)* K_2PtCl_6; FW: 486.01; yellow xtl.; m.p. 250° dec.; d. 3.499 *hygroscopic*	1g 5g
78-1963 HAZ	**Potassium hexacyanoplatinate(IV), 99%** *(16920-94-8)* $K_2Pt(CN)_6$; FW: 429.40; white pwdr.	250mg 1g 5g
44-1700	**Potassium hexacyanoruthenate(II) hydrate** *(15002-31-0)* $K_4Ru(CN)_6 \cdot XH_2O$; FW: 413.59; white pwdr.	250mg 1g 5g
93-1987	**Potassium pentachlororuthenate(III) hydrate** *(14404-33-2)* $K_2RuCl_5 \cdot XH_2O$; FW: 356.53; brown pwdr.	1g 5g
44-1750 HAZ	**Potassium perruthenate, 98%** *(10378-50-4)* $KRuO_4$; FW: 204.17; black xtl.	1g 5g
78-1967	**Potassium tetrabromoplatinate(II), 99%** *(13826-94-3)* K_2PtBr_4; FW: 592.93; red pwdr.	1g 5g
78-1970 HAZ	**Potassium tetrachloroplatinate(II) (99.9%-Pt)** *(10025-99-7)* K_2PtCl_4; FW: 415.11; pink to red pwdr.; d. 3.38 *hygroscopic*	1g 5g 25g

RUTHENIUM (Compounds)

44-1700	**Potassium hexacyanoruthenate(II) hydrate** *(15002-31-0)* *See* page 38	
93-1987	**Potassium pentachlororuthenate(III) hydrate** *(14404-33-2)* *See* page 38	
44-1750	**Potassium perruthenate, 98%** *(10378-50-4)* *See* page 38	
44-1800	**Ruthenium(III) acetylacetonate, 99%** *(14284-93-6)* $Ru(CH_3COCHCOCH_3)_3$; FW: 398.40; red to brown xtl.; m.p. 230-235°	1g 5g
44-1825	**Ruthenium(III) bromide hydrate** *(14014-88-1)* $RuBr_3 \cdot XH_2O$; FW: 340.80; black xtl.	1g 5g
44-5850 HAZ	**Ruthenium(III) chloride, anhydrous** *(10049-08-8)* $RuCl_3$; FW: 207.43; black pwdr.; m.p. >500° dec. *hygroscopic*	1g 5g 25g
44-5880 HAZ	**Ruthenium(III) chloride hydrate (40-43% Ru) (99.9%-Ru)** *(14898-67-0)* $RuCl_3 \cdot XH_2O$; FW: 207.43; black pwdr.; m.p. 100° (dec.) *hygroscopic*	1g 5g 25g
44-2500	**Ruthenium(III) iodide, anhydrous, 98+%** *(13896-65-6)* RuI_3; FW: 481.78; black xtl.	1g 5g

SODIUM (Compounds)

78-1995	**Sodium hexachloroplatinate(IV) hexahydrate, 98+%** *(19583-77-8)* $Na_2PtCl_6 \cdot 6H_2O$; FW: 453.79 (561.89); orange pwdr. *hygroscopic*	1g 5g
93-7810	**Sodium tetrachloroplatinate(II) hydrate** *(207683-21-4)* $Na_2PtCl_4 \cdot XH_2O$; FW: 382.92; reddish-brown pwdr.; m.p. 100°	1g 5g

VANADIUM (Compounds)

93-2337 HAZ	**Vanadium(V) oxide (99.99%-V) PURATREM** *(1314-62-1)* V_2O_5; FW: 181.88; -22 mesh orange pwdr.; m.p. 690°; b.p. 1750° dec.; d. 3.357	5g 25g

CALCIUM (Compounds)

93-2021 HAZ	**Calcium hydride, 95%** *(7789-78-8)* CaH_2; FW: 42.10; 1-20mm light gray granules; m.p. 816° (H_2); d. 1.9 *moisture sensitive*	50g 250g
20-2021 HAZ	**Calcium hydride, min. 97%** *(7789-78-8)* CaH_2; FW: 42.10; 0-2mm white to gray pwdr.; m.p. 816° (H_2); d. 1.9 *moisture sensitive*	50g 250g

IRIDIUM (Elemental Forms)

77-2000 HAZ	**Iridium black (99.9% Ir)** *(7439-88-5)* Ir; FW: 192.20; m.p. 2410°; b.p. 4130°; d. 22.421	500mg 2g
77-2500 HAZ	**Iridium powder (99.8%)** *(7439-88-5)* Ir; FW: 192.20; bluish-gray pwdr.; m.p. 2410°; b.p. 4130°; d. 22.421	500mg 2g

LITHIUM (Compounds)

03-0750 HAZ	**Lithium aluminum deuteride, 98% isotopic purity** *(14128-54-2)* $LiAlD_4$; FW: 41.99; gray pwdr.; m.p. 175° dec. *air sensitive, moisture sensitive*	1g 5g
93-0393 HAZ	**Lithium aluminum hydride, powder, 95%** *(16853-85-3)* $LiAlH_4$; FW: 37.94; gray pwdr.; m.p. 125° dec.; d. 0.917 *air sensitive, moisture sensitive*	10g 50g 250g 1kg
93-0306 HAZ	**Lithium amide, 95%** *(7782-89-0)* $LiNH_2$; FW: 22.96; off-white pwdr.; m.p. 373-375°; d. 1.178 *air sensitive, moisture sensitive*	50g 250g
93-0397 HAZ	**Lithium borohydride, 95%** *(16949-15-8)* $LiBH_4$; FW: 21.78; white pwdr.; m.p. 279° dec.; d. 0.66 *moisture sensitive*	1g 5g 25g
93-0374 HAZ	**Lithium deuteride, 99+% isotopic purity** *(13587-16-1)* LiD; FW: 8.95; off-white pwdr.; m.p. ~680°; d. 0.820 *air sensitive, moisture sensitive*	1g 5g
93-0328 HAZ	**Lithium hydride, min. 95%** *(7580-67-8)* LiH; FW: 7.95; gray pwdr. *air sensitive, moisture sensitive*	50g 250g
93-0340 HAZ	**Lithium nitride (99.5%-Li)** *(26134-62-3)* Li_3N; FW: 34.82; -60 mesh reddish-brown pwdr.; m.p. 845°; d. 1.38 *moisture sensitive*	5g 25g

MAGNESIUM (Elemental Forms)

93-1299 HAZ	**Magnesium chips (99+%)** *(7439-95-4)* Mg; FW: 24.32; -4 + 18 mesh; m.p. 657°; b.p. 1107°; d. 1.74	50g 250g 1kg
93-1298 HAZ	**Magnesium powder (99%)** *(7439-95-4)* Mg; FW: 24.32; -325 mesh; m.p. 657°; b.p. 1107°; d. 1.74 Note: For sale in USA. For other countries contact Strem.	100g 500g
93-1289 HAZ	**Magnesium powder (99.8%)** *(7439-95-4)* Mg; FW: 24.32; -50 mesh; m.p. 657°; b.p. 1107°; d. 1.74	250g 1kg
93-1295 HAZ	**Magnesium rod (99.8%)** *(7439-95-4)* Mg; FW: 24.32; ~454g/rod; 33 mm dia. x 305 mm long; m.p. 657°; b.p. 1107°; d. 1.74	1rod 5rods
93-1286 HAZ	**Magnesium turnings for Grignards (99.8%)** *(7439-95-4)* Mg; FW: 24.32; turnings; m.p. 657°; b.p. 1107°; d. 1.74	100g 500g

NIOBIUM (Compounds)

93-4111	**Niobium(V) oxide (99.5%-Nb)** *(1313-96-8)* Nb_2O_5; FW: 265.82; white pwdr.; m.p. 1520°; d. 4.47	50g 250g
93-4109	**Niobium(V) oxide (99.9%-Nb)** *(1313-96-8)* Nb_2O_5; FW: 265.82; white pwdr.; m.p. 1520°; d. 4.47	50g 250g
41-5200	**Niobium(V) oxide (99.995%-Nb) (50-100ppm Ta) PURATREM** *(1313-96-8)* Nb_2O_5; FW: 265.82; white pwdr.; m.p. 1520°; d. 4.47	25g 100g

PALLADIUM (Elemental Forms)

93-4631 HAZ	**Palladium powder (99.95%)** *(7440-05-3)* Pd; FW: 106.40; -60 mesh; m.p. 1552°; b.p. 3140°; d. 12.02	1g 5g
93-4630 HAZ	**Palladium powder (99.999%) PURATREM** *(7440-05-3)* Pd; FW: 106.40; -22 mesh; m.p. 1552°; b.p. 3140°; d. 12.02	1g 5g

POTASSIUM (Compounds)

93-1985 HAZ	**Potassium hydride, 30-35% in oil** *(7693-26-7)* KH; FW: 40.11; slurry; gray pwdr. *air sensitive, moisture sensitive*	300g

RHODIUM (Elemental Forms)

45-1870 HAZ	**Rhodium powder (99.8%)** *(7440-16-6)* Rh; FW: 102.91; m.p. 1966°; b.p. 3727°; d. 12.41	500mg 2g
45-1872 HAZ	**Rhodium powder (99.95%)** *(7440-16-6)* Rh; FW: 102.91; m.p. 1966°; b.p. 3727°; d. 12.41	500mg 2g

SCANDIUM (Compounds)

93-2102	**Scandium (III) chloride, anhydrous (99.99%-Sc) (REO), sublimed, PURATREM** *(10361-84-9)* $ScCl_3$; FW: 151.32; white pwdr.; m.p. 939°; d. 2.39 *hygroscopic*	250mg 1g 5g

SODIUM (Compounds)

93-1117 HAZ	**Sodium borodeuteride, 96 atom% D** *(15681-89-7)* $NaBD_4$; FW: 41.88; white pwdr.; m.p. ~400° dec.; d. 1.074 *moisture sensitive*	1g 5g
93-1118 HAZ	**Sodium borohydride, 98%** *(16940-66-2)* $NaBH_4$; FW: 37.83; white pwdr.; m.p. ~400° dec.; d. 1.074 *moisture sensitive*	50g 250g
93-1151 HAZ	**Sodium hydride, 60% in oil** *(7646-69-7)* NaH; FW: 24.00; gray pwdr. *air sensitive, moisture sensitive*	250g 1kg

TITANIUM (Compounds)

22-1180 HAZ	**Titanium(III) chloride, Al reduced, 98+%** *(12003-13-3)* $TiCl_3 \cdot 1/3AlCl_3$; FW: 198.72; purple xtl. *air sensitive, moisture sensitive*	100g 500g
22-1150 HAZ	**Titanium(IV) chloride, 99%** *(7550-45-0)* $TiCl_4$; FW: 189.73; pale yellow liq.; m.p. -25°; b.p. 136°; d. 1.726 *moisture sensitive* Note: Available prepacked in ALD cylinder- see 98-4033.	250g 1kg
93-2209 HAZ	**Titanium(IV) ethoxide (contains 5-15% isopropanol)** *(3087-36-3)* $Ti(OC_2H_5)_4$; FW: 228.14; xtl. to pale yellow liquid; b.p. 122°/1 mm; f.p. 84°F; d. 1.107 (20°) *moisture sensitive*	25g 100g 500g

TITANIUM (Compounds)

93-2211 HAZ	**Titanium(II) hydride, min. 95% (99+%-Ti)** *(7704-98-5)* TiH_2; FW: 49.92; -325 mesh gray pwdr.; m.p. 450° (dec.); d. 3.9 *air sensitive, moisture sensitive*	25g 100g 500g
93-2216 HAZ	**Titanium(IV) i-propoxide, min. 98%** *(546-68-9)* $Ti[OCH(CH_3)_2]_4$; FW: 284.25; colorless to pale yellow liq.; m.p. 20°; b.p. 58°/1 mm; f.p. 81°F; d. 0.9550 *moisture sensitive* Note: Available prepacked in ALD cylinder- see 98-4030.	250g 1kg

Technical Notes:

1. For detailed technical note visit strem.com

VANADIUM (Compounds)

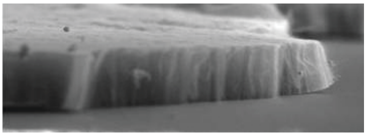
93-2335 HAZ	**Vanadium(III) bromide (99.7%-V)** *(13470-26-3)* VBr_3; FW: 290.67; -20 mesh black pwdr.; d. 4.00 *moisture sensitive*	1g 5g 25g
23-4300 HAZ	**Vanadium(III) chloride, anhydrous, min. 95%** *(7718-98-1)* VCl_3; FW: 157.30; purple pwdr.; d. 3.00 *moisture sensitive*	10g 50g

CARBON (Elemental Forms)

06-0100 **Activated carbon** *(7440-44-0)* — 300g, 1kg
C; FW: 12.011; black pwdr.; SA: 1300-1400 m^2/g; m.p. 3652-3697° (subl.); b.p. 4200°; d. 1.8-2.1 (amorphous)

06-0050 **Activated carbon** *(7440-44-0)* — 500g, 2kg
C; FW: 12.011; 4 x 10 mesh black gran.; SA: 1000 m^2/g; m.p. 3652-3697° (subl.); b.p. 4200°; d. 1.8-2.1 (amorphous)

06-0440 **Carbon nanotube array, multi-walled, on quartz (diameter= 100nm, length=30 microns)** *(308068-56-6)* — 1pc
black microfibers



Technical Note:
1. See (page 28)

06-0470 **Carbon nanotubes, multi-walled (diameter = ~140nm, length = ~7 microns) (>90% nanotubes)** *(308068-56-6)* — 1g, 5g
black pwdr.

Technical Note:
1. See (page 28)

06-0475 **Carbon nanotubes, multi-walled (diameter = ~20-25nm, length = ~1-5 microns) (85% nanotubes)** *(308068-56-6)* — 250mg, 1g
black pwdr.

Technical Note:
1. See (page 28)

06-0720 **Carbon nanotubes, multi-walled, arc-produced (diameter = 2-50nm, length = >2 microns) (55-65wt% nanotubes)** *(308068-56-6)* — 250mg, 1g
black pwdr.

Technical Note:
1. See (page 22)

06-0504 **Carbon nanotubes, multi-walled, as produced cathode deposit** *(308068-56-6)* — 1g, 5g
pieces

06-0505 **Carbon nanotubes, multi-walled, core material** *(308068-56-6)* — 1g, 5g
pieces (20-40% nanotubes)

06-0506 **Carbon nanotubes, multi-walled, ground core material** *(308068-56-6)* — 250mg, 1g, 5g
-270 mesh pwdr. (20-40%nanotubes)

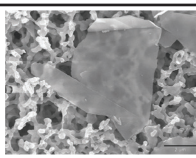
06-0508 **Carbon nanotubes, single-walled/double-walled, 90%** *(308068-56-6)* — 250mg, 1g
pwdr.

Technical Note:
1. This product is nanotubes, single-walled/double-walled, 90%. The tubes are 1-2nm in diameter with lengths of 5-30 microns. Ash is <1.5wt%.

93-0601 **Carbon powder (99+%)** *(7440-44-0)* — 250g, 1kg
C; FW: 12.011; -325 mesh pwdr.; m.p. 3652-3697° (subl.); b.p. 4200°; d. 1.8-2.1 (amorphous)

93-0602 **Carbon powder (99.999%)** *(7440-44-0)* — 5g, 25g
C; FW: 12.011; -200 mesh pwdr.; m.p. 3652-3697° (subl.); b.p. 4200°; d. 1.8-2.1 (amorphous)

06-0210 **Graphene nanoplatelets (6-8 nm thick x 5 microns wide)** *(1034343-98-0)* — 25g, 100g
C; black platelet
Note: See (page 14)



Technical Note:
1. For detailed technical note visit strem.com

06-0215 **Graphene nanoplatelets (6-8 nm thick x 15 microns wide)** *(1034343-98-0)* — 25g, 100g
C; black platelet

Technical Note:
1. See 06-0210 (page 14)

CARBON (Elemental Forms)

06-0220 **Graphene nanoplatelets (6-8 nm thick x 25 microns wide)** *(1034343-98-0)* 25g
C; black platelet 100g

Technical Note:
1. See 06-0210 (page 14)

06-0225 **Graphene nanoplatelets aggregates (sub-micron particles, surface area 300m²/g)** *(1034343-98-0)* 25g, 100g
black platelet
Note: See (page 14)

Technical Note:
1. For detailed technical note visit strem.com

06-0230 **Graphene nanoplatelets aggregates (sub-micron particles, surface area 500m²/g)** *(1034343-98-0)* 25g, 100g
black platelet

Technical Note:
1. See 06-0225 (page 14)

06-0235 **Graphene nanoplatelets aggregates (sub-micron particles, surface area 750m²/g)** *(1034343-98-0)* 25g, 100g
black platelet

Technical Note:
1. See 06-0225 (page 14)

ALUMINUM (Elemental Forms)

93-1372	**Aluminum foil (99.9995%)** *(7429-90-5)* Al; FW: 26.98; 0.127 mm thick x 100 mm wide; m.p. 660°; b.p. 2056°; d. 2.702	50 x 100mm 250 x 100mm
13-0026	**Aluminum ingot (99.999%)** *(7429-90-5)* Al; FW: 26.98; metal ingot; m.p. 660°; b.p. 2056°; d. 2.702	100g 500g
13-0038	**Aluminum rod (99.9995%)** *(7429-90-5)* Al; FW: 26.98; 6.4mm dia. (~4.34g/5cm); m.p. 660°; b.p. 2056°; d. 2.702	5cm 25cm
13-0044	**Aluminum shot (99.999%)** *(7429-90-5)* Al; FW: 26.98; 6.35 x 6.35 mm cylinders; m.p. 660°; b.p. 2056°; d. 2.702	25g 100g
13-0048	**Aluminum wire annealed (99.999%)** *(7429-90-5)* Al; FW: 26.98; 0.5mm dia. (~0.53g/m); m.p. 660°; b.p. 2056°; d. 2.702	10m 50m

AMMONIUM (Compounds)

93-0208	**Ammonium chloride, 99.5+% (ACS)** *(12125-02-9)* NH_4Cl; FW: 53.49; white gran.; m.p. 340° subl.; b.p. 520°; d. 1.527	500g 2kg
93-0242	**Ammonium chloride (99.999%) PURATREM** *(12125-02-9)* NH_4Cl; FW: 53.49; white xtl.; m.p. 340° subl.; b.p. 520°; d. 1.527	25g 100g
93-7801 HAZ	**Ammonium hexachloroplatinate(IV), 99%** *(16919-58-7)* $(NH_4)_2PtCl_6$; FW: 443.89; yellow pwdr.; m.p. dec.; d. 3.065 *hygroscopic*	1g 5g
93-0225	**Ammonium sulfate, 99+% (ACS)** *(7783-20-2)* $(NH_4)_2SO_4$; FW: 132.14; white xtl.; m.p. 235° dec.; d. 1.769	500g 2kg

ANTIMONY (Compounds)

97-0380 HAZ	**Antimony(III) oxide, elec. gr. (99.999%-Sb) PURATREM** *(1309-64-4)* Sb_2O_3; FW: 291.50; white pwdr.; m.p. 656°; b.p. 1550° subl.; d. 5.67	25g 100g
97-0382 HAZ	**Antimony(V) oxide, elec. gr. (99.998%-Sb) PURATREM** *(1314-60-9)* Sb_2O_5; FW: 323.50; white to light yellow pwdr.; d. 3.80	5g 25g 100g
51-1430	**Antimony(III) telluride (99.96%-Sb)** *(1327-50-0)* Sb_2Te_3; FW: 626.32; black pwdr.	1g 5g

BARIUM (Elemental Forms)

56-0075 HAZ	**Barium pieces (99.7%, Sr-<1.0%)** *(7440-39-3)* Ba; FW: 137.34; 19mm and down (packed in mineral oil); m.p. 725°; b.p. 1640°; d. 3.51 *air sensitive, moisture sensitive*	10g 50g 250g
56-0074 amp HAZ	**Barium pieces, dendritic (99.9%)** *(7440-39-3)* Ba; FW: 137.34; ampouled under argon; m.p. 725°; b.p. 1640°; d. 3.51 *air sensitive, moisture sensitive*	5g 25g
56-0080 HAZ	**Barium rod (99+%, Sr-<1.6%)** *(7440-39-3)* Ba; FW: 137.34; 22mm dia. (~100g/6.9cm) (packed under oil); m.p. 725°; b.p. 1640°; d. 3.51 *air sensitive, moisture sensitive*	100g 500g

CADMIUM (Elemental Forms)

93-4851 HAZ	**Cadmium granules (99.999%)** *(7440-43-9)* Cd; FW: 112.41; 1-5 mm; m.p. 320.9°; b.p. 765°; d. 8.642	25g 100g
93-4844 HAZ	**Cadmium pieces (99.9%)** *(7440-43-9)* Cd; FW: 112.41; pieces; m.p. 320.9°; b.p. 765°; d. 8.642	100g 500g
93-4841 HAZ	**Cadmium powder (99.9%)** *(7440-43-9)* Cd; FW: 112.41; -200 mesh; m.p. 320.9°; b.p. 765°; d. 8.642	250g 1kg
93-4848 HAZ	**Cadmium powder (99.999%)** *(7440-43-9)* Cd; FW: 112.41; -200 mesh; m.p. 320.9°; b.p. 765°; d. 8.642	10g 50g

CADMIUM (Elemental Forms)

93-4850 HAZ	**Cadmium shot (99.95%)** *(7440-43-9)* Cd; FW: 112.41; tear drop; m.p. 320.9°; b.p. 765°; d. 8.642	50g 250g

CADMIUM (Compounds)

48-0100 HAZ	**Cadmium acetate, anhydrous (99.999%-Cd) PURATREM** *(543-90-8)* $Cd(OOCCH_3)_2$; FW: 230.50; white pwdr.; m.p. 232-235°	5g 25g
48-0150 HAZ	**Cadmium arsenide (99.999%-Cd) PURATREM** *(12006-15-4)* Cd_3As_2; FW: 487.07; dark gray solid; d. 3.031 *moisture sensitive*	5g 25g
93-4805 HAZ	**Cadmium bromide, anhydrous, 99%** *(7789-42-6)* $CdBr_2$; FW: 272.22; white pwdr.; m.p. 567°; b.p. 863°; d. 5.192 *hygroscopic*	10g 50g
48-1500 HAZ	**Cadmium chloride, anhydrous (99.995%-Cd) PURATREM** *(10108-64-2)* $CdCl_2$; FW: 183.32; white pwdr.; m.p. 568°; b.p. 960°; d. 4.047 *hygroscopic*	10g 50g
48-0200 HAZ	**Cadmium chloride hydrate (99.998%-Cd) PURATREM** *(34330-64-8)* $CdCl_2 \cdot XH_2O$; FW: 183.32; white xtl.	5g 25g
48-1501 amp HAZ	**Cadmium chloride, (99.999%-Cd) (O_2 < 50ppm) PURATREM** *(10108-64-2)* $CdCl_2$; FW: 183.32; -20 mesh white pwdr. (under argon); m.p. 568°; b.p. 960°; d. 4.047 *hygroscopic*	5g 25g
93-4836 HAZ	**Cadmium selenide (99.999+%-Cd) PURATREM** *(1306-24-7)* CdSe; FW: 191.36; black pwdr.; m.p. > 1350°; d. 5.81	5g 25g
48-1011 HAZ	**Cadmium selenide StremDots™ quantum dot (CdSe core), 50umol/L in hexanes, 525nm peak emissi** *(1306-24-7)* CdSe; orange liq. *air sensitive, (store cold)*	5ml 25ml
48-1017 HAZ	**Cadmium selenide StremDots™ quantum dot (CdSe core), 50umol/L in hexanes, 550nm peak emission** *(1306-24-7)* CdSe; red-orange liq. *air sensitive, (store cold)*	5ml 25ml
48-1023 HAZ	**Cadmium selenide StremDots™ quantum dot (CdSe core), 50umol/L in hexanes, 575nm peak emission** *(1306-24-7)* CdSe; red liq. *air sensitive, (store cold)*	5ml 25ml
48-1030 HAZ	**Cadmium selenide StremDots™ quantum dot (CdSe core), 50umol/L in hexanes, 600nm peak emission** *(1306-24-7)* red liq. *air sensitive, (store cold)*	5ml 25ml
48-1035 HAZ	**Cadmium selenide StremDots™ quantum dot (CdSe core), 50umol/L in hexanes, 625nm peak emission** *(1306-24-7)* red liq. *air sensitive, (store cold)*	5ml 25ml
96-0800	**Cadmium selenide StremDots™ quantum dot (CdSe core) kit, 50umol/L in hexanes, 525-625nm peak emissions** *(1306-24-7)* *See* page 59	
93-4821 HAZ	**Cadmium sulfate hydrate, 98+% (ACS)** *(15244-35-6)* $3CdSO_4 \cdot 8H_2O$; FW: 625.38 (769.51); white pwdr.; d. 3.09	50g 250g
93-4823 HAZ	**Cadmium sulfide, 98%** *(1306-23-6)* CdS; FW: 144.46; yellow to orange pwdr.; m.p. 1750°; d. 4.82	25g 100g 500g
93-4822 HAZ	**Cadmium sulfide (99.9+%-Cd)** *(1306-23-6)* CdS; FW: 144.46; yellow to orange pwdr.; m.p. 1750°; d. 4.82	25g 100g 500g

CADMIUM (Compounds)

93-4840 HAZ	**Cadmium sulfide (99.999%-Cd) PURATREM** *(1306-23-6)* CdS; FW: 144.46; yellow to orange pwdr.; m.p. 1750°; d. 4.82	10g 50g 250g
48-2000 HAZ	**Cadmium telluride (99.999%-Cd) PURATREM** *(1306-25-8)* CdTe; FW: 240.00; -200 mesh black pwdr.; m.p. 1041°; d. 6.20	5g 25g
93-4825 HAZ	**Cadmium telluride (99.999%-Cd) PURATREM** *(1306-25-8)* CdTe; FW: 240.00; black lumps; m.p. 1041°; d. 6.20	10g 50g

CALCIUM (Elemental Forms)

20-0074 amp HAZ	**Calcium, crystalline, dendritic (99.99%)** *(7440-70-2)* Ca; FW: 40.08; ampouled under argon; m.p. 842°; b.p. 1484°; d. 1.54 *air sensitive, moisture sensitive*	5g 25g

CALCIUM (Compounds)

93-2011	**Calcium carbonate (99.95%-Ca)** *(471-34-1)* $CaCO_3$; FW: 100.09; -325 mesh white pwdr.; d. 2.930	100g 500g
20-0200	**Calcium carbonate (99.999%-Ca) PURATREM** *(471-34-1)* $CaCO_3$; FW: 100.09; white pwdr.; d. 2.930	10g 50g
20-2060	**Calcium chloride hydrate (99.999+%-Ca) PURATREM** *(22691-02-7)* $CaCl_2{\cdot}XH_2O$; FW: 110.99; white pwdr.	5g 25g 100g
93-2017	**Calcium fluoride (99.9%-Ca)** *(7789-75-5)* CaF_2; FW: 78.08; <5 micron white pwdr.; m.p. 1360°; b.p. ~2500°; d. 3.180	250g 1kg

COPPER (Elemental Forms)

93-2991	**Copper foil (99.9985%)** *(7440-50-8)* Cu; FW: 63.54; 0.5 mm thick; m.p. 1083°; d. 8.92	50 x 50mm 100 x 100mm
93-2971 HAZ	**Copper powder (99.999%)** *(7440-50-8)* Cu; FW: 63.54; -100 mesh (under argon); m.p. 1083°; d. 8.92	5g 25g
29-0080	**Copper rod (99.999%)** *(7440-50-8)* Cu; FW: 63.54; 9.5mm dia. (~6.3g/cm); m.p. 1083°; d. 8.92	25g 100g 500g
93-2997	**Copper shot (99.9%)** *(7440-50-8)* Cu; FW: 63.54; 1-10 mm; m.p. 1083°; d. 8.92	250g 1kg
93-2998	**Copper shot (99.999%)** *(7440-50-8)* Cu; FW: 63.54; 2-8 mm; m.p. 1083°; d. 8.92	50g 250g
29-0085	**Copper shot (99.9999%)** *(7440-50-8)* Cu; FW: 63.54; 6 mm dia.; m.p. 1083°; d. 8.92	10g 50g
93-2972	**Copper wire (99.99%)** *(7440-50-8)* Cu; FW: 63.54; 0.25 mm dia.; m.p. 1083°; d. 8.92	5m 25m
93-2973	**Copper wire (99.999+%)** *(7440-50-8)* Cu; FW: 63.54; 0.76 mm dia.; m.p. 1083°; d. 8.92	1m 5m

COPPER (Compounds)

93-2989	**Copper(I) acetate, 97%** *(598-54-9)* $CuOOCCH_3$; FW: 122.59; beige to light green pwdr. *moisture sensitive*	2g 10g 50g
93-2988	**Copper(II) acetate, anhydrous, min. 97%** *(142-71-2)* $Cu(OOCCH_3)_2$; FW: 181.64; green to blue pwdr. *hygroscopic*	25g 100g
93-2901 HAZ	**Copper(II) acetate monohydrate, 98+% (ACS)** *(6046-93-1)* $Cu(OOCCH_3)_2{\cdot}H_2O$; FW: 181.64 (199.65); green to blue pwdr.; m.p. 115°; b.p. 240° dec.; d. 1.822	50g 250g 1kg

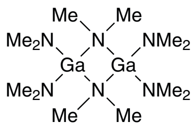
COPPER (Compounds)

93-2914 HAZ	**Copper(I) chloride, anhydrous, 97+%** *(7758-89-6)* CuCl; FW: 98.99; light brown pwdr.; m.p. 430°; b.p. 1490°; d. 4.14 *air sensitive, light sensitive*	250g 1kg
29-0360 HAZ	**Copper(I) chloride (99.99%-Cu) PURATREM** *(7758-89-6)* CuCl; FW: 98.99; light-gray to pale green solid; m.p. 430°; b.p. 1490°; d. 4.14 *air sensitive, light sensitive*	10g 50g
93-2912 HAZ	**Copper(II) chloride, anhydrous, min. 98%** *(7447-39-4)* $CuCl_2$; FW: 134.44; reddish-brown pwdr.; m.p. 620°; d. 3.386 *hygroscopic*	100g 500g
93-2913 HAZ	**Copper(II) chloride dihydrate, 99+% (ACS)** *(10125-13-0)* $CuCl_2{\cdot}2H_2O$; FW: 134.44 (170.48); green xtl.; d. 2.54	250g 1kg
93-2985 HAZ	**Copper(II) chloride dihydrate (99.999%-Cu) PURATREM** *(10125-13-0)* $CuCl_2{\cdot}2H_2O$; FW: 134.44 (170.48); green xtl.; d. 2.54	10g 50g

GALLIUM (Elemental Forms)

93-3145 HAZ	**Gallium metal (99.99%)** *(7440-55-3)* Ga; FW: 69.72; m.p. 29.78°; b.p. 2403°; d. 5.904 *air sensitive, moisture sensitive*	10g 50g
93-3146 HAZ	**Gallium metal (99.9999%)** *(7440-55-3)* Ga; FW: 69.72; m.p. 29.78°; b.p. 2403°; d. 5.904 *air sensitive, moisture sensitive*	10g 50g

GALLIUM (Compounds)

31-2030 amp HAZ	**Bis(μ-dimethylamino)tetrakis (dimethylamino) digallium, 98%** *(57731-40-5)* $C_{12}H_{36}Ga_2N_6$; FW: 403.90; white xtl. *moisture sensitive* 	1g 5g 25g
93-3130	**Gallium(III) acetylacetonate (99.99+%-Ga) PURATREM** *(14405-43-7)* $Ga(CH_3COCHCOCH_3)_3$; FW: 367.05; white to pale yellow pwdr.; m.p. 192-194° dec. >280°; b.p. 140°/10 mm subl.; d. 1.42	5g 25g
93-3103 HAZ	**Gallium arsenide (99.9999%-Ga) PURATREM** *(1303-00-0)* GaAs; FW: 144.64; 25mm and down polycrystalline pieces; m.p. 1238°; d. 5.31	1g 5g
93-3104 amp HAZ	**Gallium(II) chloride, anhydrous (99.999%-Ga) PURATREM** *(13498-12-9)* Ga_2Cl_4; FW: 281.26; white xtl.; m.p. 164°; b.p. 535° *moisture sensitive*	1g 5g
93-3141 amp HAZ	**Gallium(III) chloride, anhydrous, fused lump (99.999%-Ga) PURATREM** *(13450-90-3)* $GaCl_3$; FW: 176.03; white fused lump; m.p. 77.9°; b.p. 201.3°; d. 2.47 *moisture sensitive*	5g 25g 100g
93-3140 HAZ	**Gallium(III) chloride, anhydrous, granular (99.999%-Ga) PURATREM** *(13450-90-3)* $GaCl_3$; FW: 176.03; white crystalline pwdr.; m.p. 77.9°; b.p. 201.3°; d. 2.47 *moisture sensitive* Note: Packaged in PFA/FET bottle.	5g 25g 100g

GOLD (Elemental Forms)

79-0050 **Gold foil (99.9%)** *(7440-57-5)* — 25 x 25mm; 50 x 50mm
Au; FW: 197.20; 0.01mm thick (~0.12g/25mm x 25mm); m.p. 1064°; b.p. 2067°; d. 19.3

79-0060 **Gold foil (99.95%)** *(7440-57-5)* — 25 x 25mm; 50 x 50mm
Au; FW: 197.20; 0.1mm thick (~1.2g/25mm x 25mm); m.p. 1064°; b.p. 2067°; d. 19.3

79-6020 **Gold Nanorods (Axial Diameter - 10 nm) (Wavelength 700 nm)** *(7440-57-5)* — 5ml; 25ml
pale red-brown liq.
(store cold)
Note: Gold Nanorods Kit component.
Concentration: 30 ug/ml (±10%); **Axial Diameter (nm):** 10 (±10%); **Longitudinal Size (nm):** 29 (±10%);
Peak Longitudinal Surface Plasmon Resonance Wavelength (nm): 700;
Peak Axial Surface Plasmon Resonance Wavelength (nm): 512;
Storage Conditions: store at ~4ºC (do not freeze); **Shelf Life:** 6 months
Gold nanorods are shipped in 18MΩ DI water with < 0.1% ascorbic acid and < 0.1% CTAB surfactant capping agent.
Storage Instructions: Store at 4ºC. Do not freeze. CTAB, may cause a cloudy appearance at low temperatures. Before use, warm to room temperature to resuspend excess CTAB. Particularly for the larger nanorods, make sure to homogenize bottles after long storage periods to resuspend any sedimentation

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79-6025 **Gold Nanorods (Axial Diameter - 10 nm) (Wavelength 750 nm)** *(7440-57-5)* — 5ml; 25ml
pale red liq.
(store cold)
Note: Gold Nanorods Kit component.
Concentration: 34 ug/ml (±10%); **Axial Diameter (nm):** 10 (±10%); **Longitudinal Size (nm):** 35 (±10%);
Peak Longitudinal Surface Plasmon Resonance Wavelength (nm): 750;
Peak Axial Surface Plasmon Resonance Wavelength (nm): 512;
Storage Conditions: store at ~4ºC (do not freeze); **Shelf Life**: 6 months
Gold nanorods are shipped in 18MΩ DI water with < 0.1% ascorbic acid and < 0.1% CTAB surfactant capping agent.
Storage Instructions: Store at 4ºC. Do not freeze. CTAB, may cause a cloudy appearance at low temperatures. Before use, warm to room temperature to resuspend excess CTAB. Particularly for the larger nanorods, make sure to homogenize bottles after long storage periods to resuspend any sedimentatation

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79-6030 **Gold Nanorods (Axial Diameter - 10 nm) (Wavelength 780 nm)** *(7440-57-5)* — 5ml; 25ml
pale red solution
(store cold)
Note: Gold Nanorods Kit component.
Concentration: 35 ug/ml (±10%); **Axial Diameter (nm):** 10 (±10%); **Longitudinal Size (nm):** 38 (±10%);
Peak Longitudinal Surface Plasmon Resonance Wavelength (nm): 780;
Peak Axial Surface Plasmon Resonance Wavelength (nm): 512;
Storage Conditions: store at ~4ºC (do not freeze); **Shelf Life:** 6 months
Gold nanorods are shipped in 18MΩ DI water with < 0.1% ascorbic acid and < 0.1% CTAB surfactant capping agent.
Storage Instructions: Store at 4ºC. Do not freeze. CTAB, may cause a cloudy appearance at low temperatures. Before use, warm to room temperature to resuspend excess CTAB. Particularly for the larger nanorods, make sure to homogenize bottles after long storage periods to resuspend any sedimentatation

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79-6035 **Gold Nanorods (Axial Diameter - 10 nm) (Wavelength 808 nm)** *(7440-57-5)* — 5ml; 25ml
pale red liq.
(store cold)
Note: Gold Nanorods Kit component.
Concentration: 36 ug/ml (±10%); **Axial Diameter (nm):** 10 (±10%); **Longitudinal Size (nm):** 41 (±10%);
Peak Longitudinal Surface Plasmon Resonance Wavelength (nm): 808;
Peak Axial Surface Plasmon Resonance Wavelength (nm): 512;
Storage Conditions: store at ~4ºC (do not freeze); **Shelf Life:** 6 months
Gold nanorods are shipped in 18MΩ DI water with < 0.1% ascorbic acid and < 0.1% CTAB surfactant capping agent.
Storage Instructions: Store at 4ºC. Do not freeze. CTAB, may cause a cloudy appearance at low temperatures. Before use, warm to room temperature to resuspend excess CTAB. Particularly for the larger nanorods, make sure to homogenize bottles after long storage periods to resuspend any sedimentation.

GOLD (Elemental Forms)

79-6000 **Gold Nanorods (Axial Diameter - 25 nm) (Wavelength 550 nm)** *(7440-57-5)* 5ml
red liq. 25ml
(store cold)
Note: Gold Nanorods Kit component.
Concentration: 171 ug/ml (±10%); **Axial Diameter (nm):** 25 (±10%); **Longitudinal Size (nm):** 34 (±10%);
Peak Longitudinal Surface Plasmon Resonance Wavelength (nm): 550;
Peak Axial Surface Plasmon Resonance Wavelength (nm): 530;
Storage Conditions: store at ~4ºC (do not freeze); **Shelf Life:** 6 months;
Gold nanorods are shipped in 18MΩ DI water with < 0.1% ascorbic acid and < 0.1% CTAB surfactant capping agent.
Storage Instructions: Store at 4ºC. Do not freeze. CTAB, may cause a cloudy appearance at low temperatures. Before use, warm to room temperature to resuspend excess CTAB. Particularly for the larger nanorods, make sure to homogenize bottles after long storage periods to resuspend any sedimentation.

79-6005 **Gold Nanorods (Axial Diameter - 25 nm) (Wavelength 600 nm)** *(7440-57-5)* 5ml
blue liq. 25ml
(store cold)
Note: Gold Nanorods Kit component.
Concentration: 235 ug/ml (±10%); **Axial Diameter (nm):** 25 (±10%); **Longitudinal Size** (nm): 47 (±10%);
Peak Longitudinal Surface Plasmon Resonance Wavelength (nm): 600;
Peak Axial Surface Plasmon Resonance Wavelength (nm): 530;
Storage Conditions: store at ~4ºC (do not freeze); **Shelf Life:** 6 months
Gold nanorods are shipped in 18MΩ DI water with < 0.1% ascorbic acid and < 0.1% CTAB surfactant capping agent.
Storage Instructions: Store at 4ºC. Do not freeze. CTAB, may cause a cloudy appearance at low temperatures. Before use, warm to room temperature to resuspend excess CTAB. Particularly for the larger nanorods, make sure to homogenize bottles after long storage periods to resuspend any sedimentation.

79-6010 **Gold Nanorods (Axial Diameter - 25 nm) (Wavelength 650 nm)** *(7440-57-5)* 5ml
blue liq. 25ml
(store cold)
Note: Gold Nanorods Kit component.
Concentration: 150 ug/ml (±10%); **Axial Diameter (nm):** 25 (±10%); **Longitudinal Size (nm):** 60 (±10%);
Peak Longitudinal Surface Plasmon Resonance Wavelength (nm): 650;
Peak Axial Surface Plasmon Resonance Wavelength (nm): 530;
Storage Conditions: store at ~4ºC (do not freeze); **Shelf Life**: 6 months
Gold nanorods are shipped in 18MΩ DI water with < 0.1% ascorbic acid and < 0.1% CTAB surfactant capping agent.
Storage Instructions: Store at 4ºC. Do not freeze. CTAB, may cause a cloudy appearance at low temperatures. Before use, warm to room temperature to resuspend excess CTAB. Particularly for the larger nanorods, make sure to homogenize bottles after long storage periods to resuspend any sedimentation

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79-6015 **Gold Nanorods (Axial Diameter - 25 nm) (Wavelength 700 nm)** *(7440-57-5)* 5ml
gray liq. 25ml
(store cold)
Note: Gold Nanorods Kit component.
Concentration: 91 ug/ml (±10%); **Axial Diameter (nm):** 25 (±10%); **Longitudinal Size (nm):** 73 (±10%);
Peak Longitudinal Surface Plasmon Resonance Wavelength (nm): 700;
Peak Axial Surface Plasmon Resonance Wavelength (nm): 530;
Storage Conditions: store at ~4ºC (do not freeze); **Shelf Life:** 6 months
Gold nanorods are shipped in 18MΩ DI water with < 0.1% ascorbic acid and < 0.1% CTAB surfactant capping agent.
Storage Instructions: Store at 4ºC. Do not freeze. CTAB, may cause a cloudy appearance at low temperatures. Before use, warm to room temperature to resuspend excess CTAB. Particularly for the larger nanorods, make sure to homogenize bottles after long storage periods to resuspend any sedimentation

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96-1530 **Gold Nanorods Kit (Axial Diameter - 25 nm, wavelength 550-700 nm)** *(7440-57-5)*
See page 59

96-1535 **Gold Nanorods Kit (Axial Diameter - 10 nm, wavelength 700-808 nm)** *(7440-57-5)*
See page 59

93-7912 **Gold powder (99.9+%)** *(7440-57-5)* 500mg
Au; FW: 197.20; 1.5-3.0 micron spherical; m.p. 1064°; b.p. 2067°; d. 19.3 2g

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93-7915 **Gold powder (99.95%)** *(7440-57-5)* 500mg
Au; FW: 197.20; 2-5 micron; m.p. 1064°; b.p. 2067°; d. 19.3 2g

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93-7902 **Gold powder (99.999%)** *(7440-57-5)* 500mg
Au; FW: 197.20; -20 mesh; m.p. 1064°; b.p. 2067°; d. 19.3 2g

GOLD (Elemental Forms)

93-7913	**Gold shot (99.95%)** *(7440-57-5)* Au; FW: 197.20; 6.35 mm and down, semi-spherical; m.p. 1064°; b.p. 2067°; d. 19.3	500mg 2g
79-0075	**Gold shot (99.999%)** *(7440-57-5)* Au; FW: 197.20; 0.8-6 mm; m.p. 1064°; b.p. 2067°; d. 19.3	500mg 2.5g
79-0095	**Gold wire (99.99%)** *(7440-57-5)* Au; FW: 196.97; 1.4 mm dia.; b.p. 2067°; d. 19.3	2cm 10cm
79-0085	**Gold wire (99.999%)** *(7440-57-5)* Au; FW: 196.97; 1.4mm dia. (~0.6g/2cm); b.p. 2067°; d. 19.3	2cm 10cm

INDIUM (Elemental Forms)

49-0050	**Indium foil (99.99%)** *(7440-74-6)* In; FW: 114.76; 0.127mm thick (~2.3g/50 x 50mm); m.p. 156.6°; b.p. 2080°; d. 7.31	50 x 50mm 100 x 100mm 150 x 300mm
93-4940 HAZ	**Indium powder (99.99%)** *(7440-74-6)* In; FW: 114.76; -325 mesh; m.p. 156.6°; b.p. 2080°; d. 7.31	5g 25g
93-4941 HAZ	**Indium powder (99.999%)** *(7440-74-6)* In; FW: 114.76; -325 mesh; m.p. 156.6°; b.p. 2080°; d. 7.31	5g 25g
93-4944	**Indium shot (99.99%)** *(7440-74-6)* In; FW: 114.76; 4 mm tear drops; m.p. 156.6°; b.p. 2080°; d. 7.31	5g 25g
93-4943	**Indium shot (99.9999%)** *(7440-74-6)* In; FW: 114.76; 4-8 mm; m.p. 156.6°; b.p. 2080°; d. 7.31	5g 25g
49-1000	**Indium wire (99.9985%)** *(7440-74-6)* In; FW: 114.76; 0.5mm dia. (~3.6g/2.5m); m.p. 156.6°; b.p. 2080°; d. 7.31	2.5m 10m

INDIUM (Compounds)

93-4923 HAZ	**Indium (III) nitrate pentahydrate (99.999%-In) PURATREM** *(13465-14-0)* $In(NO_3)_3 \cdot XH_2O$; FW: 300.83 (390.83); white xtl. *hygroscopic*	10g 50g
93-4936	**Indium(III) acetate (99.99%-In) PURATREM** *(25114-58-3)* $In(OOCCH_3)_3$; FW: 291.95; white xtl. *moisture sensitive*	5g 25g
93-4901	**Indium(III) acetylacetonate, 98%** *(14405-45-9)* $In(CH_3COCHCOCH_3)_3$; FW: 412.15; off-white pwdr.; m.p. 180-185°	5g 25g
93-4920	**Indium(III) antimonide (99.99%-In) PURATREM** *(1312-41-0)* InSb; FW: 236.57; black xtl.; m.p. 535°; d. 5.76	5g 25g
93-4929	**Indium(III) bromide, anhydrous (99.999%-In) PURATREM** *(13465-09-3)* $InBr_3$; FW: 354.55; white to light yellow pwdr.; m.p. ~436°; d. 4.74 *hygroscopic*	5g 25g
93-4930	**Indium(I) chloride, anhydrous (99.99%-In) PURATREM** *(13465-10-6)* InCl; FW: 150.27; golden yellow pwdr.; m.p. ~225°; b.p. 608°; d. 4.19 *air sensitive, moisture sensitive*	2g 10g
93-4932	**Indium(III) chloride, anhydrous (99.999%-In) PURATREM** *(10025-82-8)* $InCl_3$; FW: 221.18; white pwdr.; m.p. 586°; d. 3.46 *hygroscopic*	5g 25g 100g
93-4931	**Indium(III) chloride tetrahydrate (99.99%-In) PURATREM** *(22519-64-8)* $InCl_3 \cdot 4H_2O$; FW: 221.18 (293.26); white xtl.	5g 25g 100g
49-1500	**Indium(III) fluoride, anhydrous, 98%** *(7783-52-0)* InF_3; FW: 171.82; white pwdr.; m.p. ~1170°; b.p. > 1200° *hygroscopic*	5g 25g
93-4915	**Indium(III) iodide (99.999%-In) PURATREM** *(13510-35-5)* InI_3; FW: 495.53; yellow to red solid; m.p. 210°; d. 4.69 *hygroscopic*	1g 5g 25g
93-4906	**Indium(III) oxide (99.998%-In) PURATREM** *(1312-43-2)* In_2O_3; FW: 277.64; yellow pwdr.; d. 7.179	5g 25g
93-4911	**Indium(III) sulfide (99.99%-In) PURATREM** *(12030-24-9)* In_2S_3; FW: 325.83; orange pwdr.; m.p. 1050°; d. 4.45	5g 25g

IRON (Elemental Forms)

26-0070	**Iron lump (99.98%)** *(7439-89-6)* Fe; FW: 55.80; 12 x 12 x 2mm and down (irregular); m.p. 1535°; b.p. 3000°; d. 7.86	250g 1kg 5kg
93-2605 HAZ	**Iron powder (99.99%)** *(7439-89-6)* Fe; FW: 55.80; -22 mesh; m.p. 1535°; b.p. 3000°; d. 7.86	10g 50g

LITHIUM (Compounds)

93-0382 amp	**Lithium iodide, anhydrous, min. 98%** *(10377-51-2)* LiI; FW: 133.84; white to off-white pwdr.; m.p. 450°; b.p. 1180°; d. 3.494 *hygroscopic*	25g 100g
93-0381	**Lithium iodide trihydrate, 99+%** *(7790-22-9)* $LiI{\cdot}3H_2O$; FW: 133.84 (187.89); colorless to yellow xtl.; d. 3.43 *hygroscopic*	50g 250g

MAGNESIUM (Compounds)

93-1225	**Magnesium fluoride, 99%** *(7783-40-6)* MgF_2; FW: 62.32; white pwdr.; m.p. 1248°; b.p. 2239°; d. 3.0	500g 2kg
93-1226	**Magnesium fluoride (99.99+%-Mg) PURATREM** *(7783-40-6)* MgF_2; FW: 62.32; 1-4mm white pieces; m.p. 1248°; b.p. 2239°; d. 3.0	25g 100g

MOLYBDENUM (Elemental Forms)

42-0070	**Molybdenum foil (99.95%)** *(7439-98-7)* Mo; FW: 95.94; 0.25mm thick (~25.6g/100x 100mm); m.p. 2610°; b.p. 5560°; d. 10.2	100 x 100mm 150 x 300mm 300 x 300mm
42-0075	**Molybdenum pellets (99.7%)** *(7439-98-7)* Mo; FW: 95.94; 16 x 6 mm; m.p. 2610°; b.p. 5560°; d. 10.2	100g 500g
93-4257 HAZ	**Molybdenum powder (99.9%)** *(7439-98-7)* Mo; FW: 95.94; 3-7 micron; m.p. 2610°; b.p. 5560°; d. 10.2	100g 500g
93-4256 HAZ	**Molybdenum powder (99.95%)** *(7439-98-7)* Mo; FW: 95.94; -100 mesh; m.p. 2610°; b.p. 5560°; d. 10.2	100g 500g
93-4255	**Molybdenum rod (99.95%)** *(7439-98-7)* Mo; FW: 95.94; 6.4 mm dia. (~3.6g/cm); m.p. 2610°; b.p. 5560°; d. 10.2	50g 250g
42-0080	**Molybdenum sheet (99.95%)** *(7439-98-7)* Mo; FW: 95.94; 2.5mm thick (~64g/50 x 50mm); m.p. 2610°; b.p. 5560°; d. 10.2	50 x 50mm 100 x 100mm 500 x 100mm
42-0010	**Molybdenum wire (99.97%)** *(7439-98-7)* Mo; FW: 95.94; 2.0mm dia. (32.1g/m); m.p. 2610°; b.p. 5560°; d. 10.2	100cm 500cm
93-4252	**Molybdenum wire (99.97%)** *(7439-98-7)* Mo; FW: 95.94; 0.5 mm dia.; m.p. 2610°; b.p. 5560°; d. 10.2	25m 100m
93-4254	**Molybdenum wire (99.97%)** *(7439-98-7)* Mo; FW: 95.94; 0.25 mm dia.; m.p. 2610°; b.p. 5560°; d. 10.2	25m 100m
93-4259	**Molybdenum wire (99.97%)** *(7439-98-7)* Mo; FW: 95.94; 0.05 mm dia.; m.p. 2610°; b.p. 5560°; d. 10.2	250m 1000m

NANOMATERIALS (Elemental Forms)

78-0062 HAZ	**Platinum-ruthenium/tetra-n-octylammonium chloride colloid (~7 wt% Pt, ~3.5 wt% Ru)** *(7440-06-4)* $Pt_{50}Ru_{50}/(C_8H_{17})_4NCl$; 1.7 nm ±0.5 nm; waxy, black residue Note: Made to order. Suggest use within 3 months of receipt. Long term shelf life not established.	250mg 1g

Technical Note:

1. Very soluble in THF. Soluble in toluene. Precursor for fuel cell catalysts.

References:

1. *J. Mol. Catal.,* **1994**, *86*, 129
2. *Synthetic Methods of Organometallic and Inorganic Chemistry,* Vol. 10, Chapter 20, p. 209-223, Theime Verlag, NY, 2002.
3. *Catalysis and Electrocatalysis at Nanoparticles Surfaces*, Chapter 10, p. 343-377, Marcel Dekker, NY, 2003.

14-0650 HAZ	**Silicon powder (nanocrystalline), min. 97%** *(7440-21-3)* Si; brown pwdr.; SA: <20 m^2/g *air sensitive*	5g 25g

NICKEL (Elemental Forms)

28-0001	**Nickel foil (99%)** *(7440-02-0)* Ni; FW: 58.71; 0.127mm thick x 30mm wide; m.p. 1453°; b.p. 2732°; d. 8.90	20cm 100cm
28-0002	**Nickel foil (99%)** *(7440-02-0)* Ni; FW: 58.71; 0.127mm thick x 30cm wide (~67.8g/20 x 30cm); m.p. 1453°; b.p. 2732°; d. 8.90	20 x 30cm 100 x 30cm 500 x 30cm
28-0003	**Nickel foil (99%)** *(7440-02-0)* Ni; FW: 58.71; 0.0254mm thick x 30cm wide (~13.6g/20 x 30cm); m.p. 1453°; b.p. 2732°; d. 8.90	20 x 30cm 100 x 30cm
93-2873	**Nickel foil (99.5%)** *(7440-02-0)* Ni; FW: 58.71; 0.79 mm thick x 100 mm wide; m.p. 1453°; b.p. 2732°; d. 8.90	100 x 100mm 500 x 100mm
93-2875	**Nickel foil (99.9%)** *(7440-02-0)* Ni; FW: 58.71; 0.025 mm thick; m.p. 1453°; b.p. 2732°; d. 8.90	150 x 150mm 300 x 300mm
28-0005	**Nickel pellets (99.9%)** *(7440-02-0)* Ni; FW: 58.71; 5-12mm; m.p. 1453°; b.p. 2732°; d. 8.90	250g 1kg
93-2883 HAZ	**Nickel powder (99.5%)** *(7440-02-0)* Ni; FW: 58.71; -100 mesh; m.p. 1453°; b.p. 2732°; d. 8.90	100g 500g
93-2867 HAZ	**Nickel powder (99.9%)** *(7440-02-0)* Ni; FW: 58.71; -300 mesh; m.p. 1453°; b.p. 2732°; d. 8.90	100g 500g
93-2880 HAZ	**Nickel powder (99.9%)** *(7440-02-0)* Ni; FW: 58.71; 3-7 micron; m.p. 1453°; b.p. 2732°; d. 8.90	100g 500g
93-2881	**Nickel rod (99+%)** *(7440-02-0)* Ni; FW: 58.71; 6.35 mm dia.; m.p. 1453°; b.p. 2732°; d. 8.90	30cm 120cm
93-2882	**Nickel rod (99+%)** *(7440-02-0)* Ni; FW: 58.71; 3.2 mm dia.; m.p. 1453°; b.p. 2732°; d. 8.90	30cm 120cm
93-2871	**Nickel wire (99%)** *(7440-02-0)* Ni; FW: 58.71; 0.5 mm dia.; m.p. 1453°; b.p. 2732°; d. 8.90	25m 100m
93-2869	**Nickel wire (99+%)** *(7440-02-0)* Ni; FW: 58.71; 1 mm dia.; m.p. 1453°; b.p. 2732°; d. 8.90	10m 50m
28-1500	**Nickel wire (99.995%)** *(7440-02-0)* Ni; FW: 58.71; 1mm dia.; m.p. 1453°; b.p. 2732°; d. 8.90	25cm 100cm

NIOBIUM (Compounds)

93-4111	**Niobium(V) oxide (99.5%-Nb)** *(1313-96-8)* Nb_2O_5; FW: 265.82; white pwdr.; m.p. 1520°; d. 4.47	50g 250g
93-4109	**Niobium(V) oxide (99.9%-Nb)** *(1313-96-8)* Nb_2O_5; FW: 265.82; white pwdr.; m.p. 1520°; d. 4.47	50g 250g
41-5200	**Niobium(V) oxide (99.995%-Nb) (50-100ppm Ta) PURATREM** *(1313-96-8)* Nb_2O_5; FW: 265.82; white pwdr.; m.p. 1520°; d. 4.47	25g 100g

PLATINUM (Elemental Forms)

78-0050	**Platinum foil (99.95%)** *(7440-06-4)* Pt; FW: 195.09; 0.004mm thick (~0.05g/25x 25mm); m.p. 1769°; b.p. 3827°; d. 21.45	25 x 25mm 50 x 50mm
78-0005	**Platinum foil (99.99%)** *(7440-06-4)* Pt; FW: 195.09; 0.025mm thick (~0.34g/25x 25mm); m.p. 1769°; b.p. 3827°; d. 21.45	25 x 25mm 50 x 50mm
93-7830 HAZ	**Platinum powder (99.9%)** *(7440-06-4)* Pt; FW: 195.09; -60 mesh; m.p. 1769°; b.p. 3827°; d. 21.45	1g 5g
93-7832 HAZ	**Platinum powder (99.9%)** *(7440-06-4)* Pt; FW: 195.09; avg. particle size 0.8-2.5 micron; m.p. 1769°; b.p. 3827°; d. 21.45	1g 5g
93-7833 HAZ	**Platinum powder (99.9%)** *(7440-06-4)* Pt; FW: 195.09; avg. particle size 0.27-0.47 micron; m.p. 1769°; b.p. 3827°; d. 21.45	1g 5g
78-1800 HAZ	**Platinum powder (99.999%)** *(7440-06-4)* Pt; FW: 195.09; -22 mesh; m.p. 1769°; b.p. 3827°; d. 21.45	500mg 2g
78-0082	**Platinum wire (99.95%)** *(7440-06-4)* Pt; FW: 195.09; 1.0 mm dia. (~0.17g/cm); m.p. 1769°; b.p. 3827°; d. 21.45	5cm 25cm
78-0085	**Platinum wire (99.95%)** *(7440-06-4)* Pt; FW: 195.09; 0.5mm dia. (~1.05g/25cm); m.p. 1769°; b.p. 3827°; d. 21.45	5cm 25cm 100cm
78-0075	**Platinum wire (99.99+%)** *(7440-06-4)* Pt; FW: 195.09; 0.254mm dia. (~0.277g/25cm); m.p. 1769°; b.p. 3827°; d. 21.45	25cm 100cm
78-0080	**Platinum wire (99.99+%)** *(7440-06-4)* Pt; FW: 195.09; 0.127mm dia. (~0.27g/m); m.p. 1769°; b.p. 3827°; d. 21.45	1m 5m

PLATINUM (Compounds)

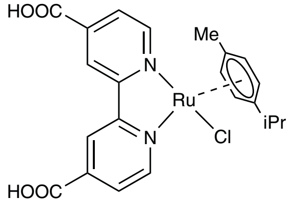
93-7801	**Ammonium hexachloroplatinate(IV), 99%** *(16919-58-7)* *See* page 33	
78-0200 HAZ	**Chloroplatinic acid hexahydrate (38-40% Pt) (99.9%-Pt)** *(18497-13-7)* $H_2PtCl_6 \cdot 6H_2O$; FW: 409.82 (517.92); orange pwdr.; m.p. 60° *light sensitive, hygroscopic, (store cold)*	1g 5g 25g
78-1960	**Potassium hexachloroplatinate(IV), 99%** *(16921-30-5)* *See* page 38	
78-1995	**Sodium hexachloroplatinate(IV) hexahydrate, 98+%** *(19583-77-8)* *See* page 38	

POTASSIUM (Compounds)

93-1922 HAZ	**Potassium fluoride, anhydrous, 98%** *(7789-23-3)* KF; FW: 58.10; white pwdr.; m.p. 846°; b.p. 1505°; d. 2.48 *hygroscopic*	25g 100g 500g
93-1982 HAZ	**Potassium fluoride, anhydrous (99.97%-K)** *(7789-23-3)* KF; FW: 58.10; white pwdr.; m.p. 846°; b.p. 1505°; d. 2.48 *hygroscopic*	5g 25g
78-1960 HAZ	**Potassium hexachloroplatinate(IV), 99%** *(16921-30-5)* K_2PtCl_6; FW: 486.01; yellow xtl.; m.p. 250° dec.; d. 3.499 *hygroscopic*	1g 5g

RUTHENIUM (Compounds)

44-0128 **Chloro(4,4'-dicarboxy-2,2'-bipyridine)(p-cymene)ruthenium(II) chloride, min. 98%**
$[RuCl(C_{12}H_8N_2O_4)(C_{10}H_{14})]^+Cl^-$; FW: 550.40; orange pwdr.
250mg
1g



Technical Note:
1. Product used as a dye to sensitize solar cells.

SELENIUM (Elemental Forms)

93-3416 HAZ	**Selenium powder (99.5%)** *(7782-49-2)* Se; FW: 78.96; -200 mesh; m.p. 170-217°; b.p. 690°; d. 4.81	25g 100g 500g
34-0090 HAZ	**Selenium powder (99.99%)** *(7782-49-2)* Se; FW: 78.96; -200 mesh; m.p. 170-217°; b.p. 690°; d. 4.81	100g 500g
93-3417 HAZ	**Selenium shot (99.99%)** *(7782-49-2)* Se; FW: 78.96; gray pellets (~2mm dia.); m.p. 170-217°; b.p. 690°; d. 4.81	50g 250g

SELENIUM (Compounds)

93-3406 HAZ	**Selenium(IV) oxide, 99.8%** *(7446-08-4)* SeO_2; FW: 110.96; off-white pwdr.; b.p. 340-350° subl.; d. 3.95	100g 500g
93-3405 HAZ	**Selenium(IV) oxide (99.999%-Se) PURATREM** *(7446-08-4)* SeO_2; FW: 110.96; off-white pwdr.; b.p. 340-350° subl.; d. 3.95	5g 25g

SILICON (Elemental Forms)

14-0600	**Silicon chips (99.9999%)** *(7440-21-3)* Si; FW: 28.09; 1-3 mm; m.p. 1420°; b.p. 2600°; d. 2.42	100g 500g
93-1496 HAZ	**Silicon powder (99+%)** *(7440-21-3)* Si; FW: 28.09; -325 mesh; m.p. 1420°; b.p. 2600°; d. 2.42	100g 500g
14-0700 HAZ	**Silicon powder (99.999%)** *(7440-21-3)* Si; FW: 28.09; -325 mesh; m.p. 1420°; b.p. 2600°; d. 2.42	25g 100g 500g
14-0655 HAZ	**Silicon powder (amorphous), min. 97%** *(7440-21-3)* Si; brown pwdr.; SA: >50 m^2/g *air sensitive*	5g 25g
14-0650	**Silicon powder (nanocrystalline), min. 97%** *(7440-21-3)* *See* page 52	

SILVER (Elemental Forms)

47-0058	**Silver needles (99.999%)** *(7440-22-4)* Ag; FW: 107.87; m.p. 960.5°; b.p. 2212°; d. 10.49	10g 50g 250g
47-0060	**Silver plate (99.95%)** *(7440-22-4)* Ag; FW: 107.87; 3.175mm thick (~83.3g/5 x 5cm); m.p. 960.5°; b.p. 2212°; d. 10.49	5 x 5cm 10 x 10cm
93-4758 HAZ	**Silver powder (99.9%)** *(7440-22-4)* Ag; FW: 107.87; 4-7 micron; SA: 0.1-0.4 m^2/g; m.p. 960.5°; b.p. 2212°; d. 10.49	5g 25g
93-4759 HAZ	**Silver powder (99.9%)** *(7440-22-4)* Ag; FW: 107.87; -325 mesh; SA: 0.5-1.0 m^2/g; m.p. 960.5°; b.p. 2212°; d. 10.49	5g 25g
93-4755 HAZ	**Silver powder (99.95%)** *(7440-22-4)* Ag; FW: 107.87; -100 mesh; m.p. 960.5°; b.p. 2212°; d. 10.49	25g 100g
93-4757 HAZ	**Silver powder (99.999%)** *(7440-22-4)* Ag; FW: 107.87; -22 mesh; m.p. 960.5°; b.p. 2212°; d. 10.49	5g 25g

SILVER (Elemental Forms)

47-0070	**Silver rod (99.9%)** *(7440-22-4)* Ag; FW: 107.87; 6.35mm dia. (~3.3g/cm); m.p. 960.5°; b.p. 2212°; d. 10.49	2cm 10cm
47-0080	**Silver shot (99.9%)** *(7440-22-4)* Ag; FW: 107.87; 1-5 mm; m.p. 960.5°; b.p. 2212°; d. 10.49	10g 50g
47-0085	**Silver shot (99.99%)** *(7440-22-4)* Ag; FW: 107.87; 1-3mm; m.p. 960.5°; b.p. 2212°; d. 10.49	10g 50g
93-4763	**Silver shot (99.999%)** *(7440-22-4)* Ag; FW: 107.87; 1-3 mm; m.p. 960.5°; b.p. 2212°; d. 10.49	10g 50g
47-0200	**Silver wire (99.9%)** *(7440-22-4)* Ag; FW: 107.87; 2.0 mm dia. (~33g/m); m.p. 960.5°; b.p. 2212°; d. 10.49	50cm 250cm
47-0250	**Silver wire (99.9%)** *(7440-22-4)* Ag; FW: 107.87; 1.0 mm dia. (~8.2g/m); m.p. 960.5°; b.p. 2212°; d. 10.49	1m 5m 25m
47-0300	**Silver wire, annealed (99.9%)** *(7440-22-4)* Ag; FW: 107.87; 0.5 mm dia. (~2g/m); m.p. 960.5°; b.p. 2212°; d. 10.49	2m 10m 50m
47-0350	**Silver wire (99.9%)** *(7440-22-4)* Ag; FW: 107.87; 0.25 mm dia. (~0.52g/m); m.p. 960.5°; b.p. 2212°; d. 10.49	25m 100m

SODIUM (Compounds)

93-1141 HAZ	**Sodium fluoride, 99% (ACS)** *(7681-49-4)* NaF; FW: 41.99; white pwdr.; m.p. 988°; b.p. 1695°; d. 2.558	100g 500g
11-2000 HAZ	**Sodium fluoride (99.99+%-Na) PURATREM** *(7681-49-4)* NaF; FW: 41.99; white pwdr.; m.p. 988°; b.p. 1695°; d. 2.558	25g 100g
78-1995	**Sodium hexachloroplatinate(IV) hexahydrate, 98+%** *(19583-77-8)* $Na_2PtCl_6 \cdot 6H_2O$; FW: 453.79 (561.89); orange pwdr. *hygroscopic*	1g 5g
93-3414 HAZ	**Sodium selenite, 99%** *(10102-18-8)* Na_2SeO_3; FW: 172.94; white pwdr.	50g 250g

STRONTIUM (Elemental Forms)

93-3831 HAZ	**Strontium pieces (99%)** *(7440-24-6)* Sr; FW: 87.63; 20-30mm (packed in mineral oil); m.p. 769°; b.p. 1384°; d. 2.54 *air sensitive, moisture sensitive*	25g 100g
38-0074 amp HAZ	**Strontium pieces, dendritic (99.9%)** *(7440-24-6)* Sr; FW: 87.63; ampouled under argon; m.p. 769°; b.p. 1384°; d. 2.54 *air sensitive, moisture sensitive*	25g

STRONTIUM (Compounds)

93-3804	**Strontium carbonate, min. 97% (contains ~1.0-2.5% barium carbonate)** *(1633-05-2)* $SrCO_3$; FW: 147.63; white pwdr.; m.p. 1497°; d. 3.70	250g 1kg
93-3803	**Strontium carbonate (low alkali and heavy metals) (99.9%-Sr)** *(1633-05-2)* $SrCO_3$; FW: 147.63; white pwdr.; m.p. 1497°; d. 3.70	50g 250g
38-1100	**Strontium carbonate (99.995%-Sr) PURATREM** *(1633-05-2)* $SrCO_3$; FW: 147.63; white pwdr.; m.p. 1497°; d. 3.70	10g 50g

SULFUR (Elemental Forms)

93-1616 HAZ	**Sulfur (99.999%)** *(7704-34-9)* S; FW: 32.06; 6mm pieces and down; m.p. 112.8°; b.p. 444.67°; d. 2.07	25g 100g 500g
93-1617 HAZ	**Sulfur powder, precipitated, purified** *(7704-34-9)* S; FW: 32.06; -60 mesh pwdr.; m.p. 112.8°; b.p. 444.67°; f.p. 405°F; d. 2.07	250g 1kg
93-1618 HAZ	**Sulfur powder, sublimed (99+%)** *(7704-34-9)* S; FW: 32.06; -100 mesh pwdr.; m.p. 112.8°; b.p. 444.67°; f.p. 405°F; d. 2.07	250g 1kg

TELLURIUM (Compounds)

93-5224 HAZ	**Tellurium broken ingot (99.99+%)** *(13494-80-9)* Te; FW: 127.60; m.p. 449.5°; b.p. 989.8°; d. 6.24	25g 100g
52-0070 HAZ	**Tellurium broken ingot (99.999%)** *(13494-80-9)* Te; FW: 127.60; 25mm and down; m.p. 449.5°; b.p. 989.8°; d. 6.24	25g 100g 500g
52-0030 HAZ	**Tellurium broken ingot (99.9999%)** *(13494-80-9)* Te; FW: 127.60; 2cm and down; m.p. 449.5°; b.p. 989.8°; d. 6.24	10g 50g
93-5222 HAZ	**Tellurium powder (99.8%)** *(13494-80-9)* Te; FW: 127.60; -100 mesh; m.p. 449.5°; b.p. 989.8°; d. 6.24	25g 100g 500g
52-5200 HAZ	**Tellurium powder (99.9%)** *(13494-80-9)* Te; FW: 127.60; -325 mesh	25g 100g 500g
93-5220 HAZ	**Tellurium powder (99.999%)** *(13494-80-9)* Te; FW: 127.60; 60 mesh; m.p. 449.5°; b.p. 989.8°; d. 6.24	10g 50g

TELLURIUM (Compounds)

93-5205 HAZ	**Tellurium(IV) chloride (99.9%-Te)** *(10026-07-0)* $TeCl_4$; FW: 269.41; off-white pwdr.; m.p. 224°; b.p. 380°; d. 3.26 *moisture sensitive*	10g 50g
93-5204	**Tellurium(IV) oxide, 99+%** *(7446-07-3)* TeO_2; FW: 159.60; off-white pwdr.; m.p. 733°; b.p. 450° subl.	50g 250g
93-5216	**Tellurium(IV) oxide (99.999%-Te) PURATREM** *(7446-07-3)* TeO_2; FW: 159.60; off-white pwdr.; m.p. 733°; b.p. 450° subl.	10g 50g

TIN (Elemental Forms)

93-5091	**Tin foil (99.99%)** *(7440-31-5)* Sn; FW: 118.70; 0.127 mm thick x 25 mm wide; m.p. 231.9°; b.p. 2260°; d. 7.31	100 x 25mm 500 x 25mm
50-0250	**Tin foil (99.998%)** *(7440-31-5)* Sn; FW: 118.70; 0.25mm thick (~4.6g/50 x50mm); m.p. 231.9°; b.p. 2260°; d. 7.31	50 x 50mm 100 x 100mm
93-5089	**Tin powder (99.5%)** *(7440-31-5)* Sn; FW: 118.70; -100 mesh; m.p. 231.9°; b.p. 2260°; d. 7.31	100g 500g
93-5086	**Tin powder (99.8%)** *(7440-31-5)* Sn; FW: 118.70; -325 mesh; m.p. 231.9°; b.p. 2260°; d. 7.31	50g 250g
93-5090	**Tin powder (99.995%)** *(7440-31-5)* Sn; FW: 118.70; -100 mesh; m.p. 231.9°; b.p. 2260°; d. 7.31	10g 50g
93-5088	**Tin shot (99.8%)** *(7440-31-5)* Sn; FW: 118.70; 8-20 mesh; m.p. 231.9°; b.p. 2260°; d. 7.31	50g 250g
50-0070	**Tin shot (99.999%)** *(7440-31-5)* Sn; FW: 118.70; 1-3 mm; m.p. 231.9°; b.p. 2260°; d. 7.31	5g 25g
50-0080	**Tin shot (99.9999%)** *(7440-31-5)* Sn; FW: 118.70; 3 mm; m.p. 231.9°; b.p. 2260°; d. 7.31	5g 25g 100g

TIN (Compounds)

93-5026	**Tin(IV) oxide (99.9%-Sn)** *(18282-10-5)* SnO_2; FW: 150.69; white pwdr.; m.p. 1630°; d. 7.0	100g 500g
50-2500	**Tin(IV) oxide (99.998%-Sn) PURATREM** *(18282-10-5)* SnO_2; FW: 150.69; -22 mesh off-white pwdr.; m.p. 1630°; d. 7.0	5g 25g

TITANIUM (Compounds)

93-2204	**Titanium(IV) n-butoxide, 98+%** *(5593-70-4)* $Ti(OC_4H_9)_4$; FW: 340.35; colorless liq.; m.p. -55°; b.p. 312° (206°/10mm); f.p. 170°F; d. 0.994 (25°) *moisture sensitive*	500g 2kg
22-1170	**Titanium(IV) t-butoxide (99.95%-Ti)** *(3087-39-6)* $Ti(OC_4H_9)_4$; FW: 340.35; colorless liq.; b.p. 70°/0.2mm; d. 0.89 *moisture sensitive*	5g 25g
22-1180 HAZ	**Titanium(III) chloride, Al reduced, 98+%** *(12003-13-3)* $TiCl_3 \cdot 1/3AlCl_3$; FW: 198.72; purple xtl. *air sensitive, moisture sensitive*	100g 500g
22-1150 HAZ	**Titanium(IV) chloride, 99%** *(7550-45-0)* $TiCl_4$; FW: 189.73; pale yellow liq.; m.p. -25°; b.p. 136°; d. 1.726 *moisture sensitive* Note: Available prepacked in ALD cylinder- see 98-4033.	250g 1kg
93-2209 HAZ	**Titanium(IV) ethoxide (contains 5-15% isopropanol)** *(3087-36-3)* $Ti(OC_2H_5)_4$; FW: 228.14; xtl. to pale yellow liquid; b.p. 122°/1 mm; f.p. 84°F; d. 1.107 (20°) *moisture sensitive*	25g 100g 500g
22-2209 amp HAZ	**Titanium(IV) ethoxide (99.99%-Ti) PURATREM** *(3087-36-3)* $Ti(OC_2H_5)_4$; FW: 228.14; xtl. to pale orange liq.; m.p. 54°; b.p. 138°/5mm; f.p. 84°F; d. 1.088 *moisture sensitive*	5g 25g
93-2206	**Titanium(IV) oxide, 99+%** *(13463-67-7)* TiO_2; FW: 79.90; 1.0-1.3 micron white pwdr.; m.p. 1830-1850°; b.p. 2500-3000°; d. 4.26	250g 1kg
93-2207	**Titanium(IV) oxide (99.99+%-Ti) PURATREM** *(13463-67-7)* TiO_2; FW: 79.90; white pwdr.; m.p. 1830-1850°; b.p. 2500-3000°; d. 4.26	25g 100g
22-1400	**Titanium(IV) oxide nanopowder Anatase** *(1317-80-2)* TiO_2; FW: 79.90; white pwdr.	5g 25g

Specific Surface Area (BET): ≥500 m^2/g; **True Density:** 3.7 g/cc; **Crystallite Size:** Amorphous; **Mean Aggregate Size**: 5 μm; **Average Pore Diameter:** 32Å; **Loss on Ignition:** ≤12%; **Total Pore Volume:** ≥0.4 cc/g; **Moisture Content:** ≤4%; **Bulk Density:** 0.6 g/cc; **Ti Content (Based on Metal):**> 99.999%

93-2208	**Titanium(IV) oxide, sintered lumps, 99.5%** *(13463-67-7)* TiO_2; FW: 79.90; white lump; m.p. 1830-1850°; b.p. 2500-3000°; d. 4.26	25g 100g
93-2216 HAZ	**Titanium(IV) i-propoxide, min. 98%** *(546-68-9)* $Ti[OCH(CH_3)_2]_4$; FW: 284.25; colorless to pale yellow liq.; m.p. 20°; b.p. 58°/1 mm; f.p. 81°F; d. 0.9550 *moisture sensitive* Note: Available prepacked in ALD cylinder- see 98-4030.	250g 1kg

Technical Notes:
1. For detailed technical note visit strem.com.

98-4030 HAZ	**Titanium(IV) i-propoxide, min. 98%, 93-2216, contained in 50 ml Swagelok® cylinder (96-1070) for CVD/ALD** *(546-68-9)* $Ti[OCH(CH_3)_2]_4$; FW: 284.25; colorless liq.; m.p. 20°; b.p. 58°/1mm; f.p. 81°F; d. 0.9550 *moisture sensitive* Note: High temperature Swagelok® cylinder assembly 96-1071 available at extra cost.	25g

TUNGSTEN (Elemental Forms)

93-7456 HAZ	**Tungsten powder (99.9%)** *(7440-33-7)* W; FW: 183.85; 12 micron; m.p. 3410°; b.p. 5660°; d. 19.3	50g 250g
93-7455 HAZ	**Tungsten powder (99.9+%)** *(7440-33-7)* W; FW: 183.85; -100 mesh; m.p. 3410°; b.p. 5660°; d. 19.3	50g 250g
93-7437 HAZ	**Tungsten powder (99.95%)** *(7440-33-7)* W; FW: 183.85; 0.6-0.9 microns; m.p. 3410°; b.p. 5660°; d. 19.3	50g 250g

TUNGSTEN (Elemental Forms)

74-0075	**Tungsten rod annealed (99.98%)** *(7440-33-7)* W; FW: 183.85; 3.175mm dia. (~1.53g/cm); m.p. 3410°; b.p. 5660°; d. 19.3	25cm 100cm 5 x 100cm
93-7450	**Tungsten wire (99.95%)** *(7440-33-7)* W; FW: 183.85; 0.5 mm dia.; m.p. 3410°; b.p. 5660°; d. 19.3	5m 25m
93-7452	**Tungsten wire (99.95%)** *(7440-33-7)* W; FW: 183.85; 0.2 mm dia.; m.p. 3410°; b.p. 5660°; d. 19.3	20m 100m
93-7438	**Tungsten wire (99.95%)** *(7440-33-7)* W; FW: 183.85; 0.127 mm dia.; m.p. 3410°; b.p. 5660°; d. 19.3	50m 250m
93-7439	**Tungsten wire (99.95%)** *(7440-33-7)* W; FW: 183.85; 0.05 mm dia.; m.p. 3410°; b.p. 5660°; d. 19.3	100m
93-7451	**Tungsten wire (99.95%)** *(7440-33-7)* W; FW: 183.85; 0.025 mm dia.; m.p. 3410°; b.p. 5660°; d. 19.3	100m 500m

ZINC (Compounds)

93-3052 amp HAZ	**Zinc chloride (99.99%-Zn) PURATREM** *(7646-85-7)* $ZnCl_2$; FW: 136.28; -10 mesh spheres; m.p. 283°; b.p. 732°; d. 2.91	10g 50g
30-3006 HAZ	**Zinc chloride, anhydrous, min. 97% (ACS)** *(7646-85-7)* $ZnCl_2$; FW: 136.28; white pwdr.; m.p. 283°; b.p. 732°; d. 2.91 *hygroscopic*	100g 500g
93-3041	**Zinc selenide (99.99%-Zn) PURATREM** *(1315-09-9)* ZnSe; FW: 144.33; yellow, granular solid; m.p. > 1100°; d. 5.42	5g 25g 100g
93-3023	**Zinc selenide (99.999%-Zn) PURATREM** *(1315-09-9)* ZnSe; FW: 144.33; yellow pwdr.; m.p. > 1100°; d. 5.42	10g 50g
93-3046	**Zinc telluride (99.99%-Zn) PURATREM** *(1315-11-3)* ZnTe; FW: 192.97; gray pwdr.; m.p. 1240°; d. 6.34	10g 50g

KITS - Cadmium Selenide StremDots™ Quantum Dot (CdSe core) Kit

96-0800 HAZ — **Cadmium selenide StremDots™ quantum dot (CdSe core) kit, 50umol/L in hexanes, 525-625nm peak emissions**
Components also available for individual sale.
Contains the following:

48-1011	Cadmium selenide StremDots™ quantum dot (CdSe core), 50umol/L in hexanes, 525nm peak emissi *(1306-24-7)*	5ml	See page 45
48-1017	Cadmium selenide StremDots™ quantum dot (CdSe core), 50umol/L in hexanes, 550nm peak emission *(1306-24-7)*	5ml	See page 45
48-1023	Cadmium selenide StremDots™ quantum dot (CdSe core), 50umol/L in hexanes, 575nm peak emission *(1306-24-7)*	5ml	See page 45
48-1030	Cadmium selenide StremDots™ quantum dot (CdSe core), 50umol/L in hexanes, 600nm peak emission *(1306-24-7)*	5ml	See page 45
48-1035	Cadmium selenide StremDots™ quantum dot (CdSe core), 50umol/L in hexanes, 625nm peak emission *(1306-24-7)*	5ml	See page 45

Item #	Peak Emission	Particle size (diameter)	Quantum Yield
48-1011	525nm	2.8nm	>20%
48-1017	550nm	3.5nm	>10%
48-1023	575nm	3.9nm	>10%
48-1030	600nm	4.7nm	>20%
48-1035	625nm	5.3nm	>20%

Kit contains 5ml of each of the above 5 products. Ligand capping agent oleylamine. Stable in dispersions > 6 months.
*Particle size reported excludes ligand capping agent. All sizes determined by TEM.
† Available at nanoparticle concentration of 50μmol per liter.

KITS - Gold Nanorods Kit (Axial Diameter - 25nm, Wavelength 550-700nm)

96-1530 — **Gold Nanorods Kit (Axial Diameter - 25 nm, wavelength 550-700 nm)**
Components also available for individual sale.
Contains the following:

79-6000	Gold Nanorods (Axial Diameter - 25 nm) (Wavelength 550 nm) *(7440-57-5)*	25ml	See page 49
79-6005	Gold Nanorods (Axial Diameter - 25 nm) (Wavelength 600 nm) *(7440-57-5)*	25ml	See page 49
79-6010	Gold Nanorods (Axial Diameter - 25 nm) (Wavelength 650 nm) *(7440-57-5)*	25ml	See page 49
79-6015	Gold Nanorods (Axial Diameter - 25 nm) (Wavelength 700 nm) *(7440-57-5)*	25ml	See page 49

KITS - Gold Nanorods Kit (Axial Diameter - 10nm, Wavelength 700-808nm)

96-1535 — **Gold Nanorods Kit (Axial Diameter - 10 nm, wavelength 700-808 nm)**
Components also available for individual sale.
Contains the following:

79-6020	Gold Nanorods (Axial Diameter - 10 nm) (Wavelength 700 nm) *(7440-57-5)*	25ml	See page 48
79-6025	Gold Nanorods (Axial Diameter - 10 nm) (Wavelength 750 nm) *(7440-57-5)*	25ml	See page 48
79-6030	Gold Nanorods (Axial Diameter - 10 nm) (Wavelength 780 nm) *(7440-57-5)*	25ml	See page 48
79-6035	Gold Nanorods (Axial Diameter - 10 nm) (Wavelength 808 nm) *(7440-57-5)*	25ml	See page 48

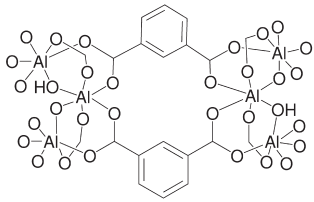
MOFs AND LIGAND FOR MOF SYNTHESIS

ALUMINUM (Compounds)

13-0300 NEW

Aluminum hydroxide isophthalate MOF (CAU-10, Isophthalate:Al=0.9-1.0) *(1416330-84-1)*
$Al(OH)(C_8H_4O_4)_x$, X = 0.9-1.0; white solid;
SA: 620-640 m^2/g; P.Vol. 0.23-0.27 cm^3/g
Note: Particle size: 0.4-0.7 micron, Thermal stability: 400ºC, Activation temperature: 150ºC
Sold under license from Inven2 AS for research purposes only.
PCT/GB2009/001087.

500mg
2g



Technical Note:

1. MOF exhibits water adsorption characteristics which make it a promising adsorbent for application in heat-exchange processes [1]

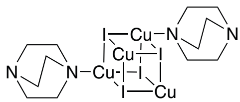
References:

1. *Water adsorption behaviour of CAU-10-H: a thorough investigation of its structure–property relationships,* J. Mater. Chem. A, **2016**, *4*, 11859.
2. *Structures, Sorption Characteristics, and Nonlinear Optical Properties of a New Series of Highly Stable Aluminum MOFs*., Chem. Mater. **2013**, *25*, 17−26.

COPPER (Compounds)

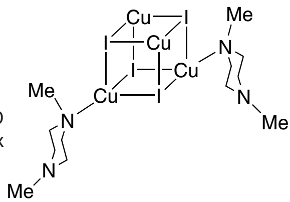
29-3015 **Bis(1,4-diazabicyclo [2.2.2]octane)tetra (copper(I) iodide) $(CuI)_4(DABCO)_2$** *(928170-42-7)*
$C_{12}H_{24}Cu_4I_4N_4$; FW: 986.15; yellow pwdr.; SA: >514; P.Vol. 0.25
air sensitive

500mg
2g



29-0550 **Bis(N,N'-dimethylpiperazine)tetra[copper(I) iodide], 98% MOF** *(1401708-91-5)*
$(CuI)_4(C_6H_{14}N_2)_2$; FW: 990.18; white pwdr.
moisture sensitive, (store cold)

500mg
2g



Technical Note:

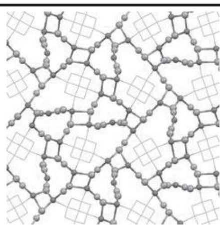
1. The copper iodide, N,N'dimethylpiperazine complex is a 3D photoluminescent, fairly open network, with a lamda max excitation of 321 nm and a lamda max emission of 525nm.

References:

1. *Dalton Trans.,* **2012**, *41*, 11663

29-0565 **(Hexamethylenetetramine)penta[copper(I) cyanide], 98% MOF** *(1042093-98-0)*
$C_6H_{12}N_4(CuCN)_5$; FW: 588.00; white pwdr.
hygroscopic, (store cold)

500mg
2g



Technical Note:

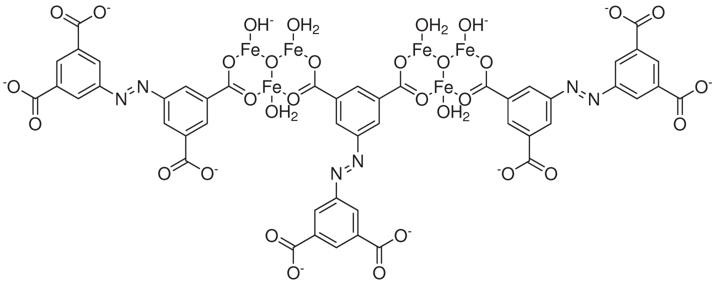
1. The copper cyanide hexamethylenetetramine complex is a 3D photoluminescent, very densely-packed, network of tetradentate ligands with a lamda max excitation of 282 and 304nm, and a lamda max emission of 417 and 522nm.

References:

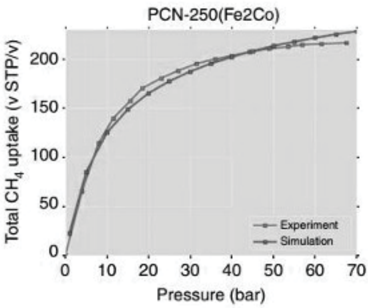
1. *Inorg. Chem.,* **2007**, *46*, 8897
2. *Inorg. Chem.,* **2008**, *47*, 6947
3. *Inorg. Chem. Acta.,* **2010**, *364*, 102
4. *Dalton Trans.,* **2012**, *41*, 11663

IRON (Compounds)

26-3725 **Iron azobenzene tetracarboxylic, Porous [PCN-250(Fe)], AYRSORB™ F250** 500mg
(1771755-22-6) 2g
Dark red-brown pwdr. 10g
Note: Sold in collaboration with framergy for research purposes only.
Patent: US 9,724,668 B2.



Technical Note:
1. Metal-Organic Framework (MOF) exhibiting superior uptake of hydrogen and methane. Stable in water and aqueous solutions.



Tech. Note (1)
Ref. (1)

References:

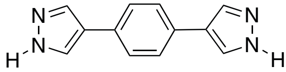
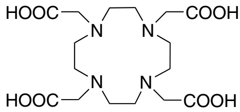
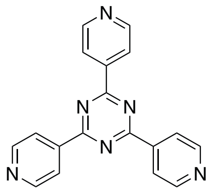
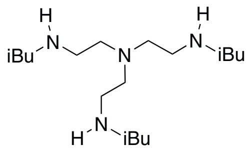
1. *Nat. Commun.,* **2014**, *5*, 5723
2. *Sci. Technol. Adv. Mater.,* **2015**, *16*, 054202

26-2340 **Iron(III) 1,3,5-benzenetricarboxylate hydrate, porous (F-free MIL-100(Fe), KRICT F100) [Iron trimesate]** *(1257379-83-1)* 500mg, 2g
$[Fe_3O(H_2O)_2(OH)\{C_6H_3(COO)_3\}_2]\cdot XH_2O$; red solid;
SA: 2120 (Langmuir); 1950 (BET); P.Vol. 1.075
Note: Sold under agreement with KRICT for research and development purposes only.
Patents US 8507399 B2, US 8252950 B2.

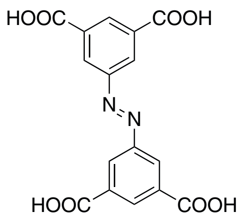
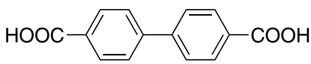
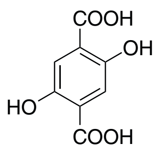
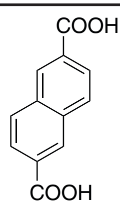
KRICT F100

Technical Note:
1. For detailed technical note visit strem.com

NITROGEN (Compounds)

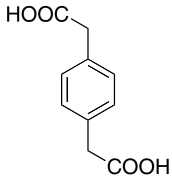
07-0435	**1,4-Di(4'-pyrazolyl)benzene, min. 97% H_2BDP** *(1036248-62-0)* $C_{12}H_{10}N_4$; FW: 210.24; pale yellow solid Note: Ligand for MOF synthesis.		500mg 2g
07-1942	**1,4,7,10-Tetraazacyclododecane-N,N',N'',N'''-tetraacetic acid, min. 98% DOTA** *(60239-18-1)* $C_{16}H_{28}N_4O_8$; FW: 404.42; white pwdr. Note: Ligand for MOF synthesis.		250mg 1g 5g
07-3235	**2,4,6-(Tri-4-pyridinyl)-1,3,5-triazine, min. 97% TPT** *(42333-78-8)* $C_{18}H_{12}N_6$; FW: 312.33; off-white pwdr. Note: Ligand for MOF synthesis		250mg 1g 5g
07-3110	**Tris(isobutylaminoethyl)amine, min 97%** *(331465-73-7)* $C_{18}H_{42}N_4$; FW: 314.55; colorless to pale yellow, viscous liq. *hygroscopic* Note: Ligand for MOF synthesis.		500mg 2g

OXYGEN (Compounds)

08-0125	**3,3',5,5'-Azobenzene tetracarboxylic acid, TazbH$_4$, 97%** *(365549-33-33)* $C_{16}H_{10}N_2O_8$; FW: 358.26; yellow-orange pwdr. Note: Ligand for MOF Synthesis		1g 5g
08-0175	**[1,1'-Biphenyl]-4,4'-dicarboxylic acid, min. 98%** *(787-70-2)* $C_{14}H_{10}O_4$; FW: 242.23; white to pale-yellow solid Note: Ligand for MOF synthesis.		5g 25g
08-1220	**2,5-Dihydroxyterephthalic acid, 98% H$_4$DOBDC** *(610-92-4)* $C_6H_2(OH)_2(COOH)_2$; FW: 198.13; yellow pwdr. Note: Ligand for MOF Synthesis		1g 5g 25g
08-1235	**2,6-Naphthalenedicarboxylic acid, min. 98%** *(1141-38-4)* $C_{10}H_6(COOH)_2$; FW: 216.19; white pwdr.; m.p. >300° Note: Ligand for MOF synthesis.		5g 25g

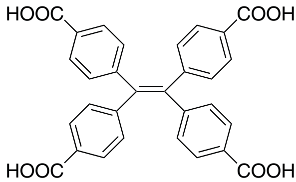
OXYGEN (Compounds)

08-1165 **1,4-Phenylenediacetic acid, 97%** *(7325-46-4)*
$C_6H_4(CH_2COOH)_2$; FW: 194.18; white to off-white solid
Note: Ligand for MOF synthesis.



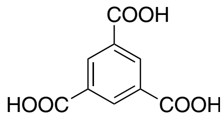
1g
5g

08-3060 **1,1,2,2-Tetra(4-carboxylphenyl)ethylene, 99%**
H_4TCPE *(1351279-73-6)*
$C_{30}H_{20}O_8$; FW: 508.48; pale yellow pwdr.
Note: Ligand for MOF synthesis.



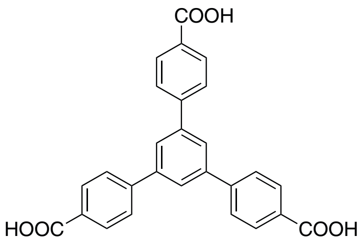
25mg
100mg

08-0195 **1,3,5-Tricarboxybenzene, min. 95% (Trimesic acid)**
BTC *(554-95-0)*
$C_6H_3(COOH)_3$; FW: 210.14; white pwdr.
Note: Ligand for MOF synthesis.



50g
250g

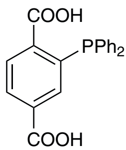
08-0635 **1,3,5-Tris(4-carboxyphenyl)benzene, min. 98%**
BTB *(50446-44-1)*
$C_{27}H_{18}O_6$; FW: 438.43; white to yellow solid;
m.p. 322-327°
Note: Ligand for MOF synthesis.



1g
5g

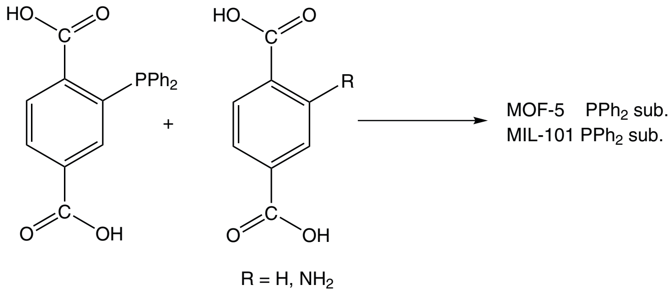
PHOSPHORUS (Compounds)

15-7170 **2-(Diphenylphosphino)terephthalic acid, 98%**
(1537175-69-1)
$C_{20}H_{18}O_4P$; FW: 350.30; white pwdr.
Note: Ligand for MOF synthesis. Developed at the Paul Scherrer Institute, Switzerland PCT/EP2013/051405.



50mg
250mg

Technical Note:
1. Starting material for the construction of diphenylphosphino-substituted MOFs.

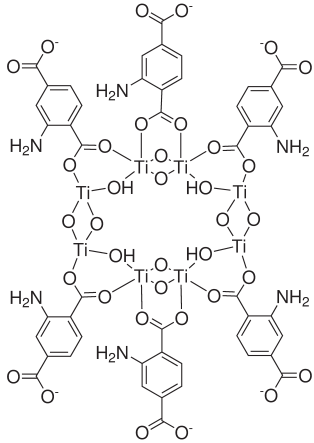


Tech. Note (1)
Ref. (1)

References:
1. *Ind. Eng. Chem. Res.*, **2014**, *53*, 9120.

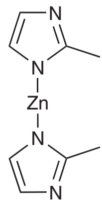
TITANIUM (Compounds)

22-1070 NEW	**Hexakis[μ-(2-amino-1,4-benzenedicarboxylato)][tetra-μ-hydroxyocta-μ-oxooctatitanium], NH2-MIL-125(Ti), AYRSORB™ T125** *(1309760-94-8)* $C_{48}H_{34}N_6O_{36}Ti_8$; FW: 1653.74; yellow pwdr.; SA: ~1530; P.Vol. ~0.74 Note: Sold in collaboration with framergy for research purposes only. Patent: US 8,940,392 B2.	250mg 1g



ZINC (Compounds)

30-4015 HAZ	**Zinc 2-methylimidazole MOF (ZIF-8)** *(59061-53-9)* $C_8H_{10}N_4Zn$; FW: 227.58; white solid; SA: 1813; P.Vol. 0.65	1g 5g

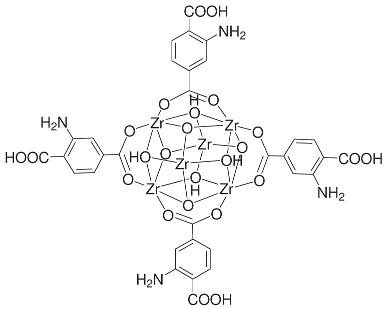


Technical Notes:

1. Use of ZIF-8 in the separation of alkanes, alkenes and aromatics
   a. Separation of xylene isomers
      Micropor. Mesopor. Mat., **2013**, *173*, 1.
   b. Separation of C6 Paraffins
      Ind. Eng. Chem. Res., **2012**, *51*, 4692.
   c. Effective separation of propylene/propane binary mixtures
      J. Membrane Sci., **2012**, *390-391*, 93.
2. Use of ZIF-8 as a catalyst and catalyst-support
   a. Catalytic activity of ZIF-8 in the synthesis of styrene carbonate
      Chem. Commun., **2013**, *32*, 36.
   b. Iridium nanoparticles stabilized by metal organic frameworks: synthesis, structural properties and catalytic performance
      Dalton Trans., **2012**, *41*, 12690.
   c. Zeolitic imidazole frameworks: Catalysts in the conversion of carbon dioxide to chloropropene carbonate
      ACS Catalysis, **2012**, *2*, 180.
   d. Expanding applications of metal-organic frameworks: zeolite imidazolate framework ZIF-8 as an efficient heterogeneous catalyst for the Knoevenagel reaction
      ACS Catalysis, **2011**, *1*, 120.
3. Use of ZIF-8 in gas purification
   a. MOF-containing mixed-matrix membranes for CO_2/CH_4 and CO_2/N_2 binary gas mixture separations
      Sep. Purif. Technol., **2011**, *81*, 31.
   b. Porous polyethersulfone-supported Zeolitic Imidazolate Framework Membranes for hydrogen separation
      J. Phys.Chem. C., **2012**, *116*, 13264.

ZIRCONIUM (Compounds)

40-1109 NEW **Zirconium aminobenzenedicarboxylate MOF (UiO-66-BDC-NH2, BDC-NH2: Zr=0.9-1.0)** *(1260119-00-3)*
$Zr_6O_4(OH)_4(C_8H_5NO_4)_x$, X = 5.4-6.0;
yellow solid; SA: 800-1075 m²/g;
P.Vol. 0.31-0.41 cm³/g
Note: Particle size: 0.1-0.5 micron, Thermal stability: 300ºC, Activation temperature: 150ºC
Sold under license from Inven2 AS for research purposes only.
PCT/GB2009/001087.



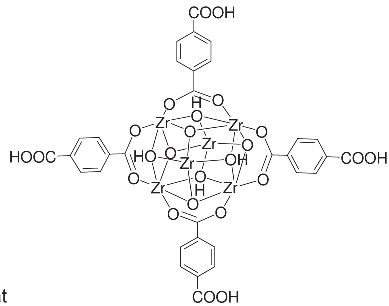
500mg
2g

Technical Notes:
1. Useful MOF for adsorption of CO_2 applications[1]
2. Catalyst MOF used in the conversion of toxic agents to non-toxic products[2]

References:

1. *Carbon Dioxide Adsorption in Amine-Functionalized Mixed-Ligand Metal-Organic Frameworks of UiO-66 Topology.,* Chem.Sus.Chem. **2014**, *7*, 3382-3388.
2. *Tailoring the Pore Size and Functionality of UiO-Type Metal−Organic Frameworks for Optimal Nerve Agent Destruction,* Inorg. Chem. **2015**, *54*, 9684−9686.
3. *Towards Metal-Organic Framework based Field Effect Chemical Sensors: UiO-66-NH2 for Nerve Agent Detection,* Chem. Sci., **2016**, *7*, 5827.

40-1108 NEW **Zirconium benzenedicarboylate MOF (UiO-66-BDC, BDC:Zr=0.66-0.98)**
$Zr_6O_4(OH)_4(C_8H_4O_4)_x$ X = 3.96-5.88;
white solid; SA: 1050-1400 m²/g;
P.Vol. 0.42-0.58 cm³/g
Note: Particle size: 0.2-0.5 micron, Thermal stability: 400ºC, Activation temperature: 300ºC
Sold under license from Inven2 AS for research purposes only.
PCT/GB2009/001087.



500mg
2g

Technical Note:
1. New zirconium-based inorganic building brick that allows the synthesis of very high surface area MOF's with unprecedented stability[3]

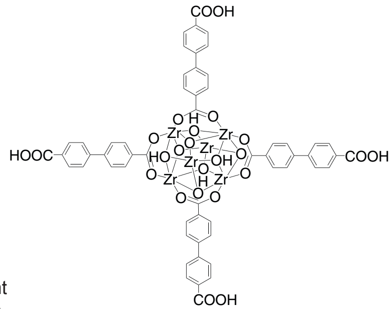
References:

1. *Tuned to Perfection: Ironing Out the Defects in Metal−Organic Framework UiO-66*
Chem. Mater. **2014**, *26*, 4068−4071.
2. *H_2 storage in isostructural UiO-67 and UiO-66 MOFs*
Phys. Chem. Chem. Phys., **2012**, *14*, 1614–1626.
3. *A New Zirconium Inorganic Building Brick Forming Metal Organic Frameworks with Exceptional Stability*. J. Am. Chem. Soc. **2008**, *130*, 13850–13851.

ZIRCONIUM (Compounds)

40-1112 NEW **Zirconium biphenyldicarboxylate MOF (UiO-66-BPDC/UiO-67, BPDC:Zr=0.9-1.0)** — 250mg, 1g

$Zr_6O_4(OH)_4(C_{14}H_8O_4)_x$, X = 5.4-6.0; white solid; SA: 2400-2500 m^2/g; P.Vol. 0.85-0.98 cm^3/g
moisture sensitive
Note: Particle size: 0.4-0.7μ, Thermal stability: 450ºC
Sold under license from Inven2 AS for research purposes only.
PCT/GB2009/001087.



Technical Notes:

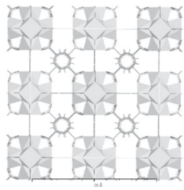
1. Metal−organic framework showing excellent stability to water, reversible water vapor adsorption, and increased volumetric capacity for methane adsorption[1]
2. Remarkable stability at high temperatures, high pressures and in the presence of different solvents, acids and bases[2,3]

References:

1. *UiO-67-type Metal−Organic Frameworks with Enhanced Water Stability and Methane Adsorption Capacity*, Inorg. Chem. **2016**, *55*, 1986−1991.
2. *H_2 storage in isostructural UiO-67 and UiO-66 MOFs*, Phys. Chem. Chem. Phys., **2012**, *14*, 1614–1626.
3. *A New Zirconium Inorganic Building Brick Forming Metal Organic Frameworks with Exceptional Stability.* J. Am. Chem. Soc. **2008**, *130*, 13850–13851.

40-1105 **Zirconium 1,4-dicarboxybenzene MOF (UiO-66, BDC:Zr=1)** *(1072413-89-8)* — 500mg, 2g

$C_{48}H_{28}O_{32}Zr_6$; FW: 1664.06; white pwdr.;
SA: 1180-1240m^2g; P.Vol. 0.45-0.48
Note: Particle size: 0.2-0.5 micron, Thermal stability: 400ºC, Activation temperature: 300ºC
Sold under license from Inven2 AS for research purposes only. EP 09738396 and US 12/989,64



Technical Note:

1. New zirconium-based inorganic building brick that allows the synthesis of very high surface area MOF's with unprecedented stability (ref 3).

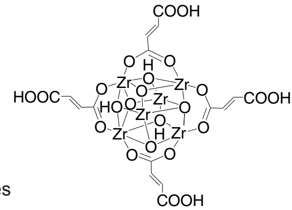
References:

1. *Tuned to Perfection: Ironing Out the Defects in Metal−Organic Framework UiO-66*
Chem. Mater. **2014**, *26*, 4068−4071, Greig C. Shearer, Sachin Chavan, Jayashree Ethiraj, Jenny G. Vitillo, Stian Svelle, Unni Olsbye, Carlo Lamberti, Silvia Bordiga and Karl Petter Lillerud
2. *H_2 storage in isostructural UiO-67 and UiO-66 MOFs*
Phys. Chem. Chem. Phys., **2012**, *14*, 1614–1626, Sachin Chavan, Jenny G. Vitillo, Diego Gianolio, Olena Zavorotynska, Bartolomeo Civalleri, Søren Jakobsen, Merete H. Nilsen, Loredana Valenzano, Carlo Lamberti, Karl Petter Lillerud and Silvia Bordiga
3. *A New Zirconium Inorganic Building Brick Forming Metal Organic Frameworks with Exceptional Stability.*
J. Am. Chem. Soc. **2008**, *130*, 13850–13851, Jasmina Hafizovic Cavka, Søren Jakobsen, Unni Olsbye, Nathalie Guillou, Carlo Lamberti, Silvia Bordiga, and Karl Petter Lillerud

ZIRCONIUM (Compounds)

40-1114 NEW **Zirconium Fumarate MOF (UiO-66-FA, FA:Zr=0.66-0.98)** 500mg, 2g

$Zr_6O_4(OH)_4(C_4H_2O_4)_x$, X = 3.96-5.88;
white solid; SA: 650-960 m^2/g;
P.Vol. 0.26-0.4 cm^3/g
Note: Particle size: 0.1-0.5 micron, Thermal stability: 200ºC, Activation temperature: 130ºC
Sold under license from Inven2 AS for research purposes only. PCT/GB2009/001087.



Technical Notes:

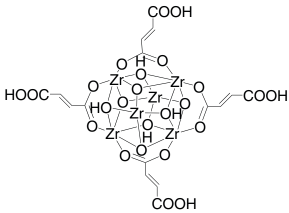
1. Metalorganic framework used in a large number of studies for the storage of hydrogen or methane[2]
2. Water adsorption in MOF's for many applications such as dehumidification, thermal batteries, and delivery of drinking water in remote areas[3]

References:

1. *Water harvesting from air with metal-organic frameworks powered by natural sunlight*. Science, **2017**, *356*, 430–434.
2. *A Facile "Green" Route for Scalable Batch Production and Continuous Synthesis of Zirconium MOFs.* Eur. J. Inorg. Chem. **2016**, 4490–4498.
3. *Water Adsorption in Porous Metal−Organic Frameworks and Related Materials*, J. Am. Chem. Soc., **2014**, *136*, 4369−4381.
4. *A water-born Zr-based porous coordination polymer: Modulated synthesis of Zr-fumarate MOF*. Microporous and mesoporous materials , **2015**, *203*,186-194.

40-1106 NEW **Zirconium trans-1, 2-ethylenedicarboxylic acid MOF (UiO-66-FA, FA:Zr=1)** 500mg, 2g

$Zr_6O_4(OH)_4(C_4H_2O_4)_6$; cream solid;
SA: 720-770 m^2/g; P.Vol. 0.29-0.32 cm^3/g
Note: Particle size: 0.1-0.5 micron,
Thermal stability: 200ºC,
Activation temperature: 150ºC
Sold under license from Inven2 AS for research purposes only. PCT/GB2009/001087.



Technical Notes:

1. Metalorganic framework used in a large number of studies for the storage of hydrogen or methane[2]
2. Water adsorption in MOF's for many applications such as dehumidification, thermal batteries, and delivery of drinking water in remote areas[3]

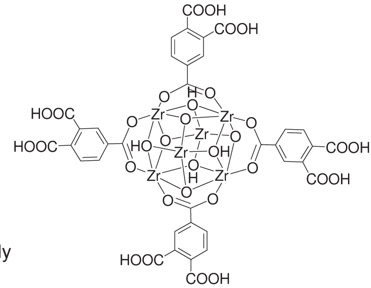
References:

1. *Water harvesting from air with metal-organic frameworks powered by natural sunlight.* Science, **2017**, *356*, 430–434.
2. *A Facile "Green" Route for Scalable Batch Production and Continuous Synthesis of Zirconium MOFs.* Eur. J. Inorg. Chem. **2016**, 4490–4498.
3. *Water Adsorption in Porous Metal−Organic Frameworks and Related Materials*, J. Am. Chem. Soc., **2014**, *136*, 4369−4381.
4. *A water-born Zr-based porous coordination polymer: Modulated synthesis of Zr-fumarate MOF*. Microporous and mesoporous materials , **2015**, *203*,186-194.

ZIRCONIUM (Compounds)

40-1111 NEW **Zirconium trimellitate MOF (UiO-66-BDC-COOH, BDC-COOH:Zr=0.9-1.0)** 500mg 2g

$Zr_6O_4(OH)_4(C_9H_4O_6)_x$, X = 5.4-6.0;
white solid; SA: 550-600 m^2/g;
P.Vol. 0.25-0.27 cm^3/g
Note: Particle size: 0.2-0.5 micron,
Thermal stability: 350ºC,
Activation temperature: 150ºC
Sold under license from Inven2 AS for research purposes only.
PCT/GB2009/001087.



Technical Notes:

1. MOF for which the introduction of copper markedly increases ammonia adsorption capacities[1]
2. Functionalized forms show the highest selectivity, good working capacity and medium ranged CO_2 adsorption enthalpy that make these materials very promising for physi-sorption-based processes[2]

References:

1. *Engineering Copper Carboxylate Functionalities on Water Stable Metal−Organic Frameworks for Enhancement of Ammonia Removal Capacities*. J. Phys. Chem. C, **2017**, *121*, 3310−3319.
2. *Functionalizing porous zirconium terephthalate UiO-66(Zr) for natural gas upgrading: a computational exploration.,* Chem. Commun., **2011**, *47*, 9603–9605.

CADMIUM (Compounds)

48-1011 HAZ	**Cadmium selenide StremDots™ quantum dot (CdSe core), 50umol/L in hexanes, 525nm peak emissi** *(1306-24-7)* CdSe; orange liq. *air sensitive, (store cold)*	5ml 25ml
48-1017 HAZ	**Cadmium selenide StremDots™ quantum dot (CdSe core), 50umol/L in hexanes, 550nm peak emission** *(1306-24-7)* CdSe; red-orange liq. *air sensitive, (store cold)*	5ml 25ml
48-1023 HAZ	**Cadmium selenide StremDots™ quantum dot (CdSe core), 50umol/L in hexanes, 575nm peak emission** *(1306-24-7)* CdSe; red liq. *air sensitive, (store cold)*	5ml 25ml
48-1030 HAZ	**Cadmium selenide StremDots™ quantum dot (CdSe core), 50umol/L in hexanes, 600nm peak emission** *(1306-24-7)* red liq. *air sensitive, (store cold)*	5ml 25ml
48-1035 HAZ	**Cadmium selenide StremDots™ quantum dot (CdSe core), 50umol/L in hexanes, 625nm peak emission** *(1306-24-7)* red liq. *air sensitive, (store cold)*	5ml 25ml
96-0800	**Cadmium selenide StremDots™ quantum dot (CdSe core) kit, 50umol/L in hexanes, 525-625nm peak emissions** *(1306-24-7)* *See* page 59	
48-1053 HAZ	**Cadmium selenide/cadmium sulfide StremDots™ quantum rod (CdSe/CdS elongated core/shell), 5 mg/ml in hexanes, 560nm peak emission** *(1306-24-7)* CdSe/CdS; dispersed, yellow solution *(store cold)*	0.5ml 2ml
48-1056 HAZ	**Cadmium selenide/cadmium sulfide StremDots™ quantum rod (CdSe/CdS elongated core/shell), 5 mg/ml in hexanes, 590nm peak emission** *(1306-24-7)* CdSe/CdS; dispersed, orange solution *(store cold)*	0.5ml 2ml
48-1059 HAZ	**Cadmium selenide/cadmium sulfide StremDots™ quantum rod (CdSe/CdS elongated core/shell), 5 mg/ml in hexanes, 620nm peak emission** *(1306-24-7)* CdSe/CdS; dispersed, red solution *(store cold)*	0.5ml 2ml
96-0813	**Cadmium selenide/cadmium sulfide StremDots™ quantum rod kit (CdSe/CdS elongated core/shell), 5 mg/ml in hexanes, 560nm, 590nm, 620nm peak emissions** *(1306-24-7)* *See* page 72	

CARBON (Compounds)

06-0330 **Graphene Quantum Dots (GQDs), Aqua-Green Luminescent** *(1034343-98-0)* 100mg
C; dark red-brown pwdr.
light sensitive, (store cold)
Note: Particle diameter: <5 nm. Sold in collaboration with Dotz Nano Ltd. for research purposes only. Suggested use within 6 months of purchase. Do not freeze. Store in DARK.

Technical Note:
1. See (page 16)

06-0332 **Graphene Quantum Dots (GQDs) in water, Aqua-Green Luminescent** *(1034343-98-0)* 100ml
C; cloudy orange liq.
light sensitive, (store cold)
Note: Particle diameter: <5 nm. Concentration: 1 mg/ml. Sold in collaboration with Dotz Nano Ltd. for research purposes only. Suggested use within 6 months of purchase. Do not freeze. Store in DARK.

Technical Note:
1. See 06-0330 (page 16)

06-0334 **Graphene Quantum Dots (GQDs), Blue Luminescent** *(1034343-98-0)* 100mg
C; dark brown pwdr.
light sensitive, (store cold)
Note: Particle diameter: <5 nm. Sold in collaboration with Dotz Nano Ltd. for research purposes only. Suggested use within 6 months of purchase. Do not freeze. Store in DARK.

Technical Note:
1. See 06-0330 (page 16)

06-0336 **Graphene Quantum Dots (GQDs) in water, Blue Luminescent** *(1034343-98-0)* 100ml
C; cloudy colorless liq.
light sensitive, (store cold)
Note: Particle diameter: <5 nm. Concentration: 1 mg/ml. Sold in collaboration with Dotz Nano Ltd. for research purposes only. Suggested use within 6 months of purchase. Do not freeze. Store in DARK.

Technical Note:
1. See 06-0330 (page 16)

06-0340 **Graphene Quantum Dots (GQDs) in water, Cyan Luminescent** *(1034343-98-0)* 100ml
C; cloudy brown liq.
light sensitive, (store cold)
Note: Particle diameter: <5 nm. Concentration: 1 mg/ml. Sold in collaboration with Dotz Nano Ltd. for research purposes only. Suggested use within 6 months of purchase. Do not freeze. Store in DARK.

Technical Note:
1. See 06-0330 (page 16)

96-7410 **Graphene Quantum Dots (GQDs) Master Kit** *(1034343-98-0)*
See page 19

96-7425 **Graphene Quantum Dots (GQDs) Mini Kit (Powders)** *(1034343-98-0)*
See page 19

96-7420 **Graphene Quantum Dots in water (GQDs) Mini Kit (Liquids)** *(1034343-98-0)*
See page 19

COPPER (Compounds)

29-8500 NEW	**Copper Indium Disulfide/Zinc Sulfide Quantum Dots, Peak Emission 550nm ± 10nm, QY > 75%** *(927198-36-5)* $CuInS_2ZnS$; yellow pwdr. Note: FWHM 250nm ± 20nm. Particle size: 5-10 nm. Recommend long-term storage in dark, under inert atmosphere. Sold under a distribution agreement with UbiQD, Inc. for research purposes only. US Patent No. US9748422. Suggested use within 12 months of receipt.	50mg 250mg
29-8510 NEW	**Copper Indium Disulfude/Zinc Sulfide Quantum Dots, Peak Emission 590nm ± 10nm, QY > 75%** *(927198-36-5)* $CuInS_2ZnS$; orange pwdr. Note: FWHM 120nm ± 20nm. Particle size: 5-10 nm. Recommend long-term storage in dark, under inert atmosphere. Sold under a distribution agreement with UbiQD, Inc. for research purposes only. US Patent No. US9748422. Suggested use within 12 months of receipt.	50mg 250mg
29-8520 NEW	**Copper Indium Disulfude/Zinc Sulfide Quantum Dots, Peak Emission 630nm ± 10nm, QY > 75%** *(927198-36-5)* $CuInS_2ZnS$; red pwdr. Note: FWHM 125nm ± 20nm. Particle size: 5-10 nm. Recommend long-term storage in dark, under inert atmosphere. Sold under a distribution agreement with UbiQD, Inc. for research purposes only. US Patent No. US9748422. Suggested use within 12 months of receipt.	50mg 250mg
29-8530 NEW	**Copper Indium Disulfude/Zinc Sulfide Quantum Dots, Peak Emission 680nm ± 10nm, QY > 75%** *(927198-36-5)* $CuInS_2ZnS$; brown pwdr. Note: FWHM 130nm ± 20nm. Particle size: 5-10 nm. Recommend long-term storage in dark, under inert atmosphere. Sold under a distribution agreement with UbiQD, Inc. for research purposes only. US Patent No. US9748422. Suggested use within 12 months of receipt.	50mg 250mg
29-8540 NEW	**Copper Indium Disulfude/Zinc Sulfide Quantum Dots, Peak Emission 800nm ± 10nm, QY > 75%** *(927198-36-5)* $CuInS_2ZnS$; black pwdr. Note: FWHM 180nm ± 20nm. Particle size: 5-10 nm. Recommend long-term storage in dark, under inert atmosphere. Sold under a distribution agreement with UbiQD, Inc. for research purposes only. US Patent No. US9748422. Suggested use within 12 months of receipt.	50mg 250mg
29-8550 NEW	**Copper Indium Disulfide/Zinc Sulfide Quantum Dots, Peak Emission 950nm ± 10nm, QY > 75%** *(927198-36-5)* $CuInS_2ZnS$; black pwdr. Note: FWHM 250nm ± 20nm. Particle size: 5-10 nm. Recommend long-term storage in dark, under inert atmosphere. Sold under a distribution agreement with UbiQD, Inc. for research purposes only. US Patent No. US9748422. Suggested use within 12 months of receipt.	50mg 250mg

LEAD (Compounds)

82-1081 HAZ	**Lead sulfide StremDots™ quantum dot (PbS core - ~3nm), 10 mg/mL in toluene, 1000nm peak emission** *(1314-87-0)* PbS; FW: 239.25; dark-red liq. Note: Suggest use within 6 months of purchase. Do not freeze. Store in DARK.	2ml 10ml
82-1083 HAZ	**Lead sulfide StremDots™ quantum dot (PbS core - ~4.5nm), 10 mg/mL in toluene, 1200nm peak emission** *(1314-87-0)* PbS; FW: 239.25; dark-red liq. Note: Suggest use within 6 months of purchase. Do not freeze. Store in DARK.	1ml 5ml
82-1085 HAZ	**Lead sulfide StremDots™ quantum dot (PbS core - ~6nm), 10 mg/mL in toluene, 1400nm peak emission** *(1314-87-0)* PbS; FW: 239.25; dark-red liq. Note: Suggest use within 6 months of purchase. Do not freeze. Store in DARK.	1ml 5ml
82-1090 HAZ	**Lead sulfide StremDots™ quantum dot (PbS core - ~8nm), 10 mg/mL in toluene, 1600nm peak emission** *(1314-87-0)* PbS; FW: 239.25; dark-red liq. Note: Suggest use within 6 months of purchase. Do not freeze. Store in DARK.	1ml 5ml

KITS - Cadmium selenide StremDots™ Quantum Dot (CdSe core) KIT

96-0800 HAZ — **Cadmium selenide StremDots™ quantum dot (CdSe core) kit, 50umol/L in hexanes, 525-625nm peak emissions**
Components also available for individual sale.
Contains the following:

48-1011	Cadmium selenide StremDots™ quantum dot (CdSe core), 50umol/L in hexanes, 525nm peak emissi *(1306-24-7)*	5ml	See page 45
48-1017	Cadmium selenide StremDots™ quantum dot (CdSe core), 50umol/L in hexanes, 550nm peak emission *(1306-24-7)*	5ml	See page 45
48-1023	Cadmium selenide StremDots™ quantum dot (CdSe core), 50umol/L in hexanes, 575nm peak emission *(1306-24-7)*	5ml	See page 45
48-1030	Cadmium selenide StremDots™ quantum dot (CdSe core), 50umol/L in hexanes, 600nm peak emission *(1306-24-7)*	5ml	See page 45
48-1035	Cadmium selenide StremDots™ quantum dot (CdSe core), 50umol/L in hexanes, 625nm peak emission *(1306-24-7)*	5ml	See page 45

Item #	Peak Emission	Particle size (diameter)	Quantum Yield
48-1011	525nm	2.8nm	>20%
48-1017	550nm	3.5nm	>10%
48-1023	575nm	3.9nm	>10%
48-1030	600nm	4.7nm	>20%
48-1035	625nm	5.3nm	>20%

Kit contains 5ml of each of the above 5 products. Ligand capping agent oleylamine. Stable in dispersions > 6 months.
*Particle size reported excludes ligand capping agent. All sizes determined by TEM.
† Available at nanoparticle concentration of 50μmol per liter.

KITS - Cadmium selenide/Cadmium sulfide StremDots™ Quantum Rod Kit

96-0813 HAZ — **Cadmium selenide/cadmium sulfide StremDots™ quantum rod kit (CdSe/CdS elongated core/shell), 5 mg/ml in hexanes, 560nm, 590nm, 620nm peak emissions**
Components also available for individual sale.
Contains the following:

48-1053	Cadmium selenide/cadmium sulfide StremDots™ quantum rod (CdSe/CdS elongated core/shell), 5 mg/ml in hexanes, 560nm peak emission *(1306-24-7)*	0.5ml	See page 69
48-1056	Cadmium selenide/cadmium sulfide StremDots™ quantum rod (CdSe/CdS elongated core/shell), 5 mg/ml in hexanes, 590nm peak emission *(1306-24-7)*	0.5ml	See page 69
48-1059	Cadmium selenide/cadmium sulfide StremDots™ quantum rod (CdSe/CdS elongated core/shell), 5 mg/ml in hexanes, 620nm peak emission *(1306-24-7)*	0.5ml	See page 69

KITS - Graphene Quantum Dots (GQDs) Master Kit

96-7410 **Graphene Quantum Dots (GQDs) Master Kit**
Sold in collaboration with Dotz Nano Ltd. for research purposes only.
Suggested use within 6 months of purchase. Do not freeze. Store in DARK.
Components also available for individual sale. Contains the following:

06-0330	Graphene Quantum Dots (GQDs), Aqua-Green Luminescent *(1034343-98-0)*	100mg	See page 16
06-0332	Graphene Quantum Dots (GQDs) in water, Aqua-Green Luminescent *(1034343-98-0)*	100ml	See page 16
06-0334	Graphene Quantum Dots (GQDs), Blue Luminescent *(1034343-98-0)*	100mg	See page 16
06-0336	Graphene Quantum Dots (GQDs) in water, Blue Luminescent *(1034343-98-0)*	100ml	See page 17
06-0340	Graphene Quantum Dots (GQDs) in water, Cyan Luminescent *(1034343-98-0)*	100ml	See page 17

Item #	Photoluminescence			
	QY+ *	λ max *	Max emission	FWHM *
06-0330 / 06-0332	>17%	485 nm	525 nm	70 nm
06-0334 / 06-0336	>65%	350 nm	445 nm	65 nm
06-0340	>25%	420 nm	490 nm	80 nm

Particle diameter: <5 nm
Topographic height: 1.0 - 2.0 nm
Concentration: 1mg/ml (for liquid items)

Abbreviations: QY+ = *Quantum Yield*; λ max = *Maximum excitation wavelength*; FWHM = *Full width at half maximum*

KITS - Graphene Quantum Dots (GQDs) Mini Kit (Powders)

96-7425 **Graphene Quantum Dots (GQDs) Mini Kit (Powders)**
Sold in collaboration with Dotz Nano Ltd. for research purposes only.
Suggested use within 6 months of purchase. Do not freeze. Store in DARK.
Components also available for individual sale. Contains the following:

06-0330	Graphene Quantum Dots (GQDs), Aqua-Green Luminescent *(1034343-98-0)*	100mg	See page 16
06-0334	Graphene Quantum Dots (GQDs), Blue Luminescent *(1034343-98-0)*	100mg	See page 16

See table listed under 96-7410 (above) for individual product specifications.

KITS - Graphene Quantum Dots (GQDs) Mini Kit (Liquids)

96-7420 **Graphene Quantum Dots in water (GQDs) Mini Kit (Liquids)**
Sold in collaboration with Dotz Nano Ltd. for research purposes only.
Suggested use within 6 months of purchase. Do not freeze. Store in DARK.
Components also available for individual sale. Contains the following:

06-0332	Graphene Quantum Dots (GQDs) in water, Aqua-Green Luminescent *(1034343-98-0)*	100ml	See page 16
06-0336	Graphene Quantum Dots (GQDs) in water, Blue Luminescent *(1034343-98-0)*	100ml	See page 17
06-0340	Graphene Quantum Dots (GQDs) in water, Cyan Luminescent *(1034343-98-0)*	100ml	See page 17

See table listed under 96-7410 (above) for individual product specifications.

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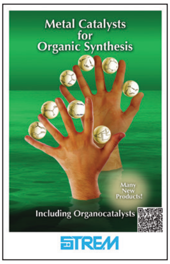

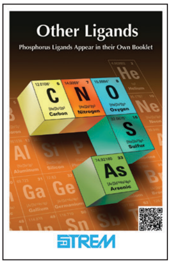

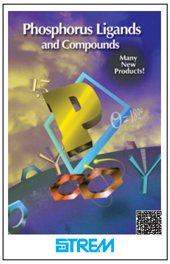

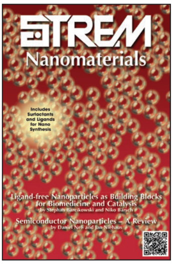

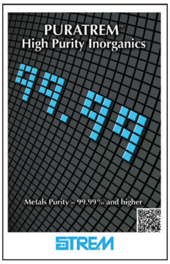

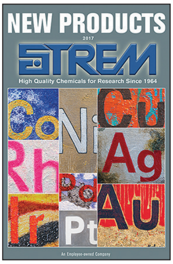

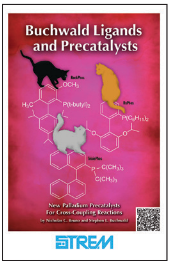

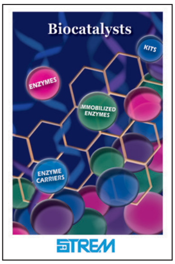

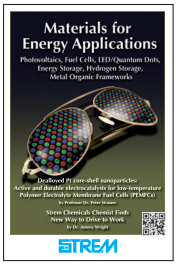

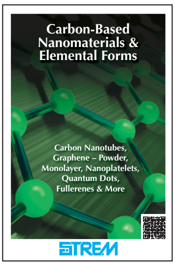

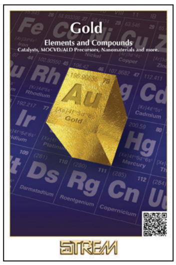

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